Climate Change Vulnerability Study

`

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PSEG LONG ISLAND

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Contents

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Glossary of Acronyms

AMI: Advanced Metering Infrastructure

AMP: Asset Management Plan

CAIDI: Customer Average Interruption Duration Index

CAPE: Convective Available Potential Energy

CCRP: Climate Change Resilience Plan

CCVS: Climate Change Vulnerability Study

CMMS: Computerized Maintenance Management System

CT: Current Transformer

DAC: Disadvantaged Community

DGA: Dissolved Gas Analysis

EHS: Environment, Health and Safety

EVM: Enhanced Vegetation Management

FEMA: Federal Emergency Management Agency

FIMP: Fire Island to Montauk Point

FR: Fire Retardant

GCM: Global Climate Model

HVAC: Heating, Ventilation, and Air Conditioning

ICS: Incident Command System

IEEE: Institute of Electrical and Electronics Engineers

IOU: Investor-Owned Utility

IPCC AR6: Intergovernmental Panel on Climate Change Sixth Assessment Report

IRP: Integrated Resource Plan

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LIDAR: Light Detection and Ranging

LIPA: Long Island Power Authority

MAIFI: Momentary Average Interruption Frequency Index

MVA: Megavolt Amperes

MW: Megawatt

NESC: National Electric Safety Code

NYISO: New York Independent System Operator

NYSERDA: New York State Energy Research and Development Authority

NYSRC: New York State Reliability Council

O&M: Operations and Maintenance

OMS: Outage Management System

OSA: Operating Service Agreement

OSHA: Occupational Safety and Health Administration

PSC: Public Service Commission

PSEG: Public Service Enterprise Group

PSL: Public Service Law

PT: Potential Transformer

RCP: Representative Concentration Pathway

SAIDI: System Average Interruption Duration Index

SAIFI: System Average Interruption Frequency Index

SIA: Storm Impact Analysis

SME: Subject Matter Expert

SSP: Shared Socioeconomic Pathway

T&D: Training and Development

THI: Temperature Humidity Index

Executive Summary

LIPA & PSEG Long Island historical investment in and prioritization of resilience

The Long Island Power Authority (LIPA) and its service provider, PSEG Long Island, are committed to providing safe and reliable power within their service territory. Increasingly, however, extreme weather events such as storms and floods are threatening the electrical system. Long Island has already experienced challenges with customer service disruptions and electrical asset damage due to extreme weather events. Climate change increases certain chronic stressors of the system and is likely to increase both the frequency and severity of these events, further stressing the system.

In the last decade, LIPA has taken steps to update its electric transmission and distribution system to be better prepared for significant weather impacts. Following Superstorm Sandy in 2012, LIPA hardened almost 1300 miles of mainline distribution to withstand stronger sustained winds and hurricane conditions. LIPA has also elevated equipment in several substations and installed protective floodwalls at three substations to protect utility assets against future flood risk.

As climate change continues to increase the frequency and severity of environmental hazard events, LIPA and PSEG Long Island are committed to adapting Long Island's electric system to withstand current and projected climate impacts. In November 2021, LIPA's Board of Trustees (the Board) adopted a policy to require resilience plans. Furthermore, LIPA is making multi-year investments in system resiliency, such as vegetation management and distribution hardening. PSEG Long Island engaged with stakeholders on the development of this Climate Change Vulnerability Study and will continue to engage in the development of its Climate Change Resilience Plan.

Summary of Priority Vulnerabilities

This Climate Change Vulnerability Study (CCVS or the Study) builds on resilience work PSEG Long Island has undertaken on behalf of LIPA by analyzing asset and operational vulnerabilities to critical climate hazards. Specifically, this Study focuses on the climate hazards most salient for LIPA's service area, which are extreme heat, cold temperatures, extreme precipitation, coastal and inland flooding, high wind, and ice. These hazards were identified based on historic impacts to LIPA assets and future climate projections for the area, as well as consultations with the utility's subject matter experts (SMEs) and stakeholders across the service area.

This Study builds an understanding of asset vulnerability by pairing exposure data for the selected climate hazards with an evaluation of asset specific sensitivity and consequence. Exposure represents the degree to which assets could experience changes in climate hazards, based on their physical location and the magnitude of projected future changes in climate hazards. Exposure information was extracted from climate projections for each hazard. Sensitivity represents the degree to which LIPA assets could be negatively affected by exposure to a climate hazard, and consequence represents the magnitude (or criticality) of negative outcomes for PSEG Long Island's systems and customers in the event of asset failure or damage. Sensitivity and consequence for different assets were assessed through extensive consultations with the utility's SMEs. Knowing asset vulnerability will allow PSEG Long Island to assess the risk to assets and operations.

Assets were categorized into three main groups – transmission, distribution, and substation – with each asset group consisting of a set of asset types. Sensitivity and consequence were combined with results from exposure analysis to arrive at vulnerability ratings. Vulnerability represents the potential for transmission and distribution assets and operations to be adversely impacted by exposure to projected climate hazards, and the significance of potential outcomes for its systems, services, and customers.

Based on the assessment of vulnerabilities, the Study identified priority vulnerabilities which represent asset-hazard pairs with the highest potential for adverse outcomes. In other words, priority vulnerabilities characterize sensitive, critical asset types that are at risk of future exposure to a given climate hazard.

Regarding asset vulnerability, substation assets were identified to be particularly vulnerable to extreme heat, coastal and inland flooding, and projected exposure to ice events. Transmission and distribution assets were identified to be highly vulnerable to high winds and ice events. Additionally, distribution assets were found to be highly vulnerable to potential impacts from extreme heat and flooding.

Table 1 lists these priority vulnerabilities (asset-hazard pairs rated to have high vulnerability). These priority vulnerabilities will inform resilience recommendations to be included in PSEG Long Island's Climate Change Resilience Plan (CCRP).

Table 1: Priority Vulnerabilities identified for LIPA's electric assets.

Climate Hazard	Transmission	Distribution	Substation
Extreme Heat		• Overhead transformers • Pole mounted regulators	• Transformers and regulators • Switchgear (distribution, including breakers, Potential Transformers (PTs), and relay)
Coastal and Inland Flooding		• Pad mount switchgear	• Transformers and regulators • Circuit breakers • Switchgear (distribution, including breakers, PTs, and relay) • Instrument Transformers (Current Transformers (CTs) and PTs) • Control room/control house/protection and control devices
High Wind	• Line structures • Overhead conductors	• Overhead structures (including poles) • Overhead conductors	
Ice	• Line structures • Overhead conductors	• Overhead structures (including poles) • Overhead conductors	• Transformers and regulators

In addition to assessing the vulnerability of physical infrastructure, the Study also qualitatively reviewed potential impacts to PSEG Long Island's internal planning and operational procedures, based on the understanding that resilience to climate change cannot be achieved through strengthening of physical infrastructure alone. Based on consultations with utility SMEs, PSEG Long Island identified several key functional areas, including workforce safety, emergency response, vegetation management, asset management, reliability planning, capacity planning, and load forecasting which are likely to be impacted by projected increases in the severity and frequency of extreme events like heat waves, flooding, and storms associated with extreme winds and ice.

Looking Ahead

By assessing climate vulnerabilities of assets, planning, and operations using updated climate science, this CCVS is a significant advance in the expanding effort of bolstering climate resilience across LIPA assets and operations. This CCVS will feed into the development of a Climate Change Resilience Plan (CCRP) and ground the assessment of which resilience measures to prioritize in the future. The CCRP will help identify mitigation measures to limit the impacts of climate change hazards on utility assets and operations, and thus help LIPA and PSEG Long Island to reduce potential outage times and restoration costs. The CCRP will also recognize that some communities may be disproportionately affected by climate hazards and consider how to prioritize disadvantaged and socially vulnerable communities and what LIPA and PSEG Long Island can do to reliably and resiliently serve those communities. LIPA will engage stakeholders such as Nassau and Suffolk Counties; the City of New York; consumer and human service organizations including the Public Utilities Law Project and the EAC Network; and environmental groups including the National Resources Defense Council, The Citizens Campaign for the Environment, Renewable Energy Long Island, and the Sustainability Institute at Molloy College in the development of the CCRP.

Introduction

Background

Long Island has experienced a range of severe weather, from high heat to flooding to extreme storm conditions. These events have had wide-reaching consequences throughout the community, impacting human health, safety, and community infrastructure. These events also stress the electrical system, threaten utility assets, and interfere with reliable and consistent delivery of electricity to customers. Climate change will likely increase the frequency and severity of extreme weather events on Long Island, further threatening people, infrastructure, and utility assets.

In the context of utilities, extreme heat can drive overheating across system assets which may lead to circuit and line outages and compromise delivery to customers. Increased flooding and climate-change driven sea level rise on Long Island may damage vulnerable utility assets in coastal and low-lying areas and flood regions resulting in customer outages. Extreme storms characterized by ice or wind events may also interrupt delivery to customers by impacting overhead assets such as poles and towers. Emergency response, worker safety, capacity planning, and load forecasting are also important human dimensions of utility system operations that are threatened by current and future climate change impacts.

LIPA owns the assets that constitute the electrical system studied in the CCVS. PSEG Long Island is an electric utility company that operates LIPA's transmission and distribution system on Long Island. To continue to provide safe, reliable and affordable power to customers, even under the threats of a changing climate, it is important for PSEG Long Island to identify potential vulnerabilities as well as opportunities for adaptation to current and future climate conditions.

With the understanding that developing storm hardening and system resiliency plans is an important part of mitigating the impacts of climate change on utility infrastructure and service delivery, New York State Public Service Law (PSL) §66 and Public Service Commission (PSC) Case 22-E-0222 requires Investor-Owned Utilities (IOUs) to prepare a Climate Change Vulnerability Study (CCVS) and a Climate Change Resilience Plan (CCRP). While LIPA is not subject to the same law or to the PSC jurisdiction, the New York State Climate Action Council's Scoping Plan recommended that LIPA and other municipal utilities also assess climate vulnerability and develop resilience plans. PSEG Long Island on behalf of LIPA is carrying out this project, which will have a similar scope to the CCVS and CCRP requirements for IOUs, with a focus on the operations of LIPA's transmission, distribution, and substation assets and PSEG Long Island's operations.

Beyond transmission, distribution and substation assets, climate change is an important consideration when projecting future electrical load and ensuring sufficient generation capacity to meet projected load. On the demand side, as average and peak temperatures increase and as heat waves become more prevalent, peak summer demand is likely to increase. Customers are also increasingly adopting electric heat pumps and electric vehicles, which will tend to increase electrical demand, especially during the heating season. On the supply side, as weather-dependent renewable resources such as wind turbines and solar generation grow as a share of total Statewide generation, projections around long term trends in future conditions such as wind patterns and cloud cover will improve future projections of resource availability. In addition, renewable resources are likely to be impacted more than thermal generation by severe weather events such as tropical storms and nor'easters.

Statewide, most generation resources offer their energy into a statewide wholesale energy market managed by the New York Independent System Operator (NYISO). The NYISO is responsible for the reliability of New York State's bulk power grid. The NYISO develops long term plans to meet projected electrical demand with sufficient generation. PSEG Long Island, on behalf of LIPA, participates in NYISO planning efforts, including extreme weather vulnerability assessments and consideration of climate change. The NYISO is also coordinating improvements in planning for extreme weather with the New York State Reliability Council (NYSRC), a nonprofit oversight body that sets statewide reliability rules and statewide resource adequacy requirements. PSEG Long Island will continue to coordinate with NYISO and the NYSRC on planning for resource adequacy and reliability of the bulk power system in the face of climate change.

In addition, every three to five years, LIPA develops an Integrated Resource Plan (IRP) that includes an assessment of LIPA's generation resources and transmission assets and provides strategies to meet future energy demand. LIPA's most recent IRP considered sensitivities around load growth due to climate change as well as extended periods of limited availability of energy from solar and wind resources. LIPA's future IRPs will also incorporate further consideration of climate change.

Stakeholder Engagement

PSEG Long Island is committed to collaborating with stakeholders and considering their input to inform policies and projects. PSEG Long Island recognizes that engaging with customers, communities, and advocates is a necessary step to enhancing community-wide resiliency. For the development of this CCVS, PSEG Long Island conducted two rounds of external stakeholder engagement consisting of meetings with five stakeholder groups:

- Environmental Advisory Committee, including the Sustainability Institute at Molloy College, NRDC, Renewable Energy Long Island, the Citizens' Campaign for the Environment, and the Renewable Energy and Sustainability Center (RESC) at Farmingdale State College
- Consumer Advocacy and Human Service Organizations, including the Public Utility Law Project (PULP), Health and Welfare Council of Long Island (HWCLI), and the EAC Network[1]
- Suffolk County
- Nassau County
- City of New York

The first round of engagements, which occurred in June of 2023, covered climate science. These initial meetings covered legislative context and climate findings from analyses using NYSERDA and Columbia University datasets, as well as supplementary climate change analyses. The next round of engagements occurred at the end of February 2024 and focused on the results of the CCVS. These meetings delved into the process behind the vulnerability assessment, including the scoring methodology, and then discussed the highest-scoring climate vulnerabilities.

PSEG Long Island intends to put customers, communities, and advocates at the front end of decision-making. This requires consistent, transparent communication with stakeholders in planning for resiliency. Accordingly, PSEG Long Island will continue to engage with stakeholders on the development of a CCRP.

Baseline Assumptions

This Study presents a robust analysis of climate change vulnerabilities with several underlying assumptions.

First, this Study focuses on assessing the vulnerabilities to the current state of LIPA's existing assets, operations, and systems. This Study does not include the impacts of future risk mitigation and how that may impact vulnerability.

[1] The Health and Welfare Council of Long Island (HWCLI) participated in the first round of stakeholder engagement held in June 2023. In February 2024, HWCLI member organization EAC Network replaced HWCLI on the Consumer stakeholder panel.

Second, this Study assumes that the climate projections used are applicable across the entire LIPA's service area. Climate projections present future possible climate realities based on assumed scenarios of different atmospheric greenhouse gas concentrations.

Priority Hazards

The scope of this report analyzes six key climate-related hazards: extreme heat, cold temperatures, extreme precipitation, coastal and inland flooding, wind, and extreme events. The Study team worked with PSEG Long Island SMEs to select these hazards based on historic impacts to the utility assets and potential impacts based on expected change over the next century.

- **Extreme Heat:** Both acute and chronic heat pose substantial challenges to the reliable and safe delivery of electricity. High temperatures can limit the capacity of the grid to deliver to customers and can cause premature aging and/or sudden failure of critically important asset types. Climate change is expected to raise ambient temperatures and increase the frequency of extreme heat events, such as heat waves.
- **Cold Temperatures**: Projections show an overall warming trend in the service area through the end of the century. However, this does not preclude the possibility of the service territory experiencing cold temperatures, as it has in the past.
- **Extreme Precipitation**: Extreme precipitation can lead to flash flooding, which can cause significant damage to utility assets. While modeling extreme storm events is difficult, scientists predict that climate change is expected to increase precipitation in the northeastern US. Thus, it is important to evaluate this hazard in this report.
- **Coastal and Inland Flooding**: Sea level rise is the main driver of coastal flooding, along with 100- and 500-year tidal floods. Climate change is expected to appreciably increase sea levels around Long Island as early as mid-century, along with consequent coastal flooding. The service area contains a large portion of coastal areas, so it is important to assess how this hazard will impact LIPA assets and operations. Historical 100-year and 500-year annual chance floods can also cause significant inland flooding. FEMA (Federal Emergency Management Agency) flood maps illustrate these flood zones and the overlaps with assets in the service area. Additionally, the coastal proximity and low elevation along the south shore puts the service area more at risk of flooding.
- **Wind**: Tropical cyclones represent the most extreme example of windstorms impacting the service area. One-in-10-year hurricane wind speeds are expected to increase with climate change, exceeding 110 mph across a large proportion of Long Island. Thus, it is critical to evaluate wind hazard and its impacts.
- **Extreme Events**: There is high uncertainty in the modeling of extreme weather events, however, current scientific literature suggests that thunderstorms and

tornadoes are expected to increase in frequency and ice storms are expected to increase in intensity with climate change. These severe weather events pose significant risks to assets, so it is important to evaluate them as part of this vulnerability study.

Assessing Climate Vulnerability

This report assesses the vulnerability of different assets in the service territory affected by projected climate hazards. An understanding of vulnerability is developed through exploring the exposure of an asset to climate hazards, considering the sensitivity of an asset to exposure, and evaluating the consequences of that asset being negatively impacted by climate hazard exposures. These terms are defined as follows:

- **Exposure:** extent to which assets will face climate hazards based on physical location
- **Sensitivity:** extent to which exposure will impact assets, operations, or systems
- **Consequence**: the potential for impacts to sensitive assets that result in negative outcomes

Climate science helps inform an evaluation of an asset's exposure to climate hazards while asset evaluations and SMEs help inform an understanding of asset sensitivity and potential consequences. Synthesizing across these different dimensions builds a picture of a specific asset's climate vulnerability, which can then be used to inform effective adaptation and resilience measures to ensure safe and reliable service to customers even as the climate changes.

Equity in Resilience Planning

The impacts of climate change are not distributed equally and climate impacts as well as responses can exacerbate existing inequities, so centering equity in climate resilience planning is important. Addressing equity in resilience planning can take several different forms, but often includes considering how impacts are distributed across the service area, how community status impacts climate vulnerability, and a consideration of how to ensure safe and reliable service to all customers.

When bringing equity into climate resilience planning, it is critical to consider how disadvantaged communities (DACs) are disproportionately impacted by climate change. Figure 1 illustrates the distribution of DACs within LIPA's service territory. The Study will address equity concerns in climate resilience when developing the CCRP and equity will be used in the CCRP as a factor when prioritizing resilience measures. The DAC map can complement climate vulnerability data to ensure that benefits associated with resilience strategies are equitably distributed across all customers and to help adequately support different areas within its service territory.

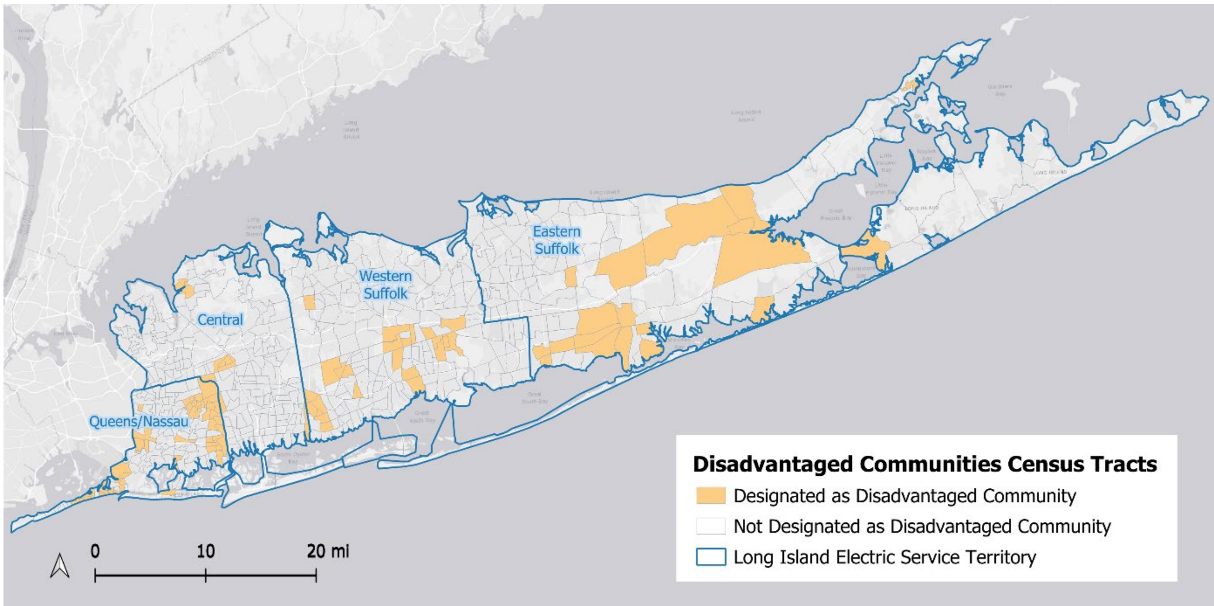

Figure 1: Map of Disadvantaged Communities (DACs).

Climate Science

Introduction

Climate summarizes the average of weather patterns over a relatively long period of time (e.g., months, seasons, years, decades). Climate changes on a year-to-year and decade-to-decade basis in response to both natural and human-caused drivers. “Climate change” refers to the change in the mean climate conditions and/or the variability of the climate over an extended period. These changes can impact the frequency and severity of extreme weather, leading to events such as heat waves, extreme precipitation, and hurricanes. Understanding potential future climate conditions enables us to prepare for change.

Climate projections present a range of plausible climate futures. Understanding these different futures can be used to help improve the resiliency of the LIPA system. Climate projections within the LIPA service area suggest that current climate hazards could intensify in the future, including an increase in the frequency and intensity of extreme temperatures, driving more severe heavy precipitation events, and causing more frequent and widespread flooding.

Climate Data Methods

The climate projections provided in this report are primarily drawn from datasets developed by Columbia University and the New York State Energy Research and Development Authority (NYSERDA).[2] These datasets use an ensemble of 16 Coupled Model Intercomparison Project Phase 6 (CMIP6) Global Climate Models (GCMs) and two future greenhouse gas emissions trajectories based on Shared Socioeconomic Pathways (SSPs), aligning with the latest climate science developed for the Intergovernmental Panel on Climate Change Sixth Assessment Report (IPCC AR6).[3] The SSPs represent a range of future climate change scenarios and development pathways that encompass various trajectories of global greenhouse gas emissions.[4] SSP2-4.5 and SSP5-8.5 scenarios are used in this report, where SSP2-4.5 represents aggressive global emissions reductions and middle-of-the-road assumptions on earth system sensitivity and SSP5-8.5 represents a failure of global emissions reduction efforts and high-end climate sensitivity. The range of

[2] For information on the prior NYSERDA report, see https://www.nyserda.ny.gov/About/Publications/Energy-Analysis-Reports-and-Studies/Environmental-Research-and-Development-Technical-Reports/Response-to-Climate-Change-in-New-York
[3] IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate. doi:10.1017/9781009157896.
[4] Riahi, K., et al., 2017. The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview. Global Environmental Change, 42, 153–168. https://doi.org/10.1016/j.gloenvcha.2016.05.009

projections within each SSP are evaluated using percentiles, comprising the low estimate (10th percentile of all model outcomes), the middle range (25th, 50th, and 75th percentiles), and a high estimate (90th percentile). The 10th, 50th, and 90th percentiles represent the low-end, median, and high-end of the projection range, respectively. This analysis includes a range of potential climate change futures, with an analytic focus on plausible lower and upper bounds of climate model projections (SSP2-4.5 50th percentile and SSP5-8.5 50th percentile, respectively).

Using the datasets developed by Columbia University, the Study Team generated projections of climate and extreme weather specific to the geography of LIPA's service area. To account for interannual and interdecadal variability in the daily temperature and precipitation datasets, the Study Team calculated variables as 30-year averages surrounding each time horizon of interest. For example, data generated for 2050 leveraged daily data averaged across projections for the 2036 to 2065 time period.

Climate projections are provided for the Bridgehampton and Central Park weather stations to represent the service area and are taken from the Columbia/NYSERDA dataset. An inverse distance weighting scheme is used to create one projection for the LIPA service area using the two stations (see Figure 2). The inverse of the distance from each station to Melville, NY (the load center) is calculated, which produces station weights of 68.3% for Central Park and 31.7% for the Bridgehampton station. This provides one standard projection to apply to the LIPA asset base.

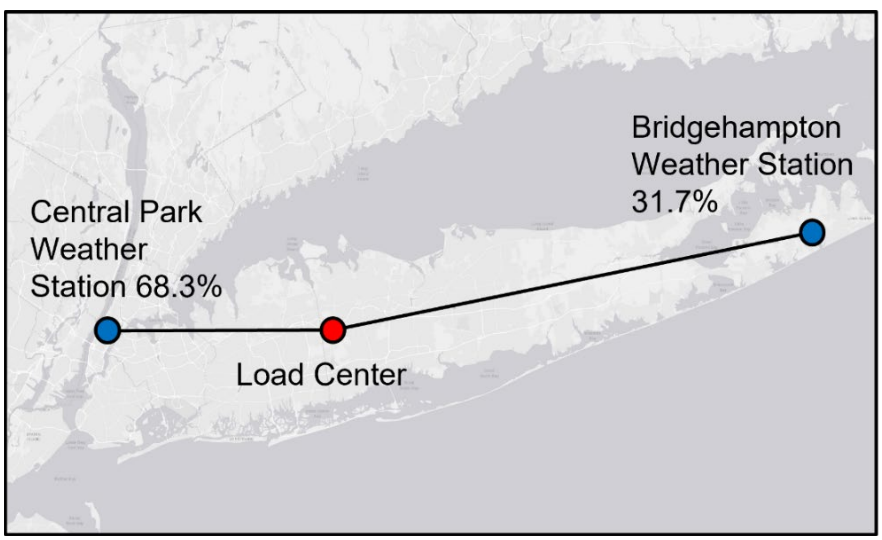

Figure 2: Visual representation of the inverse distance weighting scheme to provide one standard projection to the asset base for PSEG Long Island.

Coastal flooding is evaluated for coastal areas of Long Island using projections of 100- and 500-year tidal flood extent combined with projected sea level rise at mid-century (2050). The dataset provided by PSEG Long Island was previously used in the 2022 Sea Level Rise WaterRIDE Model update Final Report.[5] The WaterRIDE modeling software is enhanced with relative sea level rise scenarios and is used to forecast future water levels to determine minimum design flood levels and propose upgrades to infrastructure.

Inland flooding is evaluated using present-day Federal Emergency Management Agency (FEMA) flood zones. FEMA maps illustrate the extent of 100- and 500-year flood zones across the service area. Present-day FEMA flood maps are commonly used to estimate areas that may be exposed to inland flooding based on historical and present-day data, but notably do not model future flood exposure based on projections.

There is uncertainty in the science evaluating the most intense extreme weather events because of the rarity of these events relative to the length of the historical record, the small spatial and temporal scales at which these events occur, and the limited ability of current global-scale climate models to resolve events at these scales. Consequently, this Study assesses tropical cyclone wind exposure through a combination of historical data,[6] projections from a review of the scientific literature,[7] and an empirical model for wind decay after landfall.[8] Specifically, the Study Team projected geospatial estimates of late-century maximum sustained 1-in-10 year wind speeds across the service territory using a historical distribution of landfalls impacting the service territory, projected change in landfall frequencies across the North Atlantic, and decreased wind speeds after landfall using a wind decay model parameterized using historical data from the East Coast of the United States. Tropical cyclones represent the most extreme example of windstorms impacting the LIPA service area.

In addition to wind speeds from tropical cyclones, low probability extreme events, such as multi-day ice storms, rely on complex and rare meteorological conditions that are difficult to resolve in GCMs. Due to these barriers, the climate projections developed by Columbia University and NYSERDA that have been analyzed for LIPA's service area cannot fully resolve all types of extreme events. Historical analog events and climate projections from current scientific literature are used to provide a holistic understanding of potential extreme events and risks to the service area for thunderstorms and tornadoes, ice storms, and compounding extreme event scenarios.

[5] WorleyParsons. (2022 , January 31). Sea Level Rise WaterRIDE Model Update Final Report. PSEG LI.
[6] Atlantic Hurricane Database version 2 (HURDAT2). Landsea, C. W. and J. L. Franklin. 2013. Atlantic Hurricane Database Uncertainty and Presentation of a New Database Format. Monthly Weather Review, 141: 3576-3592.
[7] Knutson, T. R., et al. 2015. Global projections of intense tropical cyclone activity for the late twenty-first century from dynamical downscaling of CMIP5/RCP4.5 scenarios. Journal of Climate, 28(18): 7203-7224.
[8] Kaplan, J., and M. DeMaria. 1995. A simple empirical model for predicting the decay of tropical cyclone winds after landfall. Journal of Applied Meteorology and Climatology, 34(11): 2499-2512.

Exposure

To support PSEG Long Island's understanding of these priority hazards under climate change, this Study considers asset exposure from projected climate-related changes that may occur in the service area.

Exposure is the degree to which assets could face climate hazards based on their physical locations. Exposure is determined independently of asset sensitivity to climate. In combination with asset sensitivity to hazards and consequences of asset failure or degraded operations, asset exposure to climate hazards is used to calculate vulnerability scores in subsequent sections for each asset-hazard combination.

Key Takeaways

- The service area is projected to be exposed to extreme heat by 2060 under both temperature variables and both emissions scenarios.
- The service area is projected to experience reduced exposure to cold temperatures from 2030 onwards due to a general warming trend.
- The service area is not projected to be exposed to extreme precipitation through the end of the century.
- A small proportion of LIPA assets could be exposed to future coastal flooding, with up to 13% and 15% of assets being exposed to a 100- and 500-year coastal flooding events at midcentury, respectively.
- More than 90% of LIPA assets are projected to be exposed to 1-in-10-year hurricane maximum sustained wind speeds exceeding 110 mph by late century.
- Thunderstorms and tornadoes could increase in frequency in the future, potentially exposing LIPA assets to this hazard more frequently.
- Ice storms could become less frequent but more intense in the future, potentially exposing LIPA assets to events with greater than normal radial ice accumulation.

Exposure Methods

Exposure for temperature and precipitation hazards is determined based on future magnitudes of change for each climate hazard by decade (2030-2080) relative to the historical baseline. For this CCVS, the baseline, or base period, is a dataset of observed climate data from 1981-2010 at each weather station. For temperature and precipitation hazards, assets are classified as "exposed" when a climate hazard exceeds a designated threshold for each decade from 2030-2080. The exposure thresholds for temperature and precipitation are described in **Table 2** below.

***Table 2: Definition of exposure for temperature and precipitation*.**

	Exposure Threshold
Temperature Hazards	Three standard deviations above the historical baseline average to reflect a future climate that nearly exceeds or exceeds the historical distribution.
Precipitation Hazards	One standard deviation above the historical baseline average to account for the high interannual variability in extreme precipitation events.

Coastal and inland flooding and tropical cyclone wind speed exposure thresholds and methods are detailed in 0mph as the exposure threshold.

Table 3. The exposure analysis for both flooding projections does not account for asset elevation, in which assets intersect flood extent but are elevated above the level of inundation. For tropical cyclone wind speeds, exposure is assessed using the National Electric Safety Code (NESC) standard for extreme wind loading on Long Island of 110mph as the exposure threshold.

Table 3: Definition of exposure for inland flooding, coastal flooding, and hurricane wind.

	Exposure Threshold
Coastal and Inland Flooding	Primary asset exposure for coastal flooding is determined based on whether an asset is inundated by a 100- or 500-year flood event in 2045. Asset exposure to both coastal and inland flooding is supplemented by the number of assets inundated by a *historical* 100- or 500-year flood event.
Hurricane Wind	An asset is considered exposed to hurricane wind if an asset is projected to experience a 1-in-10-year wind speed in excess of 110 mph.

Exposure Results

One standard climate projection is used to determine whether the LIPA asset base is exposed or not exposed to extreme heat, extreme cold, and extreme precipitation (see

Figure 2). An asset is exposed to a particular climate hazard if the climate projection for a given decade is higher than a predetermined threshold of exposure.

Exposure scores represent future magnitudes of change for each main climate hazard by decade for 2030-2080 relative to the historical baseline. Exposure scores follow the conceptual framework highlighted in Table 4.

Table 4: Exposure scoring framework.

Not Exposed	LIPA assets are not exposed to this climate hazard. Exposure to this hazard is likely to experience little to no change relative to historical conditions or will shift to more favorable climate conditions over time.
Exposed	All LIPA assets are exposed to this climate hazard. Exposure to this hazard is likely to experience rapid or very high magnitude change towards less favorable climate conditions over time.

Exposure ratings for the LIPA asset base for climate hazards using the Columbia/NYSERDA dataset are summarized in Table 5, which uses the one standard climate projection to estimate future changes in climate hazards.

Table 5: Summary exposure scores for Columbia/NYSERDA climate hazards across the PSEG Long Island service territory.

Climate Hazard	Present	2030	2040	2050	2060	2070	2080
Extreme Heat	Not Exposed	Not Exposed	Not Exposed	Exposed	Exposed	Exposed	Exposed
Cold Temperature	Not Exposed	Not Exposed	Not Exposed	Not Exposed	Not Exposed	Not Exposed	Not Exposed
Extreme Precipitation	Not Exposed	Not Exposed	Not Exposed	Not Exposed	Not Exposed	Not Exposed	Not Exposed

A box shaded blue describes a time horizon in which no assets are exposed. A box shaded red describes a decade in which all assets are exposed.

Exposure for coastal flooding, wind, and extreme events are all assessed for exposure at the asset level or regionally. When geospatial projections are available (flooding and wind), some of LIPA assets are exposed. However, exposure is likely to experience change towards less favorable climate conditions over time, but the changes are geographically limited to a smaller proportion of the service territory. For extreme events (thunderstorms, tornadoes, and ice), exposure is assessed across LIPA's service area using a combination of historical data and a broad understanding of future projections from the scientific literature.

Extreme Heat

By 2050, Long Island could experience an average of up to 2 weeks per year with average temperatures above 86°F and maximum temperatures above 95°F.

LIPA's assets are projected to be exposed to extreme heat by 2060 under both temperature variables and both emissions scenarios. Climate projections show that by the mid-century, the LIPA service area could see between 10 to 14 days with average temperatures above 86°F for the lower and higher emissions scenarios, respectively (Figure 3). By the end of the century, the service area could see between 14 to 43 days per year with *average temperatures exceeding 86°F* for the lower and higher emissions scenarios, respectively. Projections reveal the following increases relative to the exposure threshold of 9 days:

- By 2050, the number of days with average temperatures above 86°F could reach the exposure threshold of 9 days for SSP2-4.5 50th percentile (lower emissions scenario).
- By 2040, the number of days with average temperatures above 86°F could reach the exposure threshold of 9 days for SSP5-8.5 50th percentile (higher emissions scenario).

Climate projections show that by mid-century, the service area could experience between 12 to 17 days per year with maximum temperatures exceeding 95°F under the lower and higher emissions scenarios, respectively (Figure 3). By end of century, the service area could see a significant increase in days above 95°F, particularly in the high emissions scenario. There could be between 19 to 42 days with maximum temperatures exceeding 95°F in the service area by the end of the century for the low and high emissions scenarios, respectively. Projections reveal the following increases relative to the exposure threshold of 14 days:

- By 2060, the number of days per year with maximum temperatures above 95°F could reach the exposure threshold of 14 days per year in the lower emissions scenario.
- By 2050, the number of days per year with maximum temperatures above 95°F could reach the exposure threshold of 14 days per year in the higher emissions scenario.

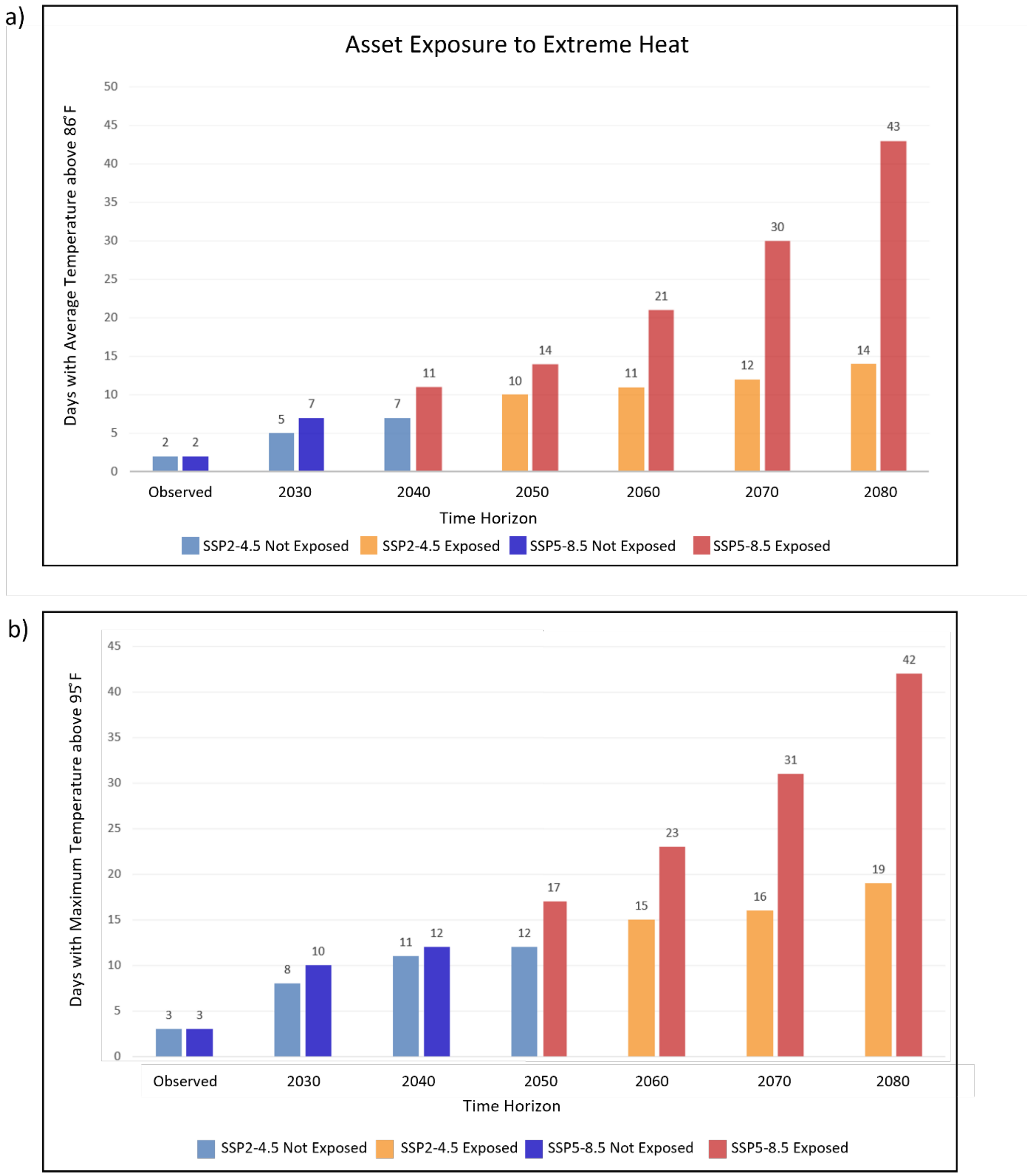

Figure 3: Asset exposure to extreme heat for days with daily average temperature above 86°F (a) and days with daily maximum temperature above 95°F (b). Bars and numbers indicate the number of days with extreme heat for each time horizon. Colors represent the emissions scenarios, SSP2-4.5 50th percentile (light blue and orange) and SSP5-8.5 50th percentile (dark blue and red). A bar shaded light or dark blue describes a time horizon in which assets are not exposed. A bar shaded orange or red describes a decade in which assets are exposed.

Cold Temperatures

By 2080, the number of days below freezing could be less than one third that of the 81 days below freezing during 1981-2010.

An overall warming trend through end of century leads to the service area experiencing reduced exposure to cold temperatures from 2030 onwards. Due to warming trends, LIPA assets are not projected to be exposed to extreme cold, as the number of days below freezing decreases consistently through the 21st century. Overall, the higher emissions scenario shows greater warming, with the number of days per year with daily minimum temperatures below 32°F projected to be 48 by mid-century, while the lower emissions scenario projects 55 days per year. This trend continues through the end of the century with the number of days below 32°F in 2080 projected to be 27 in the higher emissions scenario and 48 in the lower emissions scenario.

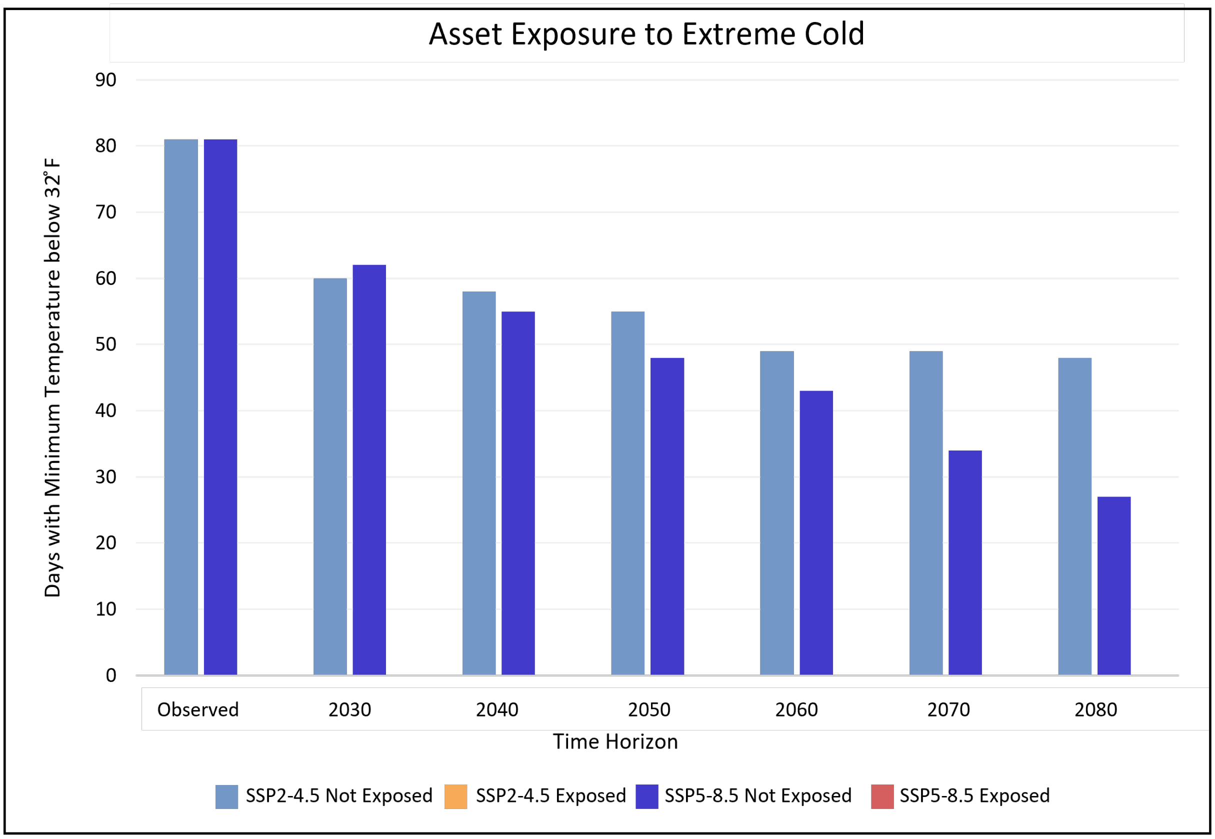

Figure 4: Asset exposure to extreme heat for days with daily minimum temperature below 32°F. Bars and numbers indicate the number of days with extreme cold for each time horizon. Colors represent the emissions scenarios, SSP2-4.5 50th percentile (light blue and orange) and SSP5-8.5 50th percentile (dark blue and red). A bar shaded light or dark blue describes a time horizon in which assets are not exposed. A bar shaded orange or red describes a decade in which assets are exposed.

Extreme Precipitation

Asset Exposure to Extreme Precipitation

LIPA assets are not projected to be exposed to extreme precipitation through the end of the century.

LIPA assets are not expected to be exposed to extreme precipitation through the end of the century. The lower emissions scenario projects an increase in *annual maximum 5-day precipitation* from a historical baseline of 5.0 inches to 5.6 inches by 2050 before stabilizing through late century. The higher emissions scenario projects an increase in maximum 5-day precipitation through the end of the century with 5.7 inches projected by 2050 and 6.1 inches by late century. Annual maximum 5-day precipitation data represent the total inches of precipitation falling during the most precipitation-heavy 5-day span per year averaged over a 30-year period. Note that global climate model projections may not fully resolve higher-intensity deluge precipitation events due to the relatively coarse spatial resolution of the dataset.

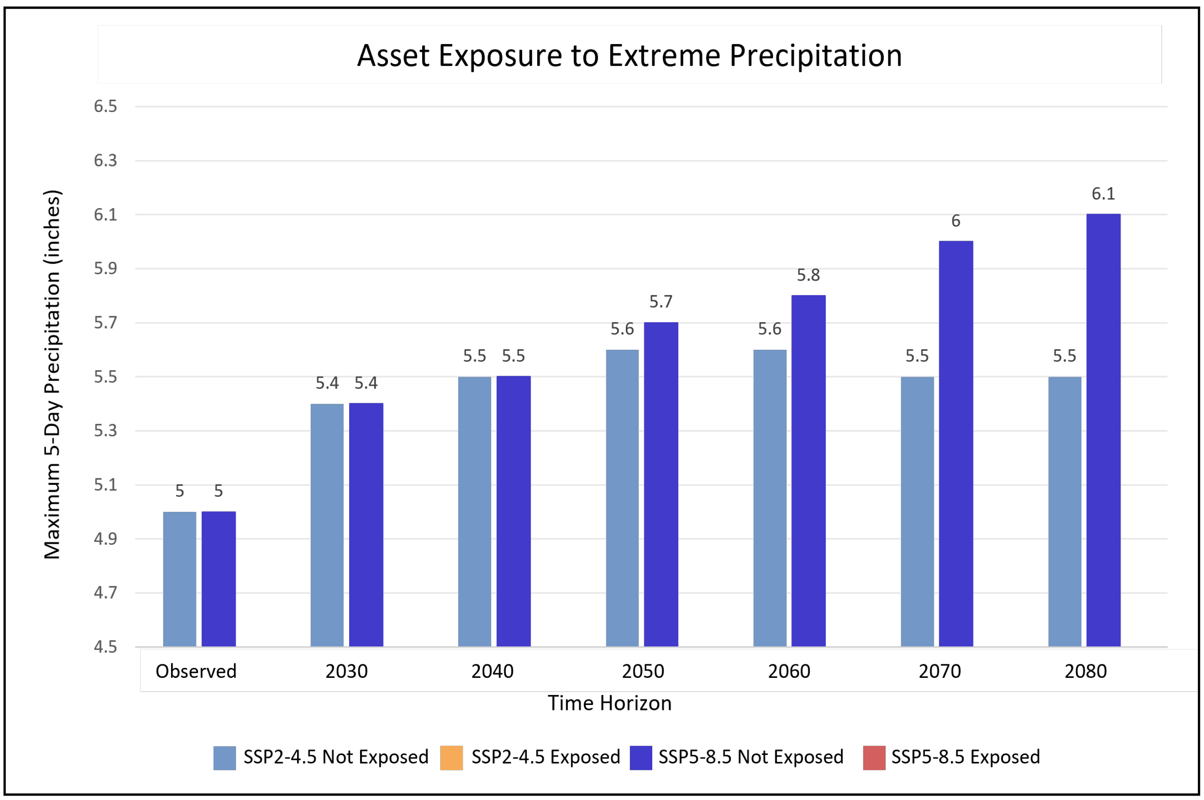

Figure 5: Asset exposure to extreme precipitation for annual maximum 5-day precipitation totals. Bars and numbers indicate the extreme precipitation totals in inches for each time horizon. Colors represent the emissions scenarios, SSP2-4.5 50th percentile (light blue and orange) and SSP5-8.5 50th percentile (dark blue and red). A bar shaded light or dark blue describes a time horizon in which assets are not exposed. A bar shaded orange or red describes a decade in which assets are exposed.

Coastal and Inland Flooding

Asset Exposure to Flooding

Up to 13% of LIPA assets could be exposed to a 100-year coastal flooding event at mid-century. Maps of underground distribution lines and substations exposed to a 100-year coastal flooding event can be seen in **Figure 6** and **Figure 7**, respectively.

6% and 8% of substations could be exposed to a 100-year and 500-year coastal flooding event at midcentury, respectively.

The majority **of underground distribution lines, underground transmission lines, and substations exposed to a 100- and/or** 500-year coastal flooding event are concentrated in two main areas (highlighted in Figure 6 and Figure 7): 1) Queens County south of JFK, southern Nassau County and southwestern Suffolk County from Rockaway Beach through Bayport and 2) eastern Suffolk County from Hampton Bays through Montauk.

Table 6 shows the number of substations and underground line miles that could be exposed to a 100-year coastal flooding event. 9% and 13% of underground distribution and underground transmission lines could be exposed, respectively, and 6% of substations could be exposed.

Up to 15% of LIPA assets could be exposed to a 500-year coastal flooding event at mid-century. Maps of underground distribution lines and substations exposed to a 500-year coastal flooding event can be seen in Figure 6 and Figure 7, respectively.

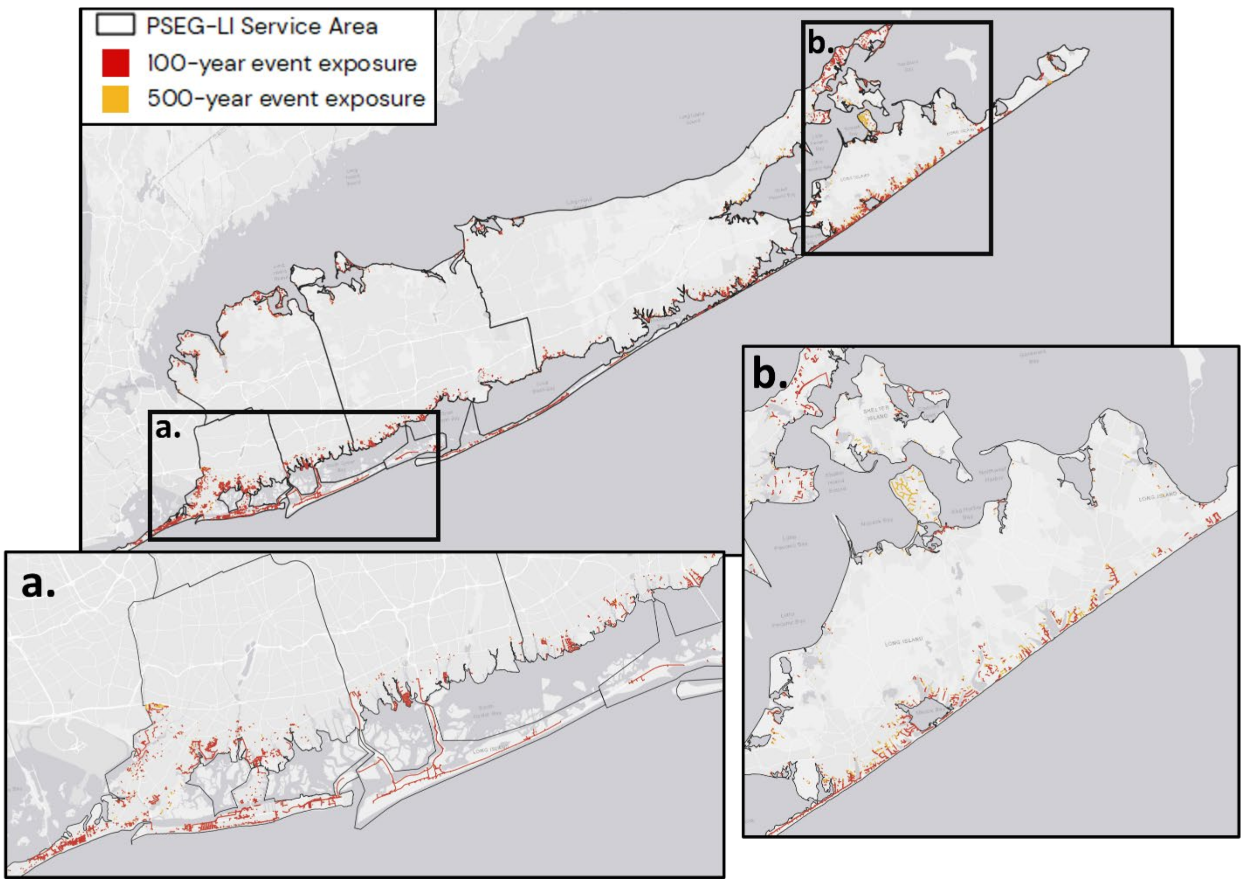

Figure 6: A map of LIPA underground distribution lines exposed to a 100-year (red) and 500-year (orange) coastal flooding event in 2050.

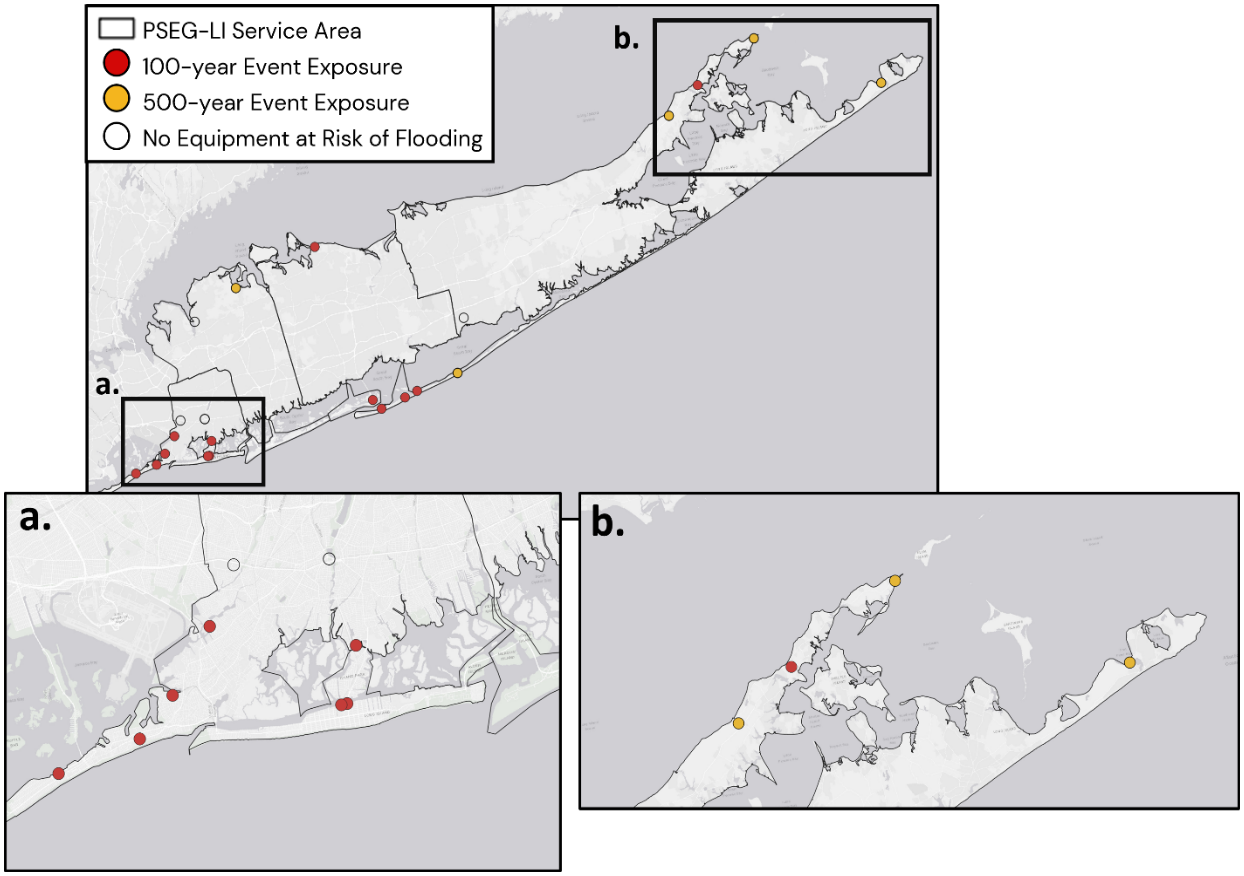

Figure 7: A map of LIPA substations exposed to a 100-year (red) and 500-year (orange) coastal flooding event in 2045. Substations within the 100- or 500-year floodplain that have no equipment that would be impacted by coastal flooding are depicted as clear circles.

The majority of underground distribution lines, underground transmission lines, and substations exposed to a 100- and/or 500-year coastal flooding event are concentrated in two main areas (highlighted in Figure 6 and Figure 7): 1) Queens County south of JFK, southern Nassau County and southwestern Suffolk County from Rockaway Beach through Bayport and 2) eastern Suffolk County from Hampton Bays through Montauk.

Table 6: LIPA asset exposure to a 100-year coastal flooding event in 2045.

Exposure to a 100-year Coastal Flooding Event			
Line Asset	Line Miles Exposed	Total Line Miles	Percentage of Line Miles Exposed
Underground Distribution Lines	443	5071	9%
Underground Transmission Lines	57	430	13%
Point Asset	Number of Assets Exposed	Total Number of Assets	Percentage of Assets Exposed
Substations	13[9]	218	6%

Table 7: LIPA asset exposure to a 500-year coastal flooding event in 2045.

Exposure to a 500-year Coastal Flooding Event			
Line Asset	Line Miles Exposed	Total Line Miles	Percentage of Line Miles Exposed
Underground Distribution Lines	517	5071	10%
Underground Transmission Lines	65	430	15%
Point Asset	Number of Assets Exposed	Total Number of Assets	Percentage of Assets Exposed
Substations	18[10]	218	8%

Asset exposure to future coastal flooding from PSEG Long Island's Sea Level Rise WaterRIDE Model largely reflects asset exposure to historical coastal and inland flooding from FEMA floodplains. Substations exposed to 100- and 500-year FEMA floodplains are

[9] 19 substations are exposed to the 100-year coastal floodplain, but 6 substations have equipment above indicated flood levels.
[10] 22 substations are exposed to the 500-year coastal floodplain, but 4 substations have equipment above indicated flood levels. Of the remaining 18 substations exposed, 12 substations have resilience measures in place to raise equipment elevation under current flooding conditions, but may be exposed under future flooding conditions.

nearly all exposed to future WaterRIDE Model coastal floodplains.[11] **This indicates that asset exposure to inland flooding will likely be low relative to coastal flooding across the LIPA service area.**

Wind

Asset Exposure to Wind from Tropical Cyclones

By late century, over 90% of overhead lines, substations, and transformers could be exposed to 1-in-10-year hurricane maximum sustained wind speeds exceeding 110 mph.

Many LIPA assets are projected to be exposed to 1-in-10-year hurricane maximum sustained wind speeds exceeding 110 mph by late century. The spatial depiction of overhead distribution lines, substations, and transformers across the service territory can be seen in Figure 8, Figure 9, and Figure 10, respectively. The northern portion of the service territory, including cities from Glen Cove through Northport and Stony Brook, are the only areas not projected to be exposed to 1-in-10-year hurricane wind speeds exceeding 110 mph by late century. This yields 98% of overhead distribution lines, 99% of overhead transmission lines, 98% of substations, and 97% of transformers that are exposed to 1-in-10-year hurricane wind speeds exceeding 110 mph (see

Table 8). In addition, 97% of distribution support structures and 99% of transmission support structures are exposed to these hurricane wind speeds by the end of the century. There are no LIPA assets exposed to 1-in-10-year hurricane wind speeds exceeding 130 mph, the highest wind speed for a Category 3 hurricane (111-130 mph maximum sustained wind speed). By end of century, the maximum 1-in-10-year wind speed is projected to be 113 mph in the service territory, an increase from a maximum of 107 mph historically. While a large proportion of assets are projected to be exposed to wind speeds exceeding 110 mph, the increase in 1-in-10-year wind speeds is modest relative to the historical period. The projected 1-in-10-year wind speed of 113 mph is well below design standards of 130 mph. See also Extreme Events section below.

While the 1-in-10-year wind speed is projected to increase to a Category 3 intensity, Category 1 (74-95 mph wind speed) hurricanes have historically impacted the Northeast US at least once every five years and Category 2 (96-110 mph) hurricanes occur at least once every 15 years. These hurricane intensities will become more likely by the end of the century.

[11] The only substation exposed to historical FEMA floodplains and not future WaterRide Model coastal floodplains is Valley Stream. This substation is exposed to the 500-year historical FEMA floodplain which also considers inland flooding.

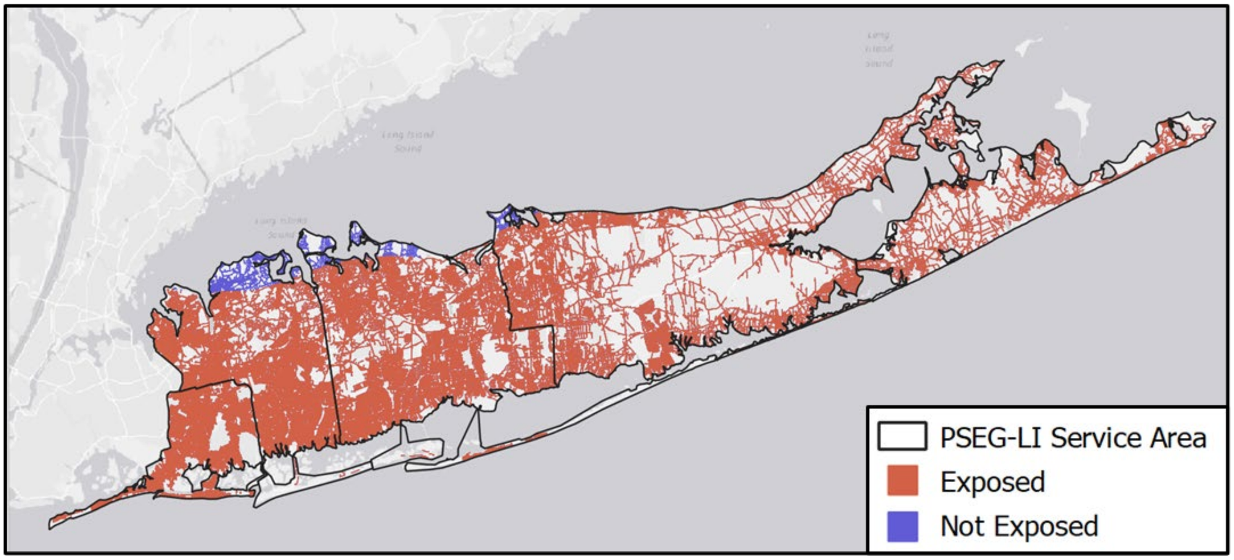

Figure 8: A map of LIPA overhead distribution lines. Lines are colored red if exposed and blue if not exposed to 1-in-10-year hurricane wind speeds exceeding 110 mph. Hurricane wind speeds are modeled for 2080-2100.

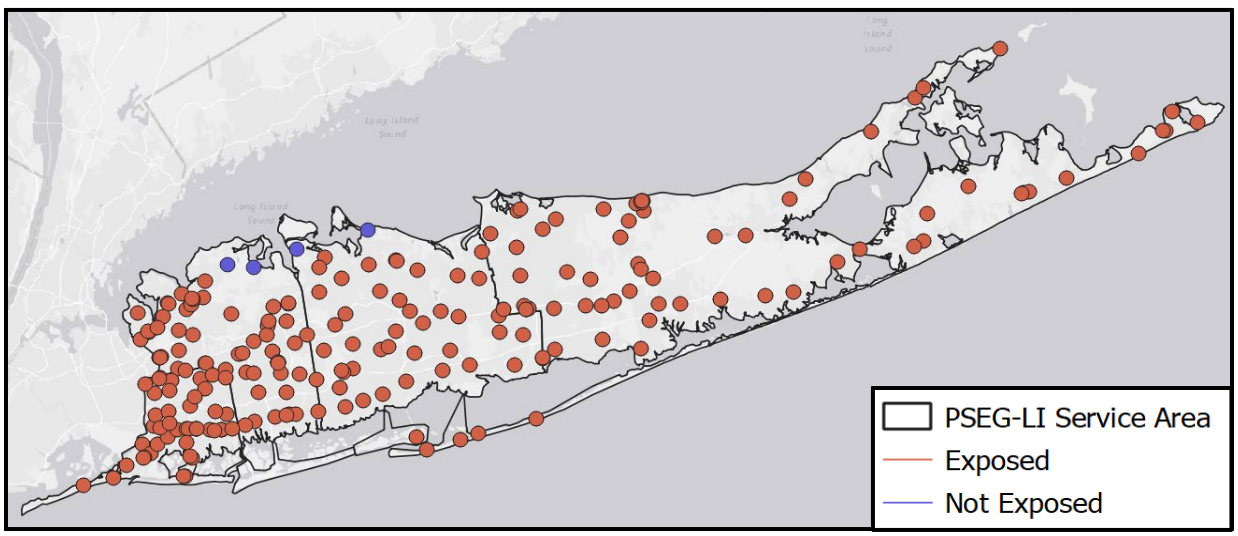

Figure 9: A map of LIPA substations. Substations are colored red if exposed and blue is not exposed to 1-in-10-year hurricane wind speeds exceeding 110 mph. Hurricane wind speeds are modeled for 2080-2100.

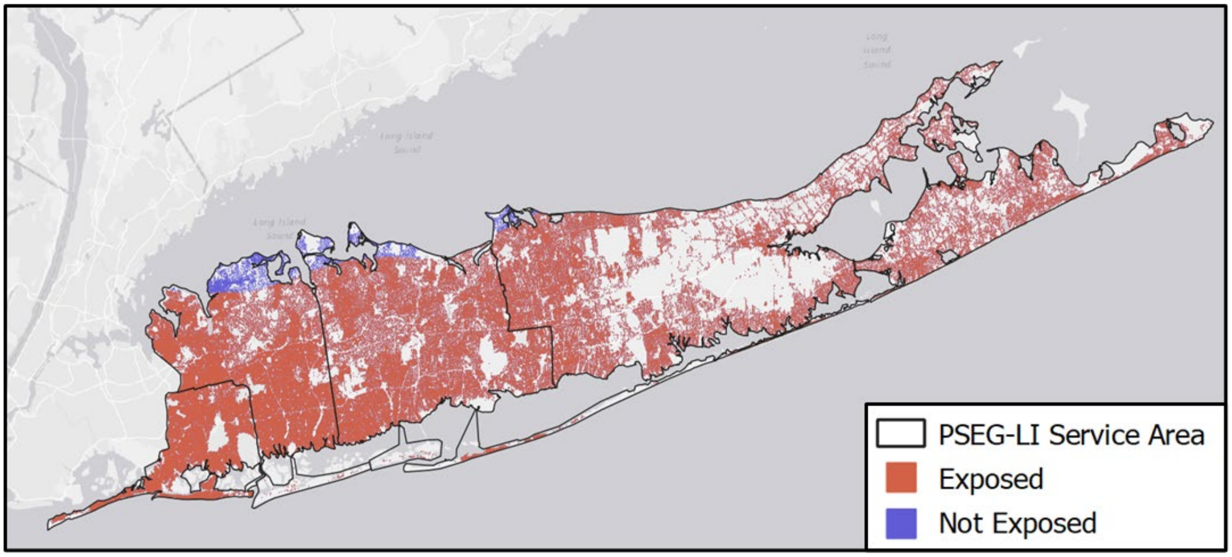

Figure 10: A map of LIPA transformers. Transformers are colored red if exposed and blue if not exposed to 1-in-10-year hurricane wind speeds exceeding 110 mph. Hurricane wind speeds are modeled for 2080-2100.

Table 8: LIPA asset exposure to extreme wind from tropical cyclones.

Exposure to 1-in-10 Year Hurricane Wind Speeds > 110 mph			
Line Asset	Line Miles Exposed	Total Line Miles	Percentage of Line Miles Exposed
Overhead Distribution Lines	8786	9036	97%
Overhead Transmission Lines	984	989	99%
Point Asset	Number of Assets Exposed	Total Number of Assets	Percentage of Assets Exposed
Substations	214	218	98%
Transformers	157,413	161,785	97%
Distribution Support Structures	537,938	554,372	97%
Transmission Support Structures	19,083	19,253	99%

The total number of line miles or number of assets exposed to 1-in-10-year hurricane wind speeds exceeding 110 mph. Hurricane winds speeds are modeled for 2080-2100.

Extreme Events

Extreme events will likely continue to increase in both frequency and intensity in the future. Extreme weather events present unique challenges to operations, planning, and infrastructure. However, climate models have difficulty resolving extreme weather events due to the small spatial and temporal scales at which these events occur, as well as the rarity of the events themselves. This challenge necessitates the use of historical analogs and projections from the scientific literature to better understand extreme events in the LIPA service area. This section highlights the projected changes in two types of extreme events: thunderstorms / tornadoes and ice storms. This section also discusses two extreme event scenarios to generate near worst-case examples that are highly unlikely but portray potential high-impact weather events under projected climate change, including a strong tropical cyclone followed by a heat wave and a severe multi-day ice storm with high winds.

Tropical cyclones typically make landfall on Long Island during the warmer months of July to October, and have resulted in significant impacts in recent years, including rainfall and storm surge. In 2011, Tropical Storm Irene brought up to 8 inches of rain and sustained winds of 40-50 mph, with gusts up to 90 mph, to the service area. In 2012, Superstorm Sandy resulted in major coastal flooding and storm surge near 14 feet at Kings Point, causing building damage and leaving hundreds of thousands of customers without power for days. The Long Island Express Hurricane in 1938, considered to be one of the strongest hurricanes to impact the region, submerged areas across Long Island, with an estimated storm tide of 15 feet in Eastern Long Island.

Historical ice storms have produced wind gusts of up to 65 mph in the service area, exacerbating the damage that ice accumulations have already caused to power lines, trees, and other infrastructure. For example, in 2011, up to 1 inch of radial ice accumulation impacted portions of the region, causing power outages and infrastructure damage.

Along with tropical cyclones and nor'easters, the service area has also been impacted by thunderstorms and tornadoes and their associated hazards in recent years. For example, in November 2021 there was a historic outbreak of tornadoes on Long Island with the most ever recorded in one day in the area.[12] The strongest tornado was rated an EF-1[13] with wind speeds topping at 110 mph.

Thunderstorm and Tornadoes

Overall, thunderstorms and tornadoes are projected to increase in frequency with climate change, although there is a high degree of uncertainty in the magnitude of

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[12] https://www.weather.gov/okx/AllNov13Tors

[13] More information on the Enhanced Fujita (EF) Scale can be found at https://www.weather.gov/oun/efscale

these trends due to competing climatic trends that drive the formation of these weather events.

Thunderstorms and tornadoes are projected to increase in frequency, but there is a high degree of uncertainty in the magnitude of these trends.

Severe weather occurs when there is upward motion from surface heating in the lower atmosphere. Thunderstorms are considered a hazard because they can lead to significant wind, flooding, lightning, and hail damage. A signature indicator of severe weather is the amount of energy within the atmosphere produced by convection; in meteorology this is known as Convective Available Potential Energy (CAPE). As CAPE values increase, so does the likelihood of severe weather, including thunderstorms, tornadoes, and hail. Several studies analyzing late 21st century climate found increasing CAPE values mainly due to increasing moisture availability with higher surface temperatures.[14,15,16,17] One study suggests the frequency of environments favorable for convective development (thunderstorm formation) could increase 5-20% per 1°C warming of global average air temperature.[18]

Climate change is projected to double the number of days with high likelihood of severe thunderstorms in the New York City area by late-21st century under the high-emissions Representative Concentration Pathway (RCP) 8.5 scenario.[19] Lightning strikes are projected to increase by approximately 12% for every 1˚ C of warming global average air temperature.[20] Extreme precipitation is also associated with thunderstorm activity. The number of high-intensity rainfall events resulting from thunderstorms could triple by late-21st

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[14] Del Genio, A.D., Yao, M.-S., & Jonas, J. 2007. Will moist convection be stronger in a warmer climate? Geophysical Research Letters, 34(16), L16703. http://dx.doi.org/10.1029/2007GL030525

[15] Trapp, R. J., Diffenbaugh, N. S., Brooks, H. E., Baldwin, M. E., Robinson, E. D., & Pal, J. S. (2007). Changes in severe thunderstorm environment frequency during the 21st century caused by anthropogenically enhanced global radiative forcing. Proceedings of the National Academy of Sciences, 104(50), 19719-19723. https://doi.org/10.1073/pnas.0705494104

[16] Van Klooster, S.L., & Roebber, P.J. 2009. Surface-based convective potential in the contiguous United States in a business-as-usual future climate. Journal of Climate, 22(12), 3317-3330, http://dx.doi.org/10.1175/2009JCLI2697.1

[17] Brooks, H. E. 2012. Severe thunderstorms and climate change. Atmospheric Research, 123, 129-138. https://doi.org/10.1016/j.atmosres.2012.04.002.

[18] Lepore, C., Abernathey, R., Henderson, N., Allen, J. T., & Tippett, M. K. (2021). Future global convective environments in CMIP6 models. Earth's Future, 9(12), e2021EF002277. https://doi.org/10.1029/2021EF002277

[19] Trapp, R. J., Diffenbaugh, N. S., Brooks, H. E., Baldwin, M. E., Robinson, E. D., & Pal, J. S. (2007). Changes in severe thunderstorm environment frequency during the 21st century caused by anthropogenically enhanced global radiative forcing. Proceedings of the National Academy of Sciences, 104(50), 19719-19723. https://doi.org/10.1073/pnas.0705494104

[20] Romps, D., Seeley, J., Vollaro, D., Molnari, J. 2014. Projected increase in lightning strikes in the United States due to global warming. Science. Vol. 346. Issue. 6211. P. 851-854. https://doi.org/10.1126/science.1259100

century across North America in a high-end RCP 8.5 scenario, including a 15-40% increase in thunderstorm precipitation rates.[21]

Tornadoes and extreme straight-line winds are most often associated with severe thunderstorms. Although CAPE is projected to increase, another severe weather variable, wind shear, is projected to decrease under future climate warming scenarios, mainly due to the reduction of the temperature gradients between the equator and poles.[22,23,24] Wind shear, which describes changes in wind speed and/or direction with height that facilitate thunderstorm intensification, is significantly more important for the development and intensity of tornadoes and hail.[25] Another study suggests that the season length and frequency of environmental conditions favorable for tornadoes, hail, and damaging wind gusts is projected to increase by late-21st century, increasing the period favorable for thunderstorm formation by up to one month during the spring and fall seasons.[26] As the conditions that form tornadoes are complex and these two severe weather variables display competing future changes, there is a high degree of uncertainty as to how tornadic activity will change in the future.

Ice Storms

Overall, models project a decrease in the frequency of ice storms in the service area, but potentially more intense radial ice accumulation when they do occur. However, there is high uncertainty in the magnitude of both of these future trends.

Models suggest that winter storms will experience a decrease in frequency as temperatures warm, which may lead to more liquid precipitation. Even though the overall likelihood of a winter storm with frozen precipitation is projected to decrease, leading to decreases in the frequency of frozen precipitation events in the future, winter storms could produce frozen precipitation at a higher intensity than present day if the atmospheric conditions are cold enough at the surface to support freezing rain.[27] The likelihood of more extreme freezing rain

[21] Prein, A. F., Liu, C., Ikeda, K., Trier, S. B., Rasmussen, R. M., Holland, G. J., & Clark, M. P. (2017). Increased rainfall volume from future convective storms in the US. Nature Climate Change, 7(12), 880-884. https://doi.org/10.1038/s41558-017-0007-7

[22] Trapp, R. J., Diffenbaugh, N. S., Brooks, H. E., Baldwin, M. E., Robinson, E. D., & Pal, J. S. (2007). Changes in severe thunderstorm environment frequency during the 21st century caused by anthropogenically enhanced global radiative forcing. Proceedings of the National Academy of Sciences, 104(50), 19719-19723. https://doi.org/10.1073/pnas.0705494104

[23] Van Klooster, S.L., & Roebber, P.J. 2009. Surface-based convective potential in the contiguous United States in a business-as-usual future climate. Journal of Climate, 22(12), 3317-3330, http://dx.doi.org/10.1175/2009JCLI2697.1

[24] Brooks, H. E. 2012. Severe thunderstorms and climate change. Atmospheric Research, 123, 129-138. https://doi.org/10.1016/j.atmosres.2012.04.002

[25] Ibid.

[26] Hoogewind, K. A., Baldwin, M. E., & Trapp, R. J. (2017). The impact of climate change on hazardous convective weather in the United States: Insight from high-resolution dynamical downscaling. Journal of Climate, 30(24), 10081-10100. https://doi.org/10.1175/JCLI-D-16-0885.1

[27] Zarzycki, C. M. 2018. Projecting changes in societally impactful northeastern U.S. snowstorms. Geophysical Research Letters, 45, 12067-12075. https://doi.org/10.1029/2018GL079820

events is also projected to shift farther north as temperatures warm over the region.[28,29] This trend is consistent with recent observations of a gradual northward migration of the rain-snow transition zone across the United States.[30] These findings suggest that when ice storms do occur, they may be more intense, even though the frequency of these storms is projected to decrease.

One study investigated projected changes to extreme ice loads used to design infrastructure over North America through the end of the century.[31] Increases in upper-level and surface temperatures over North America, driven by warming temperatures, could lead to increased freezing rain frequency and ice thickness at latitudes above 40°N in North America by the end of the century. Interestingly, radial ice accumulation caused by freezing rain on vertical surfaces is projected to increase at a greater rate relative to freezing rain on horizontal surfaces. This is due to projected increases in surface wind speed during the cold season, leading to greater ice loading on the sides of infrastructure and vegetation.

Despite projected decrease in frequency and increase in maximum intensity of ice storms, future changes to the intensity of ice storms and cold snaps come with a high degree of uncertainty due to the specific atmospheric conditions required for ice storms to occur relative to other high-impact hazards.[32]

[28] Lambert, S. J., & Hansen, B. K. 2011. Simulated changes in the freezing rain climatology of North America under global warming using a coupled climate model. Atmosphere-Ocean, 49(3), 289-295. https://doi.org/10.1080/07055900.2011.607492

[29] Cheng C., Li G., & Auld, H. 2011. Possible impacts of climate change on freezing rain using downscaled future climate scenarios: updated for eastern Canada, Atmosphere-Ocean, 49(1), 8-21. https://doi.org/10.1080/07055900.2011.555728

[30] Easterling, D., et al. 2017. Precipitation change in the United States Climate Science Special Report: Fourth National Climate Assessment Vol I, ed. D J Wuebbles Coauthors (Washington DC, USA: U.S. Global Change Research Program). pp 207–30. https://doi.org/10.7930/J0H993CC

[31] Jeong, D. I., Cannon, A. J., & Zhang, X. 2019: Projected changes to extreme freezing precipitation and design ice loads over North America based on a large ensemble of Canadian regional climate model simulations. Natural Hazards and Earth System Sciences, 19, 857–872. https://doi.org/10.5194/nhess-19-857-2019

[32] IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2391 pp. doi:10.1017/9781009157896. https://www.ipcc.ch/report/ar6/wg1/

Vulnerability Assessment

To support PSEG Long Island's understanding of its vulnerability to projected climate change, the Study team analyzed the potential vulnerability of LIPA assets and PSEG Long Island's operations to a range of climate hazards including, **extreme heat, coastal and inland flooding, wind, ice, cold temperatures, and extreme precipitation**. The Study team worked with PSEG Long Island SMEs to select these hazards based on historic impacts to assets and operations, as well as potential impacts based on projected future changes in these climate hazards over the next century. This section presents the findings from the assessment of asset and operational vulnerability which will be used by PSEG Long Island to identify and prioritize mitigation measures that would help strengthen the resilience of its assets and operations to projected climate risks.

Asset Vulnerability

This section discusses the vulnerability assessment framework used to evaluate the vulnerability of LIPA's assets to selected climate hazards (**Figure 11**).

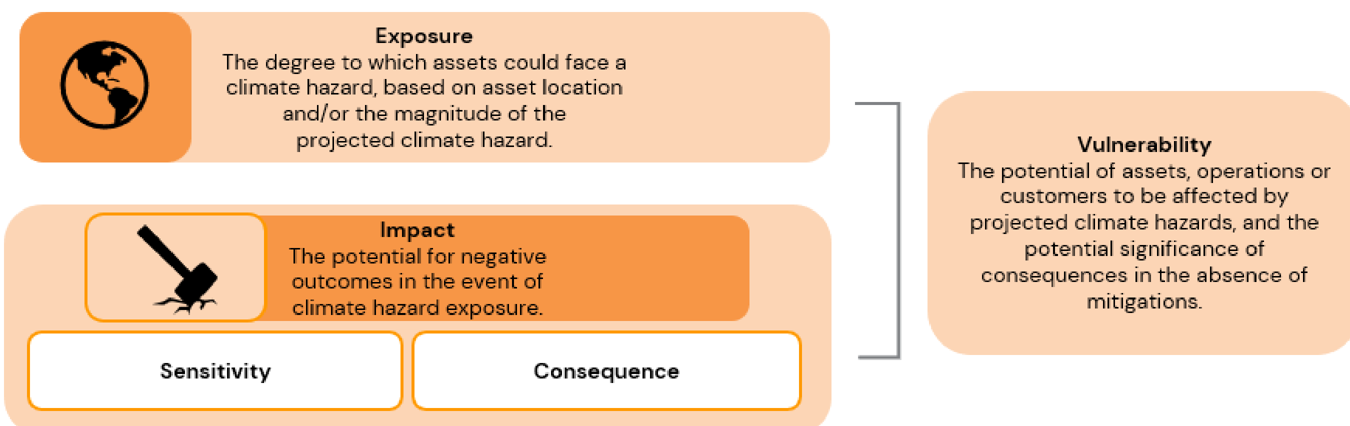

Figure 11: Vulnerability Assessment Framework

Assets were categorized into three main groups: **transmission, distribution, and substation.** Each asset group consists of a set of asset types which represent critical components of that asset group. Each asset type and hazard pair was rated for potential **impact**, which involved evaluating **sensitivity** and **consequence** and combining those scores with results from **exposure** analysis to arrive at **vulnerability** ratings.

Sensitivity and consequence were rated as low, moderate, or high and assigned a numerical score associated with respective ratings. These ratings are based on extensive consultations with PSEG Long Island's SMEs who reviewed the ratings based on their technical knowledge and experience. Criteria for determining the sensitivity, consequences, exposure, and vulnerability ratings are discussed in the following sections.

Sensitivity

Sensitivity represents the potential for LIPA's assets to be negatively affected by exposure to a climate hazard. Each asset type selected for analysis contributes to the functionality and reliability of LIPA's electric system and has a specific sensitivity to different climate hazards. For example, transmission structures are sensitive to high winds and exposure to this hazard can lead to damage to poles and towers. The sensitivities were evaluated and rated by PSEG Long Island SMEs based on their experience and understanding of climate hazards, technical specifications of electric assets, and applicable standards.

The Study team rated sensitivity on a scale of low (1), moderate (2), and high (3). Asset types that are not expected to be exposed to a particular climate hazard were assigned a rating of "not applicable" or N/A. For example, because underground conductors are not exposed to high winds, their sensitivity was rated as 0 or N/A.

Asset sensitivity was rated as:

- **Low (1),** if assets experience minimal adverse impacts from the hazard.
- **Medium (2)**, if assets only experience adverse impacts at high thresholds of exposure, such as very high temperatures or flooding levels, and/or, adverse impacts are more likely to be chronic/controlled (i.e., accelerated degradation) rather than sudden/acute (i.e., sudden failure).
- **High (3)**, if assets are subject to an increased risk of major or sudden failure in the event of exposure to a given climate hazard, and/or, existing protection or adaptation measures for the asset are typically limited or nonexistent (for example, electrical substations without flood protection walls).

Consequence

Consequence represents the magnitude of adverse outcomes for LIPA's systems and customers when an asset is damaged. Consequence often reflects the criticality of assets, as well as an asset's adaptive capacity.[33] Unlike sensitivity, consequence ratings are *independent* of which climate hazard causes the impairment. In other words, consequence ratings focus strictly on outcomes which may occur if assets were to have their operations and functionality impeded, irrespective of which climate hazard causes this.

[33] The ability for a system or asset to continue to operate and/or cope with consequences.

Like sensitivity, consequence was also rated on a scale of low (1), moderate (2), and high (3). Consequences were rated as:

- **Low (1),** if damage to an asset is likely to result in minor or minimal adverse outcomes.
- **Medium (2),** if damage to an asset is likely to result in significant adverse outcomes, including sustained outages in localized areas, safety risks to the public or utility personnel, and/or costly repairs.
- **High (3),** if damage to an asset is likely to result in widespread or long duration outages, numerous injuries, and/or major financial losses.

Impact (Sensitivity x Consequence)

Impact is the significance of negative outcomes (i.e., consequence) when a climate hazard exceeds an asset's ability to withstand the hazard (i.e., sensitivity) (Figure 12)**.** Therefore, impact is a valuable indicator that communicates not only if an asset could be impacted by a given climate hazard, but also the criticality of the outcomes to LIPA's electric system if that asset is damaged or fails.

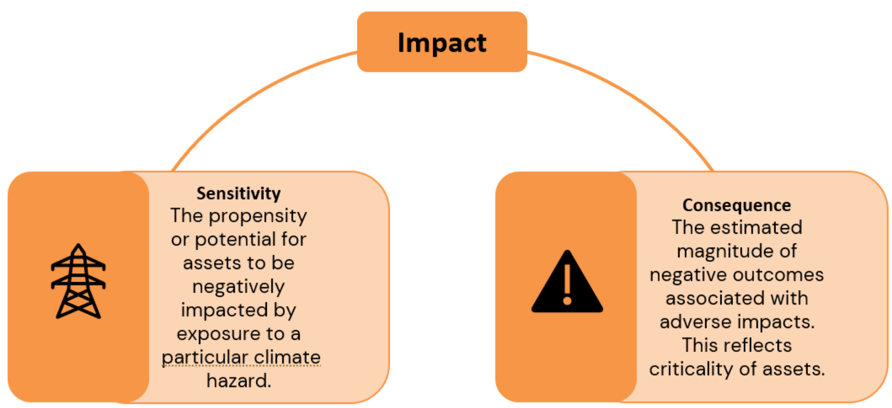

Figure 12: Components of Impact – Sensitivity and Consequence.

After sensitivity and consequence ratings are assigned to each asset type, the scores are collated to generate impact ratings. Impact is scored by multiplying the numerical values assigned to sensitivity and consequence ratings. For example, an asset type with a moderate sensitivity (2) and high consequence (3) will generate a high impact score (6), as shown in in **Table 9**.

Table 9: Impact scoring rubric.

Consequence Score	Impact			
3 (High)	0	3	6	9
2 (Moderate)	0	2	4	6
1 (Low)	0	1	2	3
Sensitivity Score	0 (NA)	1 (Low)	2 (Moderate)	3 (High)

N/A, 0, (Gray)
Low, 1-2, (Green)
Moderate, 3-4, (Yellow)
High, 6-9, (Orange/red)

Exposure

Climate hazards identified for the vulnerability assessment were selected based on projections of climate data for LIPA's service area, and the exposure analysis – the results of which have been discussed in detail in the "Exposure" section of this report.

Exposure represents the degree to which assets could face changes in climate hazards based on their physical locations and the magnitude of future changes in climate. Climate projections shed light on how the intensity and duration of different climate hazards are projected to change through the 21st century. Six climate hazards were assessed and four were identified as significant based on climate projections and results of the hazard exposure analysis. Of these four significant hazards, one (extreme heat) was assessed for each decade from 2030-2080, as described in the exposure section. The exposure assessment utilized a binary scoring method (0 or 1) to indicate the system's s projected exposure to specific hazards in the future. A "0" score (or "Not Exposed" score) indicates that the magnitude of change for a hazard, and therefore the future risk of exposure, is *not* significant. Because vulnerability is assessed as a combination of exposure, sensitivity, and consequence scores, assets which have an exposure score of 0 (or "Not Exposed") also have a vulnerability score of 0 with respect to that specific hazard.

Vulnerability

Vulnerability can be understood as the potential for LIPA's assets to be adversely impacted as a result of exposure to a projected climate hazard and the significance of those impacts as they relate to LIPA's systems, services, and customers.

After all of the asset and hazard pairs were assigned an impact score ranging from 0-9 (sensitivity multiplied by consequence), these were combined with the binary exposure scores (0 or 1) to establish vulnerability ratings. Figure 13 illustrates this. "High" vulnerability corresponds with scores ranging from 6-9, "moderate" vulnerability corresponds with scores ranging from 3-4, and "low" vulnerability is represented by scores ranging from 1-2. Vulnerability is 0 or not applicable (N/A) for those hazards which are rated as "not exposed" or exposure score of 0.

Asset types rated as “High” vulnerability represent **priority vulnerabilities** for PSEG Long Island, which are asset-hazard pairs with the highest potential for adverse outcomes. These priority vulnerabilities will be considered for further risk evaluation and will inform resilience recommendations in PSEG Long Island’s Climate Change Resilience Plan.

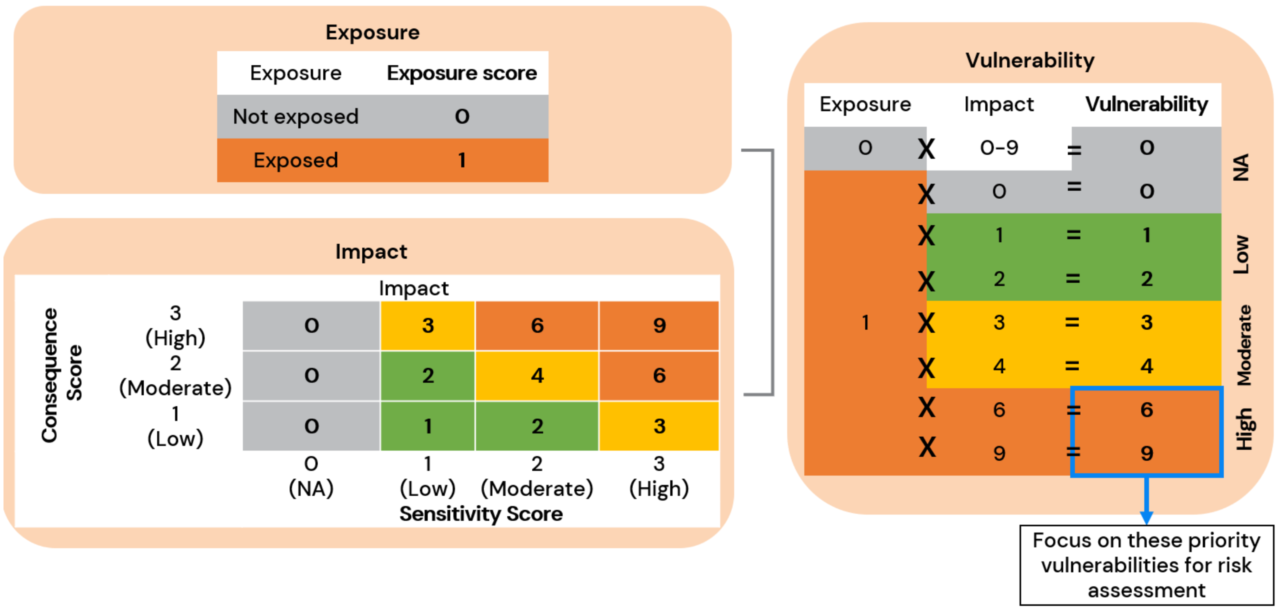

Figure 13: Methodology for assessing vulnerability score. Vulnerability is determined by multiplying binary exposure scores by impact scores. Impact scores are determined by analyzing both sensitivity and consequence.

Results

Changes in climate and extreme weather events can increase rates of electric asset failure, cause more outages, and impact system reliability within LIPA’s service area. The vulnerability assessment was aimed at identifying which asset-hazard combinations present the greatest potential for negative outcomes in the event of exposure to different climate hazards. This section presents the vulnerability scores for all asset types that were analyzed. For each climate hazard, vulnerability results are organized by the three asset groups – transmission, distribution, and substation.

Priority vulnerabilities are summarized in **Table 10**, followed by key takeaways from the asset vulnerability assessment.

Table 10: Priority Vulnerabilities identified for LIPA's electric assets.

Climate Hazard	Transmission	Distribution	Substation
Extreme Heat		• Overhead transformers • Pole mounted regulators	• Transformers and regulators • Switchgear
Coastal and Inland Flooding		• Pad mount switchgear	• Transformers and regulators • Circuit breakers • Switchgear (distribution, including breakers, PTs, and relay) • Instrument Transformers (CT's and PT's) • Control room/control house/protection and control devices
High Wind	• Line structures • Overhead conductors	• Overhead structures (including poles) • Overhead conductors	
Ice	• Line structures • Overhead conductors	• Overhead structures (including poles) • Overhead conductors	• Transformers and regulators

Key Takeaways

Transmission

- Transmission line structures and overhead conductors were assessed to be highly vulnerable to projected exposure to high wind and ice events. High winds and wind gusts pose a threat to structures and conductors from increased wind loading, wind-blown debris, and downed trees. Extreme ice events may cause damage from increased ice loading.

Distribution

- Overhead transformers, and pole mounted regulators were evaluated to be highly vulnerable to projected extreme heat events which may reduce capacity, accelerate aging, and increase the risk of failure.
- Pad mounted switchgear was found to have high vulnerability to potential impacts from flooding.
- Overhead structures and overhead conductors were found to be highly vulnerable to projected exposure to both high winds and ice events. High winds pose a risk of pole damage from increased wind loading, wind-blown debris, and downed trees. Extreme ice events may cause damage or pole failure from increased ice loading.

Substations

- Transformers, regulators, and switchgear were found to be highly vulnerable to projected exposure to extreme heat, which may impact effective capacity, reduce ratings, or accelerate asset aging/risk of failure.
- Transformers, regulators, circuit breakers, switchgear, instrument transformers, and substation control rooms/houses were found to be highly vulnerable to projected exposure to inland and coastal flooding. Substations located in floodplains or near coasts have high exposure to these hazards.
- Transformers and regulators were also evaluated to be highly vulnerable to ice loading, which may increase flashover risk.

Detailed vulnerability results for each hazard are presented below.

Extreme Heat

Increasing average temperature and extreme heat events are likely to pose risks to LIPA's electric system by mid-century. Results from the exposure analysis in this CCVS show that LIPA assets are projected to be exposed to extreme heat by 2060 under both emissions scenarios. Importantly, the length and intensity of heat waves have the potential to amplify impacts associated with increasing average temperatures on infrastructure.

Significant potential impacts that projected exposure to extreme heat events are likely to have on LIPA's electric assets include:

- Decreased asset capacity.
- Accelerated asset aging.
- Increased risk of asset failure.

Transmission

Overall, transmission assets have moderate vulnerability to extreme heat (**Table 11**). Although ground temperatures tend to remain relatively stable (particularly at burial depths of transmission feeders) components such as riser cables can be affected by heat. For transmission, only two circuits on LIPA's system have cooling systems to reduce the sensitivity to external heat. LIPA's ability to install more cooling devices is limited due to space constraints and cable types, which may present challenges to increasing assets' adaptive capacity in the future. In addition, soil thermal resistivity is also a factor that affects the ratings of underground transmission cables. Thermal resistivity is dependent on the moisture content of the soil. If climate change causes drier soil conditions, soil resistivity would increase, reducing cable ampacity. The potential for higher temperatures to impact riser cables and increases in soil conductivity may marginally increase the risk of underground transmission cable failure which can result in circuit outage, potentially interrupting customers. Increased ambient temperatures can also reduce the thermal capacity of overhead conductors and open-air components like switches.

Although line structures and pumping equipment are exposed, these are not sensitive to impacts of extreme heat; therefore, the vulnerability of these asset types is scored as N/A.

Table 11: Vulnerability Ratings for Extreme Heat and Transmission Assets.

Transmission		Impact		
	Exposure	**Sensitivity**	**Consequences**	**Vulnerability**
Line structures (poles/towers)	Exposed	N/A	Med	N/A
Conductors (overhead)	Exposed	Med	Med	Med
Conductors (underground)	Exposed	Med	Med	Med
Switches	Exposed	Med	Med	Med
Pumping equipment	Exposed	N/A	Low	N/A

Distribution

Distribution assets demonstrate a range of vulnerabilities to extreme heat. Distribution assets expected to experience the greatest impact from increased heat exposure include overhead transformers and pole mounted regulators (**Table 12**). Vulnerability scores for these assets are influenced by the assets' high sensitivity to the hazard. Higher ambient temperatures can reduce the capacity of overhead transformers and pole-mounted regulators. Increasing frequency, severity, and duration of heat waves also has the potential to accelerate aging and even increase risk of failure of transformers and regulators.

Moderate consequence ratings also contribute to high vulnerability ratings of these assets. Depending on the specific system design, failure of overhead transformers and regulators may result in customer outages.

Although overhead structures and pad mount switchgear are exposed to extreme heat, they are not sensitive to this hazard, therefore their vulnerability is scored as N/A.

Table 12: Vulnerability Ratings for Extreme Heat and Distribution Assets.

Distribution		Impact		
	Exposure	Sensitivity	Consequences	Vulnerability
Structures (Overhead) [Includes poles]	Exposed	N/A	Med	N/A
Conductors (Overhead)	Exposed	Med	Med	Med
Conductors (Underground)	Exposed	Med	Med	Med
Switches	Exposed	Med	Med	Med
Transformers (Overhead)	Exposed	High	Med	High
Transformers (Pad mount)	Exposed	High	Low	Med
Regulators (Pole mounted)	Exposed	High	Med	High
Capacitors (Pole mounted)	Exposed	Med	Low	Low
Batteries (Overhead control)	Exposed	Med	Low	Low
Surge Arresters	Exposed	Low	Low	Low
Switchgears (pad mount)	Exposed	N/A	Med	N/A

Substations

Overall, substation assets have a medium to high vulnerability to extreme heat, specifically substation transformers, regulators, and switchgear (**Table 13**). Substation transformers are typically rated based on an average ambient air temperature of 32°C (89.5°F). High temperatures can lower effective capacity by approximately 1-1.5% per 1°C increase in temperature above 40°C[34] (104°F). High heat conditions also have the potential to accelerate aging or increase the risk of asset failure through elevated equipment temperatures. Depending on substation design, substation transformer failures may result in customer outages. The complexity and lead time to replace a failed transformer is also significant.

Table 13: Vulnerability Ratings for Extreme Heat and Substation Assets.

Substation		Impact		
	Exposure	Sensitivity	Consequence	Vulnerability
Substation transformers/regulators	Exposed	High	High	High
Circuit breakers	Exposed	Low	Med	Low
Switchgear (distribution, including breakers, PTs, and relay)	Exposed	Med	High	High
Instrument Transformers (CT's and PT's)	Exposed	Med	Med	Med

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

Control Room/Control House/Protection and Control Devices	Exposed	Low	High	Med

Coastal and Inland Flooding

Flooding events present the greatest threat to LIPA's substation assets while transmission and distribution assets are not generally considered to have a high sensitivity to flooding unless floodwaters compromise the integrity of structures. While most LIPA assets are not within the historical 100-year FEMA floodplain, a small proportion of assets are and thus are exposed to historical coastal and inland flooding. Sea level rise projections were evaluated to assess the potential exposure of LIPA's electric assets to future coastal flooding. Results suggest that nearly one-tenth of LIPA's assets could be exposed to a 100-year coastal flooding event at mid-century. Although asset sensitivity to sea level rise is moderated by the gradual nature of the hazard, coastal flooding can still present challenges to PSEG Long Island's operations.

Significant impacts that projected exposure to coastal and inland flooding is likely to have on LIPA's electric assets include:

- Equipment damage and corrosion
- Increased impact loading on structures during storms or from storm surge.
- Instability of the ground near asset bases and soil weakening.
- Restricted access to manholes, preventing necessary maintenance and repairs.

Transmission

Underground conductors are moderately vulnerable to flooding (**Table** ***14***). While underground transmission systems are generally designed to be submersible and able to withstand flooding events, permanent inundation associated with sea level rise could severely weaken the load bearing capacity of surrounding soil, leading to damage of underground assets. Soil erosion and scouring of the ground near pole bases (especially near existing watercourses) can compromise the structural integrity of transmission line structures. Damage can be exacerbated by exposure to saline water, compared to freshwater.

Medium vulnerability score for underground conductors is also influenced by the medium consequence score. The failure of underground conductors may result in circuit outages affecting wide areas and potentially affecting a large number of customers. Additionally, underground conductor repair times could be significantly longer than overhead assets. Although line structures and switches are exposed, they are not sensitive to flooding hazards, and therefore their vulnerability is rated as N/A.

Table 14: Vulnerability Ratings for Coastal and Inland Flooding and Transmission Assets.

Transmission	Exposure	Impact		Vulnerability
		Sensitivity	Consequence	
Line structures (poles/towers)	Exposed	Low	Med	Low
Conductors (Overhead)	Exposed	N/A	Med	N/A
Conductors (Underground)	Exposed	Med	Med	Med
Switches	Exposed	N/A	Med	N/A
Pumping Equipment	Exposed	Low	Low	Low

Distribution

Distribution assets are generally not highly vulnerable to flooding (**Table 15**). Pad mounted switchgears are the only distribution asset type with a potentially high vulnerability to flooding, due largely to their high sensitivity to this hazard. Pad mounted switch gear, once exposed to water, cannot be re-reenergized until inspected and maintained. In extreme flooding conditions, switchgear can be displaced. Pad mounted switchgears are typically on three phase mains and their failure can result in a greater number of customer outages.

Overhead conductors, switches, overhead transformers, pole mounted regulators, pole mounted capacitors, batteries, and surge arresters although exposed to flooding hazard are not sensitive to its impacts and therefore their vulnerability is rated as N/A.

Table 15: Vulnerability Ratings for Coastal and Inland Flooding and Distribution Assets.

Distribution	Exposure	Impact		Vulnerability
		Sensitivity	Consequence	
Structures (overhead) [Includes poles]	Exposed	Med	Med	Med
Conductors (Overhead)	Exposed	N/A	Med	N/A
Conductors (Underground)	Exposed	Med	Med	Med
Switches	Exposed	N/A	Med	N/A
Transformers (Overhead)	Exposed	N/A	Med	N/A
Transformers (Pad Mount)	Exposed	High	Low	Med
Regulators (Pole Mounted)	Exposed	N/A	Med	N/A
Capacitors (Pole Mounted)	Exposed	N/A	Low	N/A
Batteries (Overhead control)	Exposed	N/A	Low	N/A
Surge Arresters	Exposed	N/A	Low	N/A
Switchgears (Pad mount)	Exposed	High	Med	High

Substations

The high vulnerability of substation assets to flooding is driven by both high sensitivity and high consequence scores. Substations contain equipment that is highly sensitive to water

(**Table 16**). So, substations located in floodplains are at an elevated risk of exposure to the hazard. Substation transformers, regulators, and circuit breakers have low tolerance for inundation leading to significant disruption or failure. Although transformer tanks tend to be hermetically sealed, water from flooding events can still enter and impact transformers control cabinets, radiators, fans, pumps, external wiring connections, and the other accessories, which can lead to damage. Depending on substation design, failure of substation assets may result in customer outages. The complexity and lead time to replace certain substation assets, including transformers, can be significant.

Flooding due to sea level rise may limit the ability of field crews to access substations for maintenance or repairs. This is especially relevant for assets near coastlines and is discussed in more detail in the section on Operational and Planning Vulnerabilities.

Table 16: Vulnerability Ratings for Coastal and Inland Flooding and Substation Assets.

Substation	Exposure	Impact		Vulnerability
		Sensitivity	Consequence	
Substation transformers/regulators	Exposed	High	High	High
Circuit breakers	Exposed	High	Med	High
Switchgear (distribution, including breakers, PTs, and relay)	Exposed	High	High	High
Instrument Transformers (CT's and PT's)	Exposed	High	Med	High
Control Room/Control House/Protection and Control Devices	Exposed	High	High	High

PSEG LONG ISLAND

CASE STUDY: SHORELINE EROSION AT THE FIRE ISLAND PINES SUBSTATION

Built around 1970, the Fire Island Pines Substation is located just east of the community of Fire Island Pines in Suffolk County. The shoreline north of the substation is threatened by chronic erosion and has experienced approximately 150 feet of erosion on the Bayfront since installation of the substation. The substation represents a critical facility for Fire Island communities and is connected to the Long Island mainland by submarine cables.

Changes to the shoreline near the substation have altered coastal dynamics and erosive processes, which have resulted in high shoreline erosion rates over time. Prior to 2004, the shoreline recession rate averaged at 1.3 feet per year, but has subsequently accelerated to 4.8 feet per year. Hard structures to the west of the substation, and the loss of the Barrett Beach Pier to the east in 2003, have changed sediment transport in the area and are essentially starving the system of the needed sand. Slumping of the bluff fronting the substation is causing the vegetation to slide off and rapid erosion prevents the bluff from reestablishing vegetation. These conditions have exposed the Fire Island Pines substation to the risk of collapsing into the water from the erosion of the bluff. Severe erosion was recorded in the winter of 2022-23, and at the current rate, it is estimated that the top of the bluff will likely be at the level of the substation fence in approximately three years.

Sea level rise is projected to further increase the water elevation at the site, potentially increasing the area directly exposed to wave action, which may accelerate erosion and the slumping of the bluff. Climate change is also likely to increase the frequency and intensity of coastal storms which can potentially aggravate the risk of exposure to flood events. Additionally, projections for warmer winters due to climate change could potentially reduce ice in the bay and increase wave action during winter months, which could lead to higher rates of erosion than historically experienced.

To address current and potential future impacts, LIPA has carried out a complete analysis of the existing conditions at the location of the substation, causes of erosive processes, and identified potential mitigation options that can be implemented, including immediate solutions are that already underway.

- **Immediate** measures: Stabilizing and protecting the exposed transmission cable by placing sand bags and clean sand fill around the cable.
- **Short-term** measures: More robust protection and stabilization measures, including using geotextile cubes anchored to the base of the bluff.
- **Mid-term** measures under the Army Corps of Engineers' Fire Island to Montauk Point (FIMP) Program: Shoreline stabilization measures such as beach nourishment, living shoreline, breakwaters, etc., and bluff stabilization measures such as bluff restoration, geotextlie structures for stabilization, etc.
- **Long-term** measures: Potentially relocating the substation depending on availability and feasibility of acquiring new land.

High Wind

High winds may adversely impact assets within LIPA's electric system. Results from the exposure assessment show that a majority (more than 90%) of LIPA assets are projected to be exposed to 1-in-10-year hurricane maximum sustained wind speeds exceeding 110 mph by late century.

Significant impacts that projected changes in exposure to high winds are likely to have on LIPA's electric assets include:

- Asset failure due to wind loading.
- Impact from downed vegetation.
- Impact from wind-driven debris.

Transmission

Transmission line structures, including poles, towers, and overhead conductors are likely to be highly vulnerable to impacts from high wind exposure, due largely to their high sensitivity to this hazard (**Table 17**). Although overhead transmission conductors' direct sensitivity to wind is low, conductors, particularly those at lower voltage levels, are susceptible to damage from falling trees. Conductors can also be damaged by electrical contact during strong winds as a result of blowout or galloping. Wind-blown debris has, in the past, impacted transmission lines and caused outages. Extreme winds may also lead to transmission tower failure.

PSEG Long Island accounts for wind in its transmission system design in accordance with the National Electric Safety Code (NESC), Rule 250 which considers extreme wind, ice, and the combination of the two. For extreme wind, PSEG Long Island designs for 130 mph, which exceeds the NESC 250-C recommended extreme wind loading criteria. Findings from the exposure analysis show that no LIPA assets are projected to be exposed to 1-in-10-year hurricane wind speeds exceeding 130 mph. However, some older wood transmission poles are designed for winds speeds of approximately 100 to 110 mph and older steel structures for wind speeds of approximately 100 to 110 mph.

Line structure failures may result in circuit outages affecting a wide area. Depending on system design, transmission outages may result in significant numbers of customer outages. Similarly, conductor failure could lead to circuit outages.

Although underground conductors and pumping equipment are exposed to high wind, they are not sensitive to this hazard; therefore, their vulnerability is scored as N/A.

Table 17: Vulnerability Ratings for High Wind and Transmission Assets.

Transmission	Exposure	Impact		Vulnerability
		Sensitivity	Consequence	
Line structures (poles/towers)	Exposed	High	Med	High
Conductors (Overhead)	Exposed	High	Med	High
Conductors (Underground)	Exposed	N/A	Med	N/A
Switches	Exposed	Med	Med	Med
Pumping Equipment	Exposed	N/A	Low	N/A

Distribution

Overhead distribution structures, including poles and overhead conductors, are likely to be highly vulnerable to impacts from exposure to extreme wind (**Table 18**). High wind events may cause pole failure, particularly in areas with a high density of trees where high winds may impact vegetation, which can fall or break, damaging infrastructure and poles. Similarly, overhead conductors can be damaged by electrical contact during strong winds (blowout) or cause downed vegetation to damage lines.

PSEG Long Island accounts for wind in its distribution system design in accordance with the NESC, Rule 250B, which for distribution, considers a combination of wind and ice. Current design standards exceed NESC Heavy which assumes ½ inch of ice accumulation and approximately 40 mph of wind and is the NESC's most stringent requirement for combined wind and ice loading. Failure of overhead distribution structures and conductors can lead to customer outages. Underground conductors, pad mounted transformers, and pad mounted switchgear are exposed but not sensitive to high wind; therefore, their vulnerability is scored as N/A.

Table 18: Vulnerability Ratings for High Wind and Distribution Assets.

Distribution	Exposure	Impact		Vulnerability
		Sensitivity	Consequence	
Structures (overhead) [Includes poles]	Exposed	High	Med	High
Conductors (Overhead)	Exposed	High	Med	High
Conductors (Underground)	Exposed	N/A	Med	N/A
Switches	Exposed	Med	Med	Med
Transformers (Overhead)	Exposed	Med	Med	Med
Transformers (Pad Mount)	Exposed	N/A	Low	N/A
Regulators (Pole Mounted)	Exposed	Low	Med	Low
Capacitors (Pole Mounted)	Exposed	Low	Low	Low
Batteries (Overhead control)	Exposed	Low	Low	Low
Surge Arresters	Exposed	Med	Low	Low
Switchgears (Pad Mount)	Exposed	N/A	Med	N/A

Substations
Overall substation assets have a low to medium vulnerability to high wind (

Table 19). For example, substation control rooms/control houses tend to be moderately vulnerable to high wind exposure. More recently constructed control rooms and houses are typically built to withstand winds of up to 150 mph, making critical damage from debris during a high wind event unlikely. However, older facilities may be constructed in a manner that could present risks when exposed to a high wind event. The failure of control rooms and houses may require elements to be taken out of service. Switchgears have a low sensitivity to high wind exposure as they are usually enclosed in a heavy box bolted to the floor.

Table 19: Vulnerability Ratings for High Wind and Substation Assets.

Substation	Exposure	Impact		Vulnerability
		Sensitivity	Consequence	
Substation transformers/regulators	Exposed	Low	High	Med
Circuit breakers	Exposed	Low	Med	Low
Switchgear (distribution, including breakers, PTs, and relay)	Exposed	Low	High	Med
Instrument Transformers (CT's and PT's)	Exposed	Low	Med	Low
Control Room/Control House/Protection and Control Devices	Exposed	Low	High	Med

Ice
A qualitative review of projected trends related to ice storms was conducted as part of the exposure analysis to better understand how this hazard will change in the future across PSEG Long Island's service area. Although there is high uncertainty in the magnitude of future trends, the review indicated that ice accumulation during the highest-intensity ice storms could increase in the future.

Significant impacts that projected changes in exposure to ice events are likely to have on LIPA's electric assets include:

- Direct failure due to ice loading.
- Impacts to moving parts.

Transmission
Transmission towers, poles, and overhead conductors have the greatest potential for negative outcomes in the event of exposure to ice events (**Table 20**) due to a combination of high sensitivity and moderate consequence scores. Although transmission towers are built to withstand a defined design tolerance for ice loading, icing above this tolerance can result in

asset failure, which can lead to structure collapse. LIPA's older, vintage structures may be at an increased risk of failure if they do not meet current standards for ice accumulation. In addition, if ice accumulates unevenly among the transmission conductors, there is a potential for faults (short circuits) to occur between conductors, and in some cases, cause a sustained outage of the transmission line. Furthermore, a combination of freezing rain and wind may cause galloping of transmission lines, where the lines experience oscillations that can cause line damage and may result in weakening and eventual failure.

As discussed earlier, PSEG Long Island designs LIPA’s transmission system in accordance with the NESC, Rule 250 which requires designers to evaluate extreme winds, as well as extreme wind with ice. PSEG Long Island assumes ice accumulation of ¾ inch with a concurrent wind speed of 50 mph for its transmission system design.

Line structure failures may result in circuit outages affecting a wide area. Depending on system design, transmission outages may result in a significant number of customer outages. Similarly, conductor failure could lead to circuit outages. Despite being exposed, underground conductors and pumping equipment are not sensitive to ice and therefore their vulnerability is scored as N/A.

Table 20: Vulnerability Ratings for Ice and Transmission Assets.

Transmission	Exposure	Impact		Vulnerability
		Sensitivity	Consequence	
Line structures (Poles/towers)	Exposed	High	Med	High
Conductors (Overhead)	Exposed	High	Med	High
Conductors (Underground)	Exposed	N/A	Med	N/A
Switches	Exposed	Med	Med	Med
Pumping Equipment	Exposed	N/A	Low	N/A

Distribution

Distribution assets have varying degrees of vulnerability to ice. Overhead distribution structures like poles and overhead conductors were evaluated to be highly vulnerable to ice exposure (**Table 21**). Structures, including poles and cross-arms, are built to withstand a defined tolerance for ice loading, however, icing above this tolerance can result in failure. Accumulation of ice structures with long length spans increases the likelihood of downed poles due to pressure by the conductor on the poles. Similarly, icing beyond the design threshold can cause conductor /attachment failure. Trees also tend to become more susceptible to limb failure with increased icing on the branches. Excessive icing can bring down branches or trees which can in turn damage distribution poles and conductors.

PSEG Long Island accounts for ice in its distribution system design in accordance with the NESC, Rule 250 which, for distribution, considers a combination of wind and ice. PSEG Long Island designs LIPA's distribution system assuming ½ inch of ice accumulation and approximately 40 mph of wind, which is the NESC's most stringent requirement for combined wind and ice loading. Failure of overhead distribution structures and poles can lead to customer outages.

Underground conductors, pad mounted transformers, and pad mounted switchgears although exposed to ice events are not sensitive to its impacts and therefore their vulnerability is scored as N/A.

Table 21: Vulnerability Ratings for Ice and Distribution Assets.

Distribution	Exposure	Impact		Vulnerability
		Sensitivity	Consequence	
Structures (overhead) [Includes poles]	Exposed	High	Med	High
Conductors (Overhead)	Exposed	High	Med	High
Conductors (Underground)	Exposed	N/A	Med	N/A
Switches	Exposed	Med	Med	Med
Transformers (Overhead)	Exposed	Med	Med	Med
Transformers (Pad Mount)	Exposed	N/A	Low	N/A
Regulators (Pole Mounted)	Exposed	Low	Med	Low
Capacitors (Pole Mounted)	Exposed	Low	Low	Low
Batteries (Overhead Control)	Exposed	Low	Low	Low
Surge Arresters	Exposed	Low	Low	Low
Switchgears (Pad Mount)	Exposed	N/A	Med	N/A

Substations

Substation assets show a range of vulnerability to ice events, with transformers and regulators being highly vulnerable. For substation transformers and regulators, icing may increase flashover risk on bushings and insulators, particularly if there is contamination on the insulator (**Table 22**). Depending on substation design, substation transformer failures may result in customer outages. The complexity and lead time to replace a failed transformer is also significant.

Table 22: Vulnerability Ratings for Ice and Substation Assets.

Substation	Exposure	Impact		Vulnerability
		Sensitivity	Consequence	
Substation transformers/regulators	Exposed	Med	High	High
Circuit breakers	Exposed	Med	Med	Med
Switchgear (distribution, including breakers, PTs, and relay)	Exposed	Low	High	Med
Instrument Transformers (CT's and PT's)	Exposed	Low	Med	Low
Control Room/Control House/Protection and Control Devices	Exposed	Low	High	Med

Cold Temperatures

Extreme cold conditions are not projected to pose major threats to LIPA's electric system in the future. The cold temperature variable evaluated in the exposure analysis included the number of days below 32°F. Results from the exposure analysis show that, although LIPA's assets have been historically exposed to freezing temperatures, in the future, assets are likely to be exposed to a decreasing frequency of freezing temperatures through the 21st century as temperatures warm. The higher emissions scenario projects more warming and therefore fewer cold days than the lower emissions scenario.

Since the exposure for all assets were rated 0 (or Not Exposed), vulnerability scores across all assets are also 0 or N/A.

Transmission

Transmission assets are not expected to experience substantial negative impacts through exposure to cold conditions (**Table 23**). Although materials become more brittle at colder temperatures, exposure to extreme cold, which is projected to reduce in the future, is not a primary driver for asset failure.

Table 23: Vulnerability Ratings for Extreme Cold and Transmission Assets.

Transmission	Exposure	Impact		Vulnerability
		Sensitivity	Consequence	
Line structures (Poles/towers)	Not exposed	Low	Med	N/A
Conductors (Overhead)	Not exposed	Med	Med	N/A
Conductors (Underground)	Not exposed	Low	Med	N/A
Switches	Not exposed	Low	Med	N/A
Pumping Equipment	Not exposed	Low	Low	N/A

Distribution

Extreme cold may affect the movement of mechanical components such as switches. However, like transmission, no distribution sub assets are expected to experience substantial negative outcomes due to the projected reduction in exposure to extreme cold conditions (**Table 24)**.

Table 24: Vulnerability Ratings for Extreme Cold and Transmission Assets.

Distribution	Exposure	Impact		Vulnerability
		Sensitivity	Consequence	
Structures (Overhead) [Includes poles]	Not exposed	Low	Med	N/A
Conductors (Overhead)	Not exposed	Med	Med	N/A
Conductors (Underground)	Not exposed	N/A	Med	N/A
Switches	Not exposed	Med	Med	N/A
Transformers (Overhead)	Not exposed	Low	Med	N/A
Transformers (Pad mount)	Not exposed	N/A	Low	N/A
Regulators (Pole mounted)	Not exposed	Med	Med	N/A
Capacitors (Pole mounted)	Not exposed	Low	Low	N/A
Batteries (Overhead control)	Not exposed	Med	Low	N/A
Surge Arresters	Not exposed	Low	Low	N/A
Switchgears (Pad Mount)	Not exposed	N/A	Med	N/A

Substations

Extreme cold may impact the functionality of substation circuit breakers (**Table 25**). Operational problems may also occur, particularly with older SF6 circuit breakers, which may leak in extreme cold. Depending on the circuit breaker's role, circuit breaker failure may result in customer outages. However, projected reduction in the exposure of assets to extreme cold points to a low vulnerability overall.

Table 25: Vulnerability Ratings for Extreme Cold and Substation Assets.

Substation	Exposure	Impact		Vulnerability
		Sensitivity	Consequence	
Substation transformers/regulators	Not exposed	Low	High	N/A
Circuit breakers	Not exposed	Med	Med	N/A
Switchgear (distribution, including breakers, PTs, and relay)	Not exposed	Low	High	N/A
Instrument Transformers (CT's and PT's)	Not exposed	N/A	Med	N/A
Control Room/Control House/Protection and Control Devices	Not exposed	Med	High	N/A

Extreme Precipitation

Results from the exposure analysis indicate that extreme precipitation is not likely to present an increased risk of exposure to LIPA's electric assets through the end of the century. The lower emissions scenario projects an increase in maximum 5-day precipitation from a historical baseline of 5.0 inches to 5.6 inches by 2050 before stabilizing through late century. The higher emissions scenario projects an increase in maximum 5-day precipitation through the end of the century with 5.7 inches projected by 2050 and 6.1 inches by late century. Since exposure scores for all assets were rated as 0 (or Not Exposed), the associated vulnerability scores are also derived to be 0 or N/A.

Transmission

Although transmission assets have some sensitivity to precipitation related impacts, projections for extreme precipitation do not point to increased future exposure and therefore vulnerabilities of all assets were found to be unchanged by this hazard.

Table 26: Vulnerability Ratings for Extreme Precipitation and Transmission Assets.

Transmission	Exposure	Impact		Vulnerability
		Sensitivity	Consequence	
Line structures (poles/towers)	Not Exposed	Low	Med	N/A
Conductors (Overhead)	Not Exposed	Low	Med	N/A
Conductors (Underground)	Not Exposed	Low	Med	N/A
Switches	Not Exposed	Low	Med	N/A
Pumping Equipment	Not Exposed	Low	Low	N/A

Distribution

Although distribution assets have some degree of sensitivity to precipitation related impacts, projections for extreme precipitation do not point to increased future exposure and therefore vulnerabilities of all assets were found to be unchanged by this hazard.

Table 27: Vulnerability Ratings for Extreme Precipitation and Distribution Assets.

Distribution	Exposure	Impact		Vulnerability
		Sensitivity	Consequence	
Structures (overhead) [Includes poles]	Not Exposed	Med	Med	N/A
Conductors (Overhead)	Not Exposed	Low	Med	N/A
Conductors (Underground)	Not Exposed	Low	Med	N/A
Switches	Not Exposed	N/A	Med	N/A
Transformers (Overhead)	Not Exposed	Low	Med	N/A
Transformers (Pad Mount)	Not Exposed	Low	Low	N/A
Regulators (Pole Mounted)	Not Exposed	Low	Med	N/A
Capacitors (Pole Mounted)	Not Exposed	Low	Low	N/A
Batteries (Overhead control)	Not Exposed	N/A	Low	N/A
Surge Arresters	Not Exposed	Low	Low	N/A
Switchgears (Pad Mount)	Not Exposed	Low	Med	N/A

Substations

Although substation assets have some degree of sensitivity to precipitation related impacts, projections for extreme precipitation do not point to increased exposure and therefore vulnerabilities of all assets were found to be unchanged by this hazard.

Table 28: Vulnerability Ratings for Extreme Precipitation and Substation Assets.

Substation	Exposure	Impact		Vulnerability
		Sensitivity	Consequence	
Substation transformers/regulators	Not Exposed	Med	High	N/A
Circuit breakers	Not Exposed	Low	Med	N/A
Switchgear (distribution, including breakers, PTs, and relay)	Not Exposed	Med	High	N/A
Instrument Transformers (CT's and PT's)	Not Exposed	Low	Med	N/A
Control Room/Control House/Protection and Control Devices	Not Exposed	Low	High	N/A

Operational and Planning Vulnerabilities

Approach

In addition to assessing the physical vulnerability of LIPA's assets to climate change, the Study team evaluated potential risks to PSEG Long Island's operation and planning processes. To support PSEG Long Island's understanding of its operation and planning vulnerabilities, key functions were analyzed in the context of potential climate hazards, including extreme heat, extreme cold, flooding, high wind, and ice. The operation and planning categories assessed included:

- Safety
- Emergency Response
- Reliability Planning
- Asset Management
- Vegetation Management
- Capacity Planning
- Load Forecasting

The Study team conducted interviews with SMEs and reviewed relevant design specifications and operational documents. The documents reviewed included emergency response procedures, environmental health guidelines, and safety standards, among others. The analysis is qualitative in nature and intended to help identify general trends and relevant climate risks that may impact current planning and operations.

Key Takeaways

Table 29 outlines the operations and planning functions reviewed, along with the climate hazards most relevant to those functions. Shaded cells with checkmarks indicate climate hazard(s) that pose a risk to each operational and planning area.

- Projected changes in the frequency and severity of extreme heat events, flooding, and storms associated with high wind gusts and icing may impact the **safety** of PSEG Long Island's workforce and customers. As these hazards change in the future, the workforce may be exposed to more extreme or dangerous working conditions, more frequently. Concerns around public safety from damaged or downed assets may also increase.
- **Emergency response** procedures are likely to be vulnerable to projected changes in the occurrence of extreme weather events, such as heat waves, flooding, and storms. Emergency response is likely to be impacted by having to respond to more severe or frequents events, which may result in resource constraints or higher repair/restorations costs and the need for more effective communications with emergency workers and customers.
- Changes in the frequency, severity, and duration of extreme weather events, including heat waves, high wind events, and icing, may have the potential to adversely impact outage rates and may require changes to the **reliability planning** process.

- Impact of climate hazards, such as extreme heat, flooding, high winds, and ice, on electric assets may lead to damage, accelerated aging of certain components, or even failure, which may result in outages. These represent potential vulnerabilities for the **asset management** function.
- Projected increases in impacts from high winds and ice events, for example during storms, can cause more downed trees and tree-driven outages. Ecological changes driven by changes in regional climate may also lead to more tree-related impacts and require changes to **vegetation management** procedures.
- Projected warming trends and an increase in extreme heat events may impact **capacity planning** functions and point to the need for continued planning to address the impact of increasing ambient temperature on the capacity of critical assets, such as substation transformers and distribution conductors.
- Projected increasing average and extreme temperature is likely to impact future demand and may require continued updates to **load forecasting** processes.

Table 29: Climate Hazards of Concern for PSEG Long Island's Operational and Planning Functions

Operations and Planning Function	Extreme Heat	Extreme Cold	Flooding	High Wind	Ice
Safety	✓		✓	✓	✓
Emergency Response	✓	✓	✓	✓	✓
Reliability Planning	✓			✓	✓
Asset Management	✓		✓	✓	✓
Vegetation Management				✓	✓
Capacity Planning	✓	✓			
Load Forecasting	✓				

Findings

This section discusses each of the operations and planning functions assessed, key climate hazards of concern and potential climate -related vulnerabilities.

Safety

Description of operational area: PSEG Long Island is committed to safety and has specifications and procedures to protect employees while performing work, including the PSEG Long Island Environment, Health and Safety (EHS) Policy and PSEG Practice 575-1, EHS Program guide, which are the highest-level Environment, Health and Safety governance documents for PSEG Long Island.

PSEG Long Island's Health and Safety Compliance organization has overall responsibility for PSEG Long Island's health and safety program, including compliance and regulatory training. In addition, major operating areas, including Transmission and Distribution (T&D), Operations, Projects and Construction, and Customer Service have dedicated safety teams. The safety teams are responsible for tracking and reporting safety metrics for their operating areas, developing safety training modules, and supporting and coordinating safety activities. PSEG Long Island reports several dimensions of the Occupational Safety and Health Administration (OSHA) incident rate at the corporate and organizational levels.

Key Climate Hazards: Extreme Heat, High Wind, Ice, Flooding

Potential Vulnerabilities: In the future, safety operations may need to adapt to address vulnerabilities and account for projected changes in climate. Emerging risks to PSEG Long Island's safety operations and planning procedures are summarized below.

More frequent extreme weather may result in more frequent work under adverse conditions, which may increase safety risks. Increased safety risks include a greater number of days of adverse conditions during which work must be performed as well as the types of conditions, such as high winds, under which work must be performed.

PSEG Long Island's operations procedures incorporate thresholds for high winds, which depend on the type of equipment, but are generally 30 to 40 mph. More days of high winds will reduce the amount of time that that work can be performed with bucket trucks, which impacts productivity.

Climate science predicts an increase in the frequency, duration, and severity of heat waves. Extreme heat can present unsafe work conditions for employees, including the risk of heat exhaustion. PSEG Long Island has existing procedures related to heat which focus on ensuring that workers acclimate to higher temperatures as the seasons change, hydrate properly, maintain awareness of how they are feeling, and take breaks as needed. The requirement for fire retardant (FR) clothing for some types of work exacerbates the issue of overheating and may require that workers take more breaks. The fact that electrical workers perform some work in energized zones means that certain heat response options, such as ice vests and misting machines, each of which may present other risks, are not available to keep crews cool.

Working in extreme heat and extreme cold poses a greater risk of injury due to a higher level of discomfort, which can cause distractions. There is also the direct risk of heat exhaustion while working in extreme heat conditions and the risk of frostbite while working in extreme cold. Rising temperatures or an increase in the frequency of extreme cold events may lengthen the amount of time required to complete tasks and PSEG Long Island needs to factor such potential impact into its planning.

Increased flooding expands the risk of workers drowning, being involved in motor vehicle collisions, experiencing electric shock due to energized bodies of water, and being exposed to water-borne contamination such as sewage.

As a result of increasing heat and drought, an increase in the instances of smoke from wildfires, such as those from Canada in 2023, may impact work. Twice in 2023, PSEG Long Island scaled operations back to essential work only, due to smoke from Canadian wildfires. As new information on potential wildfire risk becomes available PSEG Long Island will consider evaluating the increasing likelihood of wildfire smoke and associated impacts for LIPA's service area in a future study.

Emergency Response

Description of operational area: Emergency Response includes activities to prepare for and respond to a range of extreme events that affect LIPA's system, including extreme weather. These activities involve event preparedness, storm restoration, and partnerships with local governments and emergency services.

PSEG Long Island's emergency response operations are shaped by the Emergency Restoration Plan (ERP), which is updated annually and filed with the NYS Department of Public Service. The ERP is a comprehensive document that outlines strategic emergency response across all functions of the PSEG Long Island organization. PSEG Long Island uses the Incident Command System (ICS) for coordinated preparation and response to events. After Tropical Storm Isaias (2020), PSEG Long Island developed a Major Storm Enhancement Plan that included storm hardening and technology investments as well as emergency response process improvements.

The ERP prioritizes service restoration after major events based on criticality. Airports and hospitals are designated as level 1 and are the highest priority. Levels 2 and 3 include other public welfare facilities such as medical facilities, water supply facilities, sewage pumping stations, etc. Following an emergency, PSEG Long Island first repairs transmission circuits which restore the greatest number of customers per action and then continues with substations and distribution outages, also focusing on restoring the greatest number of customers per action. The ERP also incorporates considerations for customers using life sustaining equipment.

Key Climate Hazards: Extreme Heat, Extreme Cold, Flooding, High Wind, Ice

Potential Vulnerabilities: The key climate vulnerability for emergency response processes is the potential for an increase in the frequency and intensity of storms. It is also important to be prepared to respond to a range of other extreme events of increasing concern, including flooding and heatwaves.

The increasing intensity and frequency of severe weather could result in more frequent activations of emergency response procedures. While PSEG Long Island's existing emergency response procedures are flexible and designed to scale to reflect anticipated event impacts, a large increase in the number of activations has the potential to strain PSEG Long Island's resource capabilities. Due to the fact that climate change makes it more difficult to predict the intensity of events, emergency response may require new skills and protocols that would extend beyond current capabilities of both PSEG Long Island and service area municipalities. Furthermore, the increasing frequency of certain types of events increases the probability that events follow each other in quick succession, which can result in additional cumulative impacts and vulnerabilities.

The PSEG Long Island's ERP is structured with underlying flexibility to respond to climate change. PSEG Long Island updates the ERP on an annual basis with the intention of enhancing the overall storm restoration process and communications before, during, and immediately after storm events. The updated ERP integrates lessons learned from after-action reviews, industry best practices, and new technologies. The process solicits feedback from key stakeholders and process owners and uses key performance statistics to identify improvement opportunities.[35]

PSEG Long Island noted that in prior storm events, a key challenge in the emergency response process has been effective communications with customers prior to, throughout, and in the aftermath of storms. PSEG Long Island uses multiple channels for such communications, including press releases, text, email, the PSEG Long Island website, mobile applications, and social media. In advance of an anticipated major event and after major event landfall, PSEG Long Island also communicates directly with customers who rely on Life Support Equipment, municipal officials, and major account customers. To improve customer awareness around outages and restoration efforts, PSEG Long Island has recently undertaken a revamping of its outage communication infrastructure to support robust customer communications in events with widespread outages affecting a large portion of the customer base. As the frequency of storms and other extreme events increases and customers increasingly adopt mobile applications, PSEG Long Island will continue to promote digital communications channels that allow customers to self-serve and receive timely updates and information about restoration efforts.

PSEG Long Island is continually working to incorporate new technologies into the ERP to improve restoration. One example is the use of advanced metering infrastructure (AMI) to help confirm the scope of outages and support restoration. PSEG Long Island is currently

[35] PSEG Long Island 2021 Emergency Restoration Plan, Board of Trustees Meeting

expanding the use of AMI to support the ERP, and AMI also currently serves as a backup tool for the outage management system (OMS) to help confirm outages.

Another technology to support damage assessment is the use of mobile devices. PSEG Long Island currently has a limited number of people using mobile devices for damage assessment. PSEG Long Island has developed an internal application that is currently being tested which provides the ability to capture damage information electronically. PSEG Long Island is also exploring the use of drone technology for damage assessment.

Effective storm response requires securing resources at a level that is aligned with the expected damage from an incoming storm. PSEG Long Island has been working on advancing this capability with storm impact modeling. In collaboration with a technology partner, PSEG Long Island is applying machine learning algorithms to a data set of historical storms to model storm impacts and help predict the number of incidents likely to occur based on a forecasted weather event. This improves PSEG Long Island's ability to determine an appropriate level of resources for response.

Flooding poses a key challenge for the emergency response process. During Superstorm Sandy (2012), the number of flooded homes required PSEG Long Island to develop new procedures to assess whether a dwelling is safe to receive power. Because extreme flooding is rare, the procedures will require more formal integration into the ERP and training modules. The increasing potential for flooding makes this integration an important part of adapting to climate change. In addition, extreme flooding has the potential to cause "islanding", or cutting off access due to flood waters, in certain areas of the service territory, including areas on the South Fork of Long Island and in the Rockaways. Sea level rise has the potential to exacerbate this issue.

Storm restoration often requires the help of mutual assistance crews from other utilities. PSEG Long Island is part of the North Atlantic Mutual Assistance Group, one of seven regional utility mutual aid groups with agreements to help utilities obtain resources to respond to storms. Because of the increase in the number and severity of storms impacting multiple utilities, PSEG Long Island is sometimes constrained in obtaining mutual assistance for pre-staging purposes. These constraints have the potential to get worse as the climate changes. The ERP should consider such constraints in its annual updates.

Effective response to an extreme event also requires employees to be proficient at restoration tasks, often tasks that they only perform when on storm duty. As the work force changes with more senior and experienced employees retiring, PSEG Long Island will need to adapt its training for storm restoration, so that more junior and less experienced employees can develop the capabilities needed to effectively implement the ERP.

Reliability Planning

Description of operational area: Reliability planning includes establishing reliability performance targets, understanding historical reliability performance and the factors that influence that performance, and identifying capital investments and operational actions necessary to achieve targeted reliability performance levels.

PSEG Long Island has several programs focused on reliability improvements including the PowerOn Program, Circuit Improvement Program, Multiple Interruption Program and Enhanced Vegetation Management Program. PSEG Long Island conducts analyses to validate the reliability benefits of these programs and adjusts investment plans and operations accordingly.

PSEG Long Island tracks and reports several reliability performance indicators, including the System Average Interruption Frequency Index (SAIFI), System Average Interruption Duration Index (SAIDI), Customer Average Interruption Duration Index (CAIDI) and Momentary Average Interruption Frequency Index (MAIFI). PSEG Long Island also tracks customers who have experienced multiple outages.

As discussed in the section on asset management, PSEG Long Island tracks component failure data for failures that result in customer outages. In 2022, approximately 56% of interruptions were caused by equipment failure (including downed primary wires, underground primary cable failures and broken primary line taps).[36] Tree contacts were the second leading cause of interruptions, followed by all others, including pre-arranged outages, accidents, and unknown causes were the remaining contributing categories.

Key Climate Hazard: High Wind, Ice, Extreme Heat

Potential Vulnerabilities: The projected increases in frequency, severity, and duration of extreme weather events, including heat waves and extreme wind events, have the potential to impact reliability and may require changes to the reliability planning process.

The primary potential opportunity for addressing climate vulnerability for reliability planning is to increase understanding of dynamic and evolving impact of climate hazards on reliability performance and associated reliability benefit of capital and operational investment programs. Through dedicated analytic support, PSEG Long Island is making progress in identifying reliability risks and required investments and operational changes.

As discussed earlier, downed primary wires and tree contacts are among the top causes of customer interruptions, with wind being a key climate hazard associated with these events. PSEG Long Island has conducted analyses to understand the impact of wind on reliability performance and has identified the annual number of days with wind gusts exceeding 40mph as a critical metric. PSEG Long Island has correlated this metric with the historical number of customers interrupted in a way that can support advancing the understanding of the impact of an increasing frequency of storms on reliability.

Regarding the reliability benefit of capital programs, PSEG Long Island performs storm hardening effectiveness analyses which measure the effectiveness of both storm hardening

[36] New York State Department of Public Service, 2022 Electric Reliability Performance Report

programs and vegetation management programs. Comparing the performance of storm-hardened distribution circuits with non-hardened circuits, PSEG Long Island has seen a 43% decrease in incidents per mile for storm-hardened circuits due to investments made through the program.

Asset Management

Description of operational area: PSEG Long Island's asset management group is responsible for specifying, developing standards, inspecting, maintaining, repairing, replacing, and upgrading assets to achieve desired performance objectives (i.e., reliability, safety, resilience, cost).

PSEG Long Island operates a system with approximately 1,400 miles of overhead transmission lines ranging from 23 kV to 345 kV, 156 distribution substations and 14,045 miles of distribution lines. This asset base requires monitoring, evaluation, maintenance, and upgrades to achieve performance targets. The asset management process is central to these activities.

As discussed in the asset vulnerability analysis, through the impact rating process, substation transformers and circuit breakers were scored as *high* impact. Impact weighed asset sensitivity to climate hazards, including extreme heat, inland and coastal flooding, extreme cold, high winds, and ice. It also considered the consequences, should an asset not perform as designed. Another component of asset management is understanding the condition of vulnerable assets.

PSEG Long Island has a Computerized Maintenance Management System (CMMS) that is a repository for asset health information. The CMMS system has health indices for substation transformers that include the results of dissolved gas analysis (DGA), loading history, and maintenance history.

In addition to transformer health, real-time operating conditions, such as transformer internal temperature, are important for effective asset management. PSEG Long Island has established alarms for substation transformers to protect assets from overheating during normal and emergency operations.

Another aspect of asset management is understanding failure rates for assets. PSEG Long Island captures information about component failures for T&D assets and incorporates it into their Asset Management Plans (AMPs). This data is utilized along with other collected Asset Health data to inform and guide annual asset operations and maintenance (O&M) programs, Capital Asset replacement programs, and the Spare equipment program.

PSEG Long Island SMEs note that they see an increase in failure rates for overhead pole top transformers during extreme heat waves, but the overall failure rate for such transformers is generally quite low.

Key Climate Hazards: Extreme Heat, Flooding, High Wind, Ice

Potential Vulnerabilities: The increasing frequency and intensity of heat waves may increase the aging rate of transformers and marginally increase the risk of failure. However, the historical failure data for LIPA's substation transformers do not show increases in failures during years with greater numbers of heat waves. The current CMMS system provides a good foundation to gauge the impact of climate change on substation transformers and the planned upgrades and integration with other systems should further strengthen that foundation.

For overhead distribution transformers, the transformer rating program PSEG Long Island uses has the capability to quantify the reduction in lifespan due to higher ambient temperatures. The program allows users to input the projected demand and ambient temperature and it will return the estimated lifespan of the transformer.

The increasing frequency of heat waves and intense storms could result in more failures of assets if planning assumptions are not adjusted to consider future climate risks. Currently, there is robust data on component failure rates. PSEG Long Island has an opportunity to create a consolidated asset management platform to collect this data from different internal databases and analyze it in a manner that will fully support asset management processes with consideration for the anticipated effects of climate change.

Changing flood patterns are already impacting some parts of the service area, particularly on the South Shore and Fire Island where the company is seeing increasing instances of flooding, such that areas that had not generally experienced flooding are now being flooded. Erosion has impacted the Fire Island Pines substation, creating a risk of collapse, requiring the company to initiate a near term stabilization project and outline mid-term and long-term solutions, including relocating the station. In addition, much of the pad mounted and underground distribution equipment in the South Shore and Fire Island areas is not stainless steel and thus is vulnerable to corrosion and increased aging from flooding.

Vegetation Management

Description of operational area: Tree-related outages are the second leading cause of interruptions for PSEG Long Island.[37] Vegetation management is the process of assessing the risks to the electric grid caused by vegetation, planning corrective actions, executing on

[37] Ibid.

those actions, and assessing the results to inform revisions to the process. PSEG Long Island currently operates on a 'time-based' trimming approach, where approximately 25% of the system is inspected and trimmed each year.

The PSEG Long Island vegetation management program is structured across three Operating Service Agreement (OSA) metrics: Cycle Tree Trim, Trim-to-Sky, and Hazard Tree Removal. The Cycle Tree Trim component is the core vegetation management action of trimming approximately 25% of the system each year, resulting in a four-year cycle. The Trim-to-Sky program performs more enhanced trimming on the more critical sections of distribution circuits. The Hazard Tree Removal program identifies and removes diseased or dying trees, and large limbs, that pose a risk to electric lines. In addition, the company has a vine mitigation program in about 3,000 locations per year, as well as a hazard tree mitigation program.

Starting in 2014, PSEG Long Island implemented an Enhanced Vegetation Management (EVM) program which significantly expanded the clearance distances for trimming. The EVM program considers historical reliability performance and field observations when prioritizing circuits. For the circuits trimmed with a full year of history of being trimmed to the new specification, there has been a 30% reduction, on average, in customers interrupted (including major storms) after the first year.[38]

Key Climate Hazard: High Wind, Ice

Potential Vulnerabilities: A key vulnerability to the PSEG Long Island vegetation management program is the potential for the increasing frequency and intensity of storms to cause more damage and tree-driven outages.

Climate change may also impact vegetation in several other ways, including decreasing the strength of trees, increasing the growth rate, requiring more frequent trimming, and allowing invasive species to proliferate, which can also impact the strength of trees. Research on trees in some forests has indicated that climate change causes reduced wood density for certain tree species, which may reduce tree strength and increase the risk of vegetation-caused outages.[39]

As a result of warming temperatures and a corresponding increase in Growing Degree Days (a temperature-based method for estimating tree growth), tree growth rates are anticipated to increase, which may require changes to trimming cycles. It should be noted that other

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[38] Ibid.

[39] Hans Pretzsch, H. Pretzsch, Peter Biber, P. Biber, Gerhard Schütze, G. Schütze, Julia Kemmerer, J. Kemmerer, & Enno Uhl, E. Uhl. (0000). Wood density reduced while wood volume growth accelerated in Central European forests since 1870. Forest ecology and management, 429, 589-616. doi: 10.1016/j.foreco.2018.07.045

factors, such as reduced water availability, may partially counteract such increases in growth rates.

Climate change may also create more favorable conditions for invasive species to thrive which can weaken native species. The PSEG Long Island vegetation management teams note that they are already seeing such shifts with, for instance, the Pine Bark Beetle, which is resulting in greater numbers of hazard trees.

As climate change shifts growth patterns and risks, PSEG Long Island will continue to monitor developments in the state of vegetation in proximity to transmission and distribution infrastructure. PSEG Long Island does not yet have full mapping of the trees in the service territory but is investigating the use of satellite imagery and Light Detection and Ranging (LIDAR) using fixed winged aircraft to support the vegetation management program. Such technologies could also support PSEG Long Island's desire to shift from time-based trimming to risk-based trimming which would provide greater flexibility to respond to a changing climate.

Capacity Planning (Equipment Rating)

Description of operational area: Capacity planning quantifies the delivery capabilities of assets, identifies areas where demand growth and other projected system changes could result in exceeded asset ratings, and plans necessary investments to align system capacity with projected customer demand.

The PSEG Long Island capital investment plan includes investments to ensure that system capacity is aligned with expected customer demand. PSEG Long Island's capacity planning process incorporates the impact of climate hazards on system capacity via assumptions about ambient temperature in determining ratings for system components. This includes consideration of both average daily temperature and short-term high ambient temperatures. PSEG Long Island transmission conductor ambient temperature assumptions used for ratings align with the New York Independent System Operator (NYISO) guidelines.

Key Climate Hazards: Extreme Heat, Extreme Cold

Potential Vulnerabilities: Transformer ambient temperature assumptions are based on the Institute of Electrical and Electronics Engineers (IEEE) standards which themselves are based on historical experience and thus do not completely align with climate projections which project future increases in ambient temperature. A potential vulnerability for the capacity planning process is posed by actual transformer temperatures that result in equipment ratings less than design assumptions. Customer load is also expected to increase with extreme heat, which will tend to require additional equipment capacity.

PSEG Long Island considers IEEE standards in developing substation transformer ratings. Those standards contain temperature assumptions but may fail to capture variations in ambient temperature across the service territory. In particular, the potential exists for localized "hot spots", or locations in the service territory, where ambient temperatures may exceed design assumptions. Real time monitoring of substation transformers can provide insights into localized hot spots. PSEG Long Island has established alarms for substation transformers to protect assets from overheating during normal and emergency operations.

As is the practice for most utilities, asset ratings used by PSEG Long Island assets are based on NYISO specifications, past weather or IEEE standards; however, this historical approach does not proactively account for significant changes to weather not yet experienced. The capacity planning process addresses long-term system needs, and assets that are installed today may be in service for many decades. During that timeframe, ambient temperatures are projected to increase which may reduce the energy delivery capability of assets. A sustained increase in ambient temperature could stress the T&D system. In developing asset ratings, PSEG Long Island will consider incorporating anticipated increases in temperature across the service territory due to climate change.

PSEG Long Island has already begun taking steps to address the impact of increasing ambient temperatures on the capacity of assets. For substation transformers, PSEG Long Island has engaged vendors to understand options such as adding more cooling to new units and revising designs to operate in higher ambient temperatures. One area of concern raised by PSEG Long Island SMEs was the impact of aging on transformer capacity. Temperatures above the assumed ambient temperature of 30°C (86°F) would lower the transformer's effective capacity by 1-1.5% per 1°C increase.[40] SMEs are concerned that older units may in fact have a greater derating, but this is difficult to measure, and the industry has yet to focus on this issue.

PSEG Long Island has been increasing the capacity of its substations by upgrading from 28 MVA transformers to 33 MVA (megavolt amperes) transformers, since the 33 MVA units use approximately the same footprint by incorporating extra cooling fans to achieve a higher ampacity.

For overhead and pad mounted transformers PSEG Long Island formerly used an estimate of 3.5 kW per residential home on the loading of individual overhead transformers, absent specific loading information. More recently PSEG Long Island has begun to incorporate AMI data which provides more accurate information that can be used to determine if a pole top transformer is overloaded. For overhead pole top transformers, PSEG Long Island has already begun the process of upsizing pole top distribution transformers because of the marginal increase in cost to go from, for instance, a 37.5 KVA unit to a 50 KVA unit.

In rating distribution conductors, PSEG Long Island uses ambient temperature assumptions in line with IEEE standards, but the assumptions vary based on conductor type and

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

insulation. Distribution planners have access to line rating data to allow them to determine the appropriate conductor size.

For transmission lines 138 kV and above, PSEG Long Island will be moving to use ambient adjusted ratings as required by Federal Energy Regulatory Commission's Order 881. This will allow transmission operators to utilize more accurate line ratings based on current ambient temperatures. Although this will often result in higher line capacity when temperatures are lower, it will also mean that as peak seasonal temperatures increase over time there will be more instances when line capacity could become more limited. Ultimately, any decrease in line ratings due to increasing temperatures will need to be factored into changes to static ratings used for long term planning.

In the 2030s, the PSEG Long Island service territory is expected to transition to a winter-peaking system with the increased adoption of electric vehicles and home heating equipment. To prepare for extreme cold, PSEG Long Island conducts an annual winter weatherization study. The study includes a review of low temperature equipment ratings as well as tests to confirm that heating equipment is in working order.

Load Forecasting

Description of operational area: Load forecasting involves projecting the magnitude, timing, and location of future electric demand so that capital investment projects can be implemented to ensure that system capacity is sufficient for the projected demand.

PSEG Long Island uses Temperature Humidity Index (THI) as the weather variable for the summer load forecasting process. The THI combines air temperature and relative humidity to account for the fact that both elements influence peak demand, primarily through impact on the use of air conditioning.

The PSEG Long Island load forecasting process analyzed 30 years of historical weather and peak demand data for two weather stations (Central Park and Bridgehampton) as a baseline for developing the forecast. From this baseline data, statistical analysis is performed to determine the 50th, 80th, and 90th percentile peak demands which would correspond to demand values expected to be seen every 2, 5, and 10 years. These demand values are used for various aspects of the load forecasting process.

Key Climate Hazard: Extreme Heat

Potential Vulnerabilities: The potential climate vulnerabilities for the load forecasting process include the use of historical weather, which may not accurately reflect changes in weather due to climate change, as well as the use of two weather stations for consideration of future climate projections, which may not provide sufficient granularity in measurements of temperature across the PSEG Long Island service territory.

PSEG Long Island uses 30 years of historical weather to develop its load forecasts. Given the projections for increasing ambient temperatures, the use of historical weather to forecast future energy and demand is a vulnerability for PSEG Long Island’s load forecasting process. Projected increases in ambient temperatures may result in assets operating at decreased capacity while experiencing higher than usual demand, resulting in equipment overloads, which could impact reliability.

However, PSEG Long Island has already taken steps to address this vulnerability by conducting an analysis of the impact of projected changes in weather on peak demand. Using data from 14 climate models, and aligned with the SSP2-4.5 climate pathway, PSEG Long Island selected 30 years of hourly temperature and dew point data for two weather stations, Central Park and Bridgehampton, and produced the corresponding THI values for each decade from the 2030s to the 2080s. Using the THI values developed, PSEG Long Island aligned the projected THI with historically experienced peak producing weather. This analysis resulted in a projected increase in demand, solely due to climate change, of approximately 92 MW by the 2050s. The findings from this analysis are being incorporated into the PSEG Long Island load forecasting process.

PSEG Long Island uses data from two weather stations (Central Park and Bridgehampton) in the load forecasting process. The availability of only two weather stations may not be sufficient to capture geographical variations in temperature or localized “hot spots,” possibly resulting in peak demands higher than designed for at certain points in the system. As more granular measurements of weather variability across the PSEG Long Island service territory become available, PSEG Long Island will assess the impact on load forecasting accuracy.

Potential Adaptation Measures

This CCVS identifies the assets and operations that are most vulnerable to climate change within the LIPA system and PSEG Long Island operations. Adaptation measures, when appropriately implemented, can help address these vulnerabilities and bolster the utility's resilience to climate hazards. The Climate Change Resilience Plan, which will follow this Study, will build on the results of the CCVS to evaluate and propose adaptation measures that address climate risks.

Effective adaptation measures should align with at least one of the four criteria of the Adaptation Strategy Framework (Figure 14).

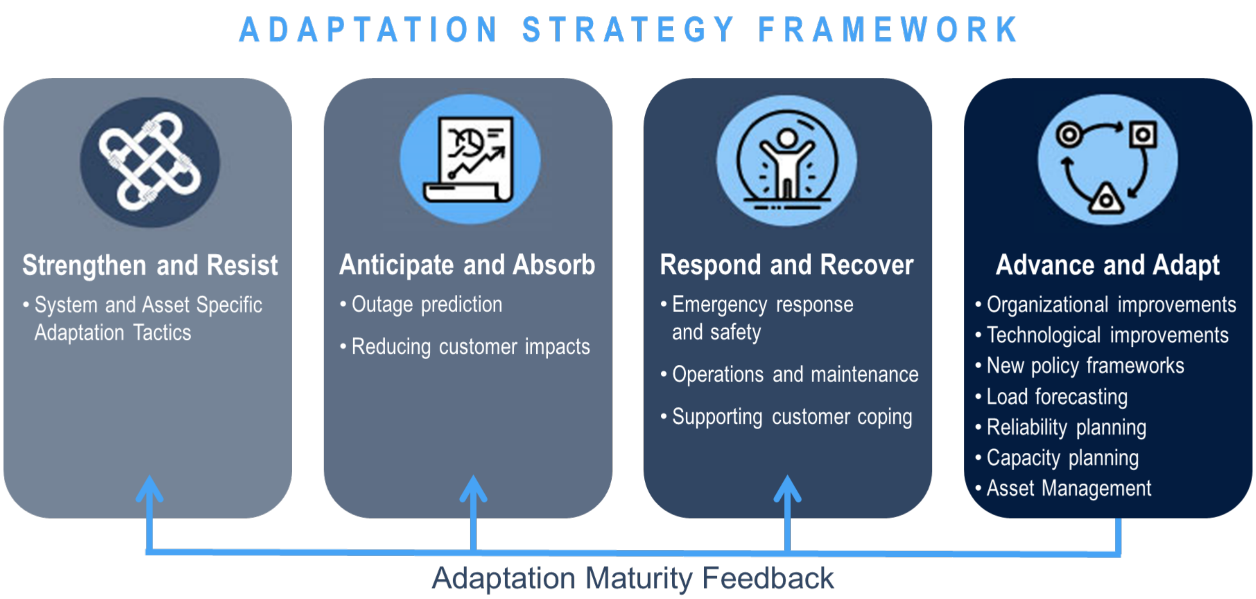

Figure 14: Adaptation Strategy Framework

This framework, first established in the PSEG Long Island Climate Change Vulnerability Report completed in August of 2022, outlines different but equally fundamental criteria of a resilient system. These criteria are:

Strengthen and Resist—adaptation measures that help the system withstand adverse impacts of climate hazards through hardening measures and infrastructural improvements aimed at strengthening assets to mitigate damage from extreme conditions. Potential adaptation measures that fit this criterion include:

- Elevating substation equipment above flood levels to prevent flood damage from coastal storms and sea level rise.
- Upgrading pole and tower design specifications to withstand major hurricane force winds and resist corrosion from coastal flooding.
- Installing HVAC (Heating, Ventilation, and Air Conditioning) systems in newly constructed control enclosures and upgrading older substation control enclosures with HVAC to address rising ambient temperatures.

Anticipate and Absorb—adaptation measures that help the system anticipate and absorb climate hazard impacts, predict potential hazards and their impacts, and give advance warning for gray sky adjustments to be made to limit the number and extent of adverse effects and allow the system to continue to operate during hazard events. Potential adaptation measures that fit this criterion include:

- Installing temperature data collection equipment to allow for real-time rating and operations decisions.
- Improving outage prediction capabilities; PSEG Long Island's Storm Impact Analytics (SIA) tool may be expanded to include heat waves, flooding events, and other climate hazards.
- Supporting the creation of microgrid systems which can enable continuous access to energy services. This can increase customer base resilience during climate hazard events, such as extenuating heat waves, which can impact service reliability.

Respond and Recover—adaptation measures that bolster the utility's ability to restore service and normal operations in the wake of a climate hazard event. These measures are mostly, but not exclusively, operations based. Examples include:

- Strengthening emergency response team skills and expertise. Strengthening staff skills for more streamlined and tailored emergency responses during complex or compounding climate hazard events. These skills may include enhanced communication systems and reporting to target priority emergencies and vulnerable customers, as well as enhanced coordination with municipalities and their emergency response teams. Identification of critical facilities and internal monitoring of these locations during extreme weather may enhance tailored responses and shorter recovery times.
- Supporting greater customer coping and increasing customer satisfaction. Providing resources (e.g., mobile power sources, cooling, heat, etc.) to customers with reduced energy service after extreme events which have led to prolonged outages. Improving communications with climate-sensitive communities within the PSEG Long Island service territory.
- Promoting preventive and proactive operations & maintenance ahead of climate hazard impacts.

- Standardizing parts inventories and maintenance to improve interchangeability and better facilitate restoration of system assets.

Advance and Adapt—adaptation measures that assist the LIPA system in advancing and adapting help to make the system more adaptation-mature, support cyclical processes to routinely revisit, assess, and update the system to be most resilient to climate risks based on the latest data, climate science, technology, and best practices. Specific measures that advance and adapt the LIPA system and PSEG Long Island operations to current and future climate hazards include:

- Utilizing climate projections and historical data to improve load forecasting. Incorporating forward-looking temperature projections into the load forecasting process and adapting the system for acute increases in demand due to extreme heat events, as well as chronic changes in average temperatures.
- Utilizing data analytics to improve asset management. Asset performance management utilizes data analytics to support predictive maintenance and better operational decisions as the climate changes.
- Establishing an improved governance structure. PSEG Long Island, LIPA, and stakeholders can establish a governance structure for climate change monitoring, updating, and planning for system improvements for physical assets and processes.

Conclusion and Next Steps

This report assessed the vulnerability of LIPA assets to seven key climate-related hazards that are currently and will continue to affect the PSEG Long Island service territory in the future. The identified vulnerabilities can strongly affect the utility’s ability to deliver electricity safely and reliably to customers in the future. As climate change progresses, assets will be threatened by more climate hazards than they are today, raising the potential for outages and increasingly stressing the reliability of service delivery. Furthermore, damage to assets from climate hazards as well as equipment failures have the potential to pose a financial burden to LIPA and PSEG Long Island through increased expenses associated with asset repair and replacement. Depending on the extent of damage and the repairs needed, costs could trickle down to the customers over time. In the wake of increasing climate hazards, safety also is becoming a growing concern for PSEG Long Island and its customers as extreme weather events can increase exposure to hazardous conditions and make outages (and associated safety concerns) more likely.

This CCVS lays science-based groundwork for future assessments of asset risk and recommendations for effective resilience measures. The CCRP that follows this CCVS will detail a resilience framework, offer suggestions on priority areas for resilience investments, and present an adaptation strategy framework to help PSEG Long Island understand how to respond to and withstand future climate hazards. The goal of the CCRP is to help PSEG Long Island implement effective and efficient resilience measures to harden utility assets and operations against future climate hazards and ensure continued reliable and affordable service. SME and stakeholder engagement will continue to be an important tool in ensuring that this work is tailored specifically to the needs and realities of PSEG Long Island operations, assets, geography, and LIPA customers.