Climate Vulnerability Assessment

Analysis of potential technical risks to electric distribution assets from projected climate changes in Massachusetts

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Acronyms

ACFEP: Annual Coastal Flood Exceedance Probabilities

AR5: IPCC's Fifth Assessment Report

CCRT: Climate Change Risk Tool

CMIP5/6: Coupled Model Intercomparison Project, Phase 5/Phase 6

CVA: Climate Vulnerability Assessment

EDC: Electric Distribution Company

ECMWF: European Centre for Medium-Range Weather Forecasts

EPRI Climate READi: Electric Power Research Institute, Climate Resilience and Adaptation initiative

FEMA: Federal Emergency Management Agency, U.S. Homeland Security

FLISR: Fault Location Isolation and Service Restoration

IEEE: Institute of Electrical and Electronics Engineers

IPCC: Intergovernmental Panel on Climate Change

MC-FRM: Massachusetts Coast Flood Risk Model

MRI: Mean Recurrence Interval

NESC: National Electric Safety Code®

NOAA: National Oceanic and Atmospheric Association, U.S. Department of Commerce

RCP: Representative Concentration Pathways

RSI: Regional Snowfall Index

SSPs: Shared Socioeconomic Pathways

SWF: Surface Water Flooding

WHG: Woods Hole Group

WICT: Wind, Icing, and Coastal flooding risk Tool

Executive Summary

National Grid ("the Company") is committed to delivering safe, affordable, and reliable electric service to its customers. The Company is also dedicated to partnering with the Commonwealth of Massachusetts to combat climate change while focusing on promoting a resilient electric system in response to a changing climate. It is well established in the recent Massachusetts Climate Change Assessment and many other state and national reports that the residents of the Commonwealth have already begun to experience the effects of climate change,[1,2,3] and National Grid is constantly monitoring and adapting to climate-related threats posed to the electrical network. As the intensity and frequency of weather-related events due to climate change increases, National Grid understands that the Company must analyze risks and prepare for projected future scenarios using industry-recognized climate projection data while maintaining the ability to be nimble as we respond to an uncertain future. Leveraging insights from previous internal analyses and extensive data from the Executive Office of Energy and Environmental Affairs' ResilientMass Clearinghouse,[4] National Grid has conducted a Climate Vulnerability Assessment (CVA) to publicly disclose the key technical risks facing the Company's electric distribution infrastructure.[5]

This CVA is a component of larger National Grid efforts focused on resilience and is a crucial step in ensuring the long-term sustainability and reliability of the Company's electric service. By systematically assessing the vulnerabilities of assets, the Company can proactively plan, engineer, and allocate resources to mitigate potential risks. This proactive approach is essential to improve grid performance, reduce service disruptions and restoration costs, and protect the communities National Grid serves.

The Company's risk assessment utilizes the risk triangle framework shown in Figure ES 1 and evaluates four key climate change hazard categories identified from prior internal assessments and aligned with the ResilientMass Plan: (1) Rising Temperatures, (2) Changes in Precipitation, (3) Coastal Flooding, and (4) Severe Events. Asset vulnerability is primarily determined through internal historical data and insights from subject matter experts, supplemented by external technical reports and assessments from the Electric Power Research Institute.

The exposure of assets is determined via two separate geospatial analytic tools: the Climate Change Risk Tool ("CCRT") and the Wind, Icing, and Coastal flooding risk Tool ("WICT"). These tools incorporate data on National Grid's electric distribution infrastructure along with climate change forecasting scenarios downscaled and applied to regional assets.

The results from the vulnerability assessment are categorized by each of the key climate hazards, with risk rankings of low, moderate, and high assigned to substations, overhead equipment, and underground infrastructure. This assessment is based on generalized asset data, and results may change and evolve as the Company continues to review individual asset details and vulnerabilities and as new data on climate change impacts in Massachusetts becomes available.

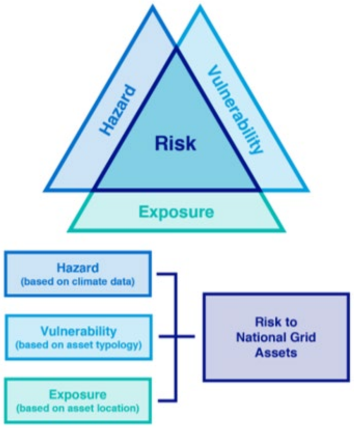

Figure ES 1: Risk triangle used for National Grid's Climate Vulnerability Assessment

The simplified risk matrix shown below in Table ES 1. summarizes the expected likelihood of increased risks from climate change while considering the severity and prevalence of hazards.

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[1] Commonwealth of Massachusetts, 2022 Massachusetts Climate Change Assessment

[2] NOAA National Centers for Environmental Information, State Climate Summaries https://statesummaries.ncics.org/chapter/ma/

[3] The U.S Government's Fifth National Climate Assessment https://nca2023.globalchange.gov/

[4] ResilientMass Climate Change Clearinghouse: https://resilient.mass.gov/home.html

[5] The Company's CVA will continue to evolve, including through the development of shared best practices with the other electric distribution companies in Massachusetts. The Company will provide updates in its Electric Sector Modernization Plan (ESMP) periodic reporting. For additional information about ESMP CVA progress updates, please refer to the Order of the Department of Public Utilities in D.P.U. 24-11.

Table ES 1: National Grid Massachusetts Climate Vulnerability Assessment Risk Matrix Results

Climate Hazards	Electric Distribution Assets		
	Substation	Overhead Equipment	Underground & Pad-Mount Equipment
Rising Temperatures	Moderate	Moderate	Low
Changes in Precipitation	High	Moderate	Moderate
Coastal Flooding	High	Moderate	Moderate
Severe Events (High Wind)	Low	High	Low

Changes in precipitation, mainly river flooding, and coastal flooding hazards are found to be a high risk to substations because the exposure from the hazard is high (flooding is expected to be relatively frequent) and the asset vulnerability is high (impact to substation assets could be severe). The Company is assessing flood mitigation measures on existing substations and has implemented more stringent design practices for all planned projects. Flooding hazards show moderate risks to non-substation distribution infrastructure, especially in regions by the coastline and rivers.

Overhead equipment is highly vulnerable to wind events, primarily from tree contact. Compound events, such as wind combined with soil instability or precipitation, further exacerbate this risk. While the Company's existing design standards for distribution poles are prudently fit for purpose, they will need to be monitored to ensure resilience against increasing storm intensity and wind speeds. Removing overhead distribution equipment and replacing it with underground distribution infrastrucure (i.e., undergrounding) can protect the system performance during wind events; targeted undergrounding is a specialized solution that can avoid many above-ground hazards.

Rising temperatures present moderate risks to substations and overhead equipment, especially regarding oil-filled equipment during periods of sustained high temperatures and increased electrical loads. Many of National Grid's assets will experience extreme heat and heat waves; however, with updated standards and maintenance practices, these risks can be mitigated.

As discussed in the ResilientMass Plan,[6] climate change models forecast wildfire occurrences in New England to increase throughout this century. National Grid has developed a wildfire response plan and will continue risk assessments, mitigation efforts, and collaborations with other utilities and state and local agencies to learn best practices and better understand appropriate mitigation plans regarding wildfires.

The Company has a strong track record of building and maintaining a resilient system that has adapted to meet evolving challenges and threats. The pursuit of the Commonwealth's clean energy and climate goals and associated electrification result in customers having an increased dependency on electric infrastructure, and resiliency investments are considered critical to the continued safe and reliable operation of the network.

This CVA represents a significant step in National Grid's development of a comprehensive resilience plan. The next steps will include investment costs and benefits, impacts to communities and critical customers, and investment prioritization strategies. This will require broader outreach efforts to conduct in-depth analyses of individual assets and expected impacts on communities. Additional collaboration with the Commonwealth and other electric distribution utilities will be essential to enhance the efficiency and cost-effectiveness of the Company's climate change resilience plan.

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[6] Commonwealth of Massachusetts, 2023 ResilientMass Plan: 2023 MA State Hazard Mitigation and Climate Adaptation Plan, Appendix Chapter 5.

1.0 Introduction and Background

National Grid is an energy company operating in the UK and the US. The Company plays a vital role in connecting millions of people to the energy they use. The Company enables the innovation that is transforming the energy system. In the US, National Grid is an electricity, natural gas, and clean energy delivery company serving more than 20 million people in New York and Massachusetts. For the electric businesses, the Company supports the adoption of clean energy by interconnecting distributed energy resources (including renewables and energy storage) onto networks efficiently and effectively, along with designing and managing networks to meet the growing needs of electric heat and transportation.

National Grid is committed to enabling the fair, cost-effective, clean energy transition for the 2.3 million electric and gas customers in the 242 cities and towns it is privileged to serve across Massachusetts. Furthermore, the Company is taking action to address the impacts of climate change on its electric assets and operations.

1.1 The Importance of a Resilient Electric Distribution System

National Grid is committed to reliably meeting the energy needs of the customers and communities it serves. To meet Massachusetts' emission reduction limits, and to follow the actions laid out in the Clean Energy and Climate Plans,[7,8] the Commonwealth is moving toward electrification, leading to greater customer dependence on the electric distribution system. This primary energy network will power the economy and all aspects of everyday life – including cooking, heating, and transportation. This increased dependency on electricity warrants a reliable and resilient electric distribution system which must also cope with growing threats from climate change.

Recent Massachusetts reports have highlighted that residents of the Commonwealth have already begun to experience the effects of climate change[9,10,11] which has reinforced the need for the Company to constantly monitor and adapt to climate-related threats posed to the electrical network.

Defining Resilience

Resiliency can broadly be defined as **the ability of the distribution system to withstand, absorb, adapt, and recover from disturbances**, including major events and climate hazard events. It is expected that Massachusetts will be experiencing more common and more severe storm events, which increases the need for an even more resilient system.

Reliability has traditionally focused on **upholding the performance of the electric system** (i.e., "Keeping the lights on"), according to regulatory reporting criteria.

Reliability is a subset of resiliency. A resilient system, by definition, is more reliable than one that is not resilient. However, a reliable system may not be resilient. Resilience focuses on the impact of significant events, such as the climate hazards discussed in this CVA.

Ultimately, there are three primary goals for improving the resiliency of the electric system:

1. Reducing the number of customer interruptions (i.e., prevent the occurrence and/or impact the scope of the outage in the first place);
2. Reducing the duration of outages when they are experienced by customers (i.e., shortening outages when they occur); and
3. Mitigating the impact on customers during outages (i.e., minimizing the impact of outages for customers).

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[7] Commonwealth of Massachusetts Clean Energy and Climate Plan for 2025 and 2030, 2022
[8] Commonwealth of Massachusetts Clean Energy and Climate Plan for 2050, 2022
[9] Commonwealth of Massachusetts, 2022 Massachusetts Climate Change Assessment
[10] Commonwealth of Massachusetts, 2023 ResilientMass Plan: 2023 MA State Hazard Mitigation and Climate Adaptation Plan
[11] Massachusetts Department of Public Heath, Extreme Heat Events

Many factors contribute to and have an impact on distribution system resiliency. For example, the system can be preventatively designed and constructed to withstand increasing risks (i.e., "hardening" the system), or certain emergency response and operational activities can be employed before, during, and immediately after an event that causes electric service disruption. At National Grid, specific areas in which system resiliency is a focus include:

- Regular reviews and updates to **construction and equipment standards** applied to distribution infrastructure projects (e.g., proactively hardening assets, such as critical structures, as they are replaced to address future forecasted climate threats);
- The Company's **vegetation management** programs (e.g., cyclical pruning to keep vegetation a safe distance from power lines);
- **Asset Management practices and distribution system planning studies** to identify existing and future system performance concerns and the infrastructure solutions required to address the concerns, vulnerabilities, or other requirements identified (e.g., identifying multi-value engineered solutions to address complex system problems);
- The consideration of both **reactive and proactive infrastructure development** programs that adopt new and/or replace/modify existing assets (e.g., targeted undergrounding of at-risk circuits, FLISR, strategic placement of dual-supply, energy storage, etc.);
- The development, continued refinement, training, and execution of the Company's Electric and Gas **Emergency Response Plans** (e.g., managing outages as safely, quickly, and efficiently as possible to get customers back online); and
- Tracking the **latest developments in climate science** and the trajectory of climate change within the service territory.

National Grid has developed robust processes in each of these areas which give the Company the ability to plan for the impacts of climate change both proactively and reactively as the impacts of climate change on distribution system performance are realized. The Company recognizes that climate change poses significant risks that cannot be resolved through isolated or short-term initiatives. National Grid's approach is to undertake a systematic engineering assessment to identify where there is vulnerability to climate hazards. The Company will then develop plans to result in minimal customer impacts from the increased severity of the hazards. By monitoring the effectiveness of the resilience plans, National Grid will ensure the strong reliability performance customers have come to expect.

1.2 Review of Previous Climate Change Vulnerability Efforts

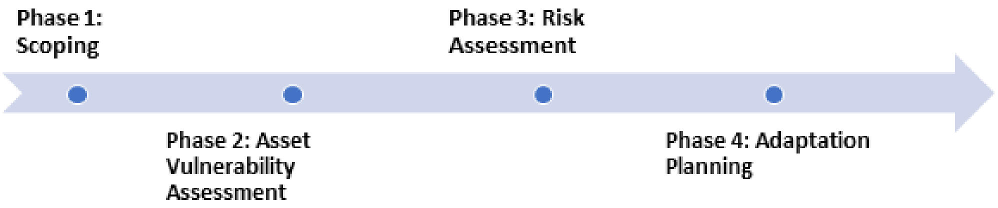
National Grid has a strong track record for building and maintaining a resilient electric system that delivers safe and reliable service marked by resiliency improvement activities. Systematically assessing the vulnerability of energy infrastructure to climate-driven risks is becoming increasingly significant in ensuring reliable and safe delivery of electricity.

To better understand National Grid's asset vulnerabilities to climate change threats, National Grid undertook a preliminary CVA in 2023 across the US and the UK business units to identify the highest-risk climate hazards and which assets may be the most vulnerable over the next five decades.

National Grid performed the preliminary CVA in four phases:

- Phase 1 – Identified the assets and climate hazards to be reviewed as part of this initial assessment.
- Phase 2 – Collected subject matter expert input and industry information to identify and understand the vulnerabilities of each asset.

- Phase 3 – Developed the Climate Change Risk Tool (CCRT), an internal modeling tool, and integrated leading climate science to identify the assets with the highest risk of various acute and chronic climate hazards.
- Phase 4 – Suggested preliminary adaptation measures to begin internal discussions of how to improve resiliency in capital plans.



This preliminary CVA laid the foundation for better-optimized resiliency planning in each region and an iterative process to continue regular climate vulnerability assessments. A key desired outcome of the preliminary CVA was to maximize reliability and resilience with the least cost investments in the Company's assets, driving affordability and quality service for customers.

This preliminary CVA helped identify strengths in the Company's existing distribution system as well as planning and asset management practices while highlighting potential vulnerabilities. The business units took the results and takeaways to inform engineering and construction standards development and bolster asset management and planning screening criteria. The preliminary CVA was also used as an opportunity to make improvements to the Climate Change Risk Tool (CCRT) to continuously improve the Company's understanding of climate change impacts.

The Company used the framework from prior assessments and learnings from external organizations as a basis to build this updated Massachusetts-specific climate change vulnerability assessment focusing on the Company's electric distribution system. Among other additions, this new work includes an additional coastal flooding tool based on the Massachusetts Coastal Zone Management datasets. Resilience planning and asset vulnerability work has been and will continue to be a critical part of National Grid's regular asset condition and planning process.

2.0 Expected Impacts of Climate Change in Massachusetts

As laid out in recent Massachusetts and national publications, climate change can no longer be considered a future threat; many of its effects, including changes in temperature and precipitation that drive increases in the frequency and severity of extreme weather events are already evident.[12,13,14,15]

The increased prevalence and severity of climate hazards make the electric system more vulnerable if left unmitigated. These vulnerabilities can reduce reliability, compromise infrastructure integrity, and impact the safety of workers and the public. National Grid will continually strive to meet the electricity needs safely and reliably of the customers and communities it serves, especially in the face of climate change.

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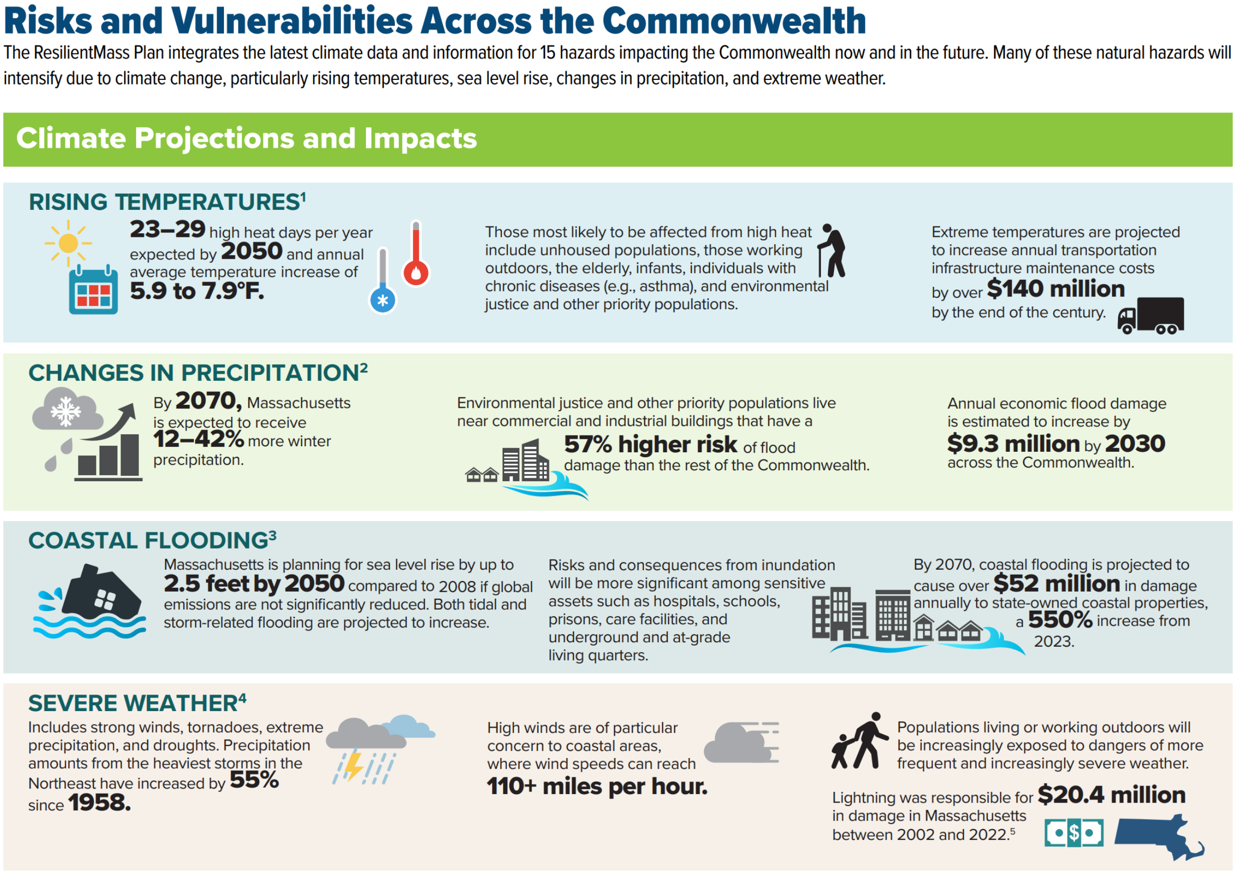
[12] https://science.nasa.gov/climate-change/effects/
[13] Commonwealth of Massachusetts, 2022 Massachusetts Climate Change Assessment
[14] NOAA National Centers for Environmental Information, State Climate Summaries https://statesummaries.ncics.org/chapter/ma/
[15] The U.S Government's Fifth National Climate Assessment https://nca2023.globalchange.gov/

2.1 Key Massachusetts Climate Hazards

The 2023 ResilientMass Plan Chapter 5: Risk Assessment and Hazard Analysis[16] identified 15 climate hazards and studied their historical frequencies, magnitudes of impact, and future probabilities. Relevant hazards with the highest risk of consequence and likelihood include those related to (1) coastal flooding and erosion, (2) precipitation, (3) temperature, and (4) other severe weather such as hurricanes and high wind events.



Risks and Vulnerabilities Across the Commonwealth

The ResilientMass Plan integrates the latest climate data and information for 15 hazards impacting the Commonwealth now and in the future. Many of these natural hazards will intensify due to climate change, particularly rising temperatures, sea level rise, changes in precipitation, and extreme weather.

Climate Projections and Impacts

RISING TEMPERATURES[1]

23–29 high heat days per year expected by **2050** and annual average temperature increase of **5.9 to 7.9°F.**

Those most likely to be affected from high heat include unhoused populations, those working outdoors, the elderly, infants, individuals with chronic diseases (e.g., asthma), and environmental justice and other priority populations.

Extreme temperatures are projected to increase annual transportation infrastructure maintenance costs by over **$140 million** by the end of the century.

CHANGES IN PRECIPITATION[2]

By **2070,** Massachusetts is expected to receive **12–42%** more winter precipitation.

Environmental justice and other priority populations live near commercial and industrial buildings that have a **57% higher risk** of flood damage than the rest of the Commonwealth.

Annual economic flood damage is estimated to increase by **$9.3 million** by **2030** across the Commonwealth.

COASTAL FLOODING[3]

Massachusetts is planning for sea level rise by up to **2.5 feet by 2050** compared to 2008 if global emissions are not significantly reduced. Both tidal and storm-related flooding are projected to increase.

Risks and consequences from inundation will be more significant among sensitive assets such as hospitals, schools, prisons, care facilities, and underground and at-grade living quarters.

By 2070, coastal flooding is projected to cause over **$52 million** in damage annually to state-owned coastal properties, a **550%** increase from 2023.

SEVERE WEATHER[4]

Includes strong winds, tornadoes, extreme precipitation, and droughts. Precipitation amounts from the heaviest storms in the Northeast have increased by **55%** since **1958.**

High winds are of particular concern to coastal areas, where wind speeds can reach **110+ miles per hour.**

Populations living or working outdoors will be increasingly exposed to dangers of more frequent and increasingly severe weather.

Lightning was responsible for **$20.4 million** in damage in Massachusetts between 2002 and 2022.[5]

Figure 1: ResilientMass Risk and Vulnerability graphic[17]

Along with the *2023* ResilientMass Plan, this CVA relies heavily on the *2022 MA Climate Assessment.*[18] These two reports, along with the datasets on the resilient.mass.gov website, provide a useful portfolio of information on the future climate change hazards that the Commonwealth may face in the next 50-plus years. Risks to National Grid's assets align with these four impact categories and thus are the basis for the organization of this climate vulnerability assessment.

National Grid's previous Company-wide climate vulnerability assessment included more climate change hazards and provided valuable insights into the potential impacts on the Company's electrical infrastructure. The key hazards identified from prior assessments align with the ResilientMass Plan's four key hazard categories. By identifying and prioritizing these four key hazards, the Company can narrow the scope of this CVA to the highest priorities and carefully assess asset classes that are deemed most vulnerable and at risk.

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[16] Commonwealth of Massachusetts, 2023 ResilientMass Plan: 2023 MA State Hazard Mitigation and Climate Adaptation Plan, Chapter 5: Risk Assessment and Hazard Analysis Plan

[17] Commonwealth of Massachusetts, 2023 ResilientMass Plan: 2023 MA State Hazard Mitigation and Climate Adaptation Plan, Executive Summary

[18] Commonwealth of Massachusetts, 2022 Massachusetts Climate Change Assessment

2.2 External Collaboration

With its technical focus, this CVA's external collaboration included entities with insights relating to electric distribution network vulnerability and climate change impacts.

2.2.1 EPRI's Climate REsilience and ADaptation Initiative (Climate READi)

National Grid is a participant in EPRI's Climate READi initiative, a three-year collaboration between utilities, academia, and researchers to use science-based insights about the future of the electric power system and the environment in which it operates. Workstreams focus on physical climate data and guidance, energy system and asset vulnerability assessments, and resilience and adaptation planning and prioritization. The output of the collaboration will provide a common framework for a comprehensive approach to physical climate risk assessment. National Grid's participation and leadership in Climate READi facilitates the Company's learning of industry-best practices to better prioritize asset investments in response to changing climate conditions.

2.2.2 Report Collaborators

In producing this Massachusetts CVA, National Grid corresponded with other regional electric distribution companies. National Grid also collaborated with the Massachusetts Executive Office of Energy and Environmental Affairs' Office of Climate Science for input on the report contents and assistance utilizing ResilientMass Clearinghouse data.

3.0 Measuring Risk

This section describes the inputs that went into this CVA and how the Company is overlaying climate data onto existing assets. The insights derived from this analysis can inform the development of a forthcoming comprehensive resilience plan, enabling the identification and prioritization of measures to address the vulnerabilities identified in this assessment.

Beyond asset impacts, procedures like fault and emergency repair, routine maintenance, construction, control center operations, and office operations could be negatively impacted by climate change. Although out of scope in this CVA, climate change risks and mitigation must also focus on human safety and process disturbances due to extreme weather events.

3.1 Climate Change Scenarios

The climate scenarios used for the bulk of this assessment are based on greenhouse gas concentration trajectories adopted by the Intergovernmental Panel on Climate Change (IPCC) in AR5.[19] AR5 is the IPCC's fifth assessment report that provides an overview of the state of knowledge concerning the science of climate change.

The trajectories are known as 'Representative Concentration Pathways' ("RCPs"). RCPs provide a uniform framework to understand the impacts of potential climate changes. The RCP scenarios reflect global climate models as well as varying levels of emission reductions and climate policy adoption including the adoption of renewable fuels and technologies. CMIP5, the fifth phase of the Coupled Model Intercomparison Project, is used in this analysis.[20]

Since there is a level of uncertainty in all climate pathways and as climate modeling continuously evolves, it is important to view future climate scenarios as a range of possibilities versus a single deterministic path. Therefore, for parts of this assessment, the Company uses RCP4.5 and RCP8.5 to capture a wide range of pathways, with RCP4.5 being recognized as an intermediate scenario when emissions peak around 2040 and then decline, and

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[19] IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp. https://www.ipcc.ch/report/ar5/syr/

[20] Note: CMIP6, the sixth and more updated dataset, is available, and National Grid is in the process of updating the models with the latest dataset. For this study The Company is using CMIP5, and CMIP6 will be used in future analyses.

RCP8.5 as a high emissions scenario in which emissions continue to rise after mid-century.[21] RCP4.5 and RCP8.5 are represented as follows:

Table 1: Climate scenarios included in the CCRT

RCP	Description	CCRT Represented Scenario
RCP 4.5	Considered an 'Intermediate Scenario.' with global warming increases range between 1.1°C (2.0°F) and 2.6°C (4.4°F) by 2100	'2°C Scenario'
RCP 8.5	Considered a 'High Emission Scenario' with global warming increases range between 2.6°C (4.4°F) and 4.8°C (8.6°F) by 2100	'4°C Scenario'

3.2 Analyzing Climate Change Risks

The analytical framework used in National Grid's climate change risk assessments is based on the conceptual risk framework set out by the Intergovernmental Panel on Climate Change,[22] which defines risk as a function of three components:

Hazard: The potential occurrence of climate-related physical events or trends that can cause damage to assets and infrastructure.

Vulnerability: Asset sensitivity to physical harm from climate hazards, based on asset typology and general characteristics. Asset vulnerability of electric distribution infrastructure can fall into two primary categories: operational and physical.

> **Operational** vulnerability impacts how the asset performs and operates. Operational vulnerability can include reduced efficiency or capacity resulting in the need to de-rate equipment or reduce the asset lifespan.
>
> **Physical** vulnerability impacts the structural or mechanical integrity of an asset. The impact can be immediate damage or failure as a result of an acute event (e.g., hurricane or flood), or the impact can be long-term fatigue or deterioration (e.g., corrosion).

Exposure: Indicates the presence of assets and infrastructure that could be adversely affected by a climate hazard. Exposure is based on geographical co-location relative to probable hazard locations.

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[21] Note: a lower warming scenario, such as RCP2.6, was not included in this analysis given its low likelihood of outcome.

[22] Figure 1.5 in Ara Begum, R., R. Lempert, E. Ali, T.A. Benjaminsen, T. Bernauer, W. Cramer, X. Cui, K. Mach, G. Nagy, N.C. Stenseth, R. Sukumar, and P. Wester, 2022: Point of Departure and Key Concepts. In: Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 121-196, doi:10.1017/9781009325844.003.

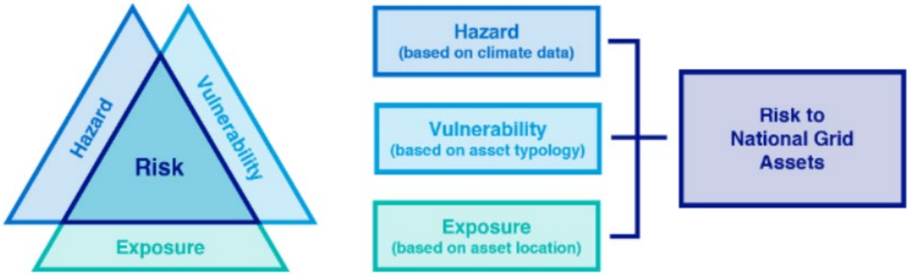

Figure 2: National Grid's Climate Change Risk Triangle

For this CVA, National Grid is using two main tools to examine key climate change hazards and the electric distribution system's exposure to these hazards: the Climate Change Risk Tool ("CCRT"), and the Wind, Icing, and Coastal flooding risk Tool ("WICT"). Both the CCRT and WICT are in-house tools and are specific to National Grid's service territory and assets. The following sub sections include details on these tools.

3.2.1 Climate Change Risk Tool (CCRT)

The CCRT, a digital asset mapping, simulation, and analysis platform, enables National Grid to understand which of the Company's assets are exposed to different climate hazards throughout different time periods. The CCRT covers the entire Company's service territory and evaluates the exposure of its assets to nine climate hazards over two climate scenarios (2°C [3.6°F] and 4°C [7.2°F] of warming based on CMIP5 data) and across multiple timeframes.

The CCRT offers both a spatial and dashboard-type display and provides information on hazard, exposure, and risk levels for National Grid assets. The CCRT analyses nine climate hazards: high temperatures, low temperatures, freeze/thaw cycles, heat waves, high winds, coastal flooding, river flooding, compound events, and lightning. Most hazards consider projections across a model ensemble for both RCP 4.5 and RCP 8.5 and consider multiple future time horizons, including the 2030s, 2040s, 2050s, and 2070s. The CCRT was developed with the support of the consultant, Arup. The first use cases for the tool were compliance filings, including the Task Force on Climate-related Disclosures[23] (TCFD) requirements and the New York Climate Change Vulnerability Study and Resilience Plan.[24] The CCRT provides a consistent, long-term assessment of physical climate change risks to National Grid's UK and US assets using the latest climate science developed in conjunction with business unit subject matter experts. The CCRT converts scientific climate data into a platform that provides visualization of the physical risks on The Company's installed asset base. It accounts for regional variations in climate science to aid in local decision-making.

CCRT climate data sees utilization of historical climate data from various sources (including FEMA National Flood Hazard Layer & ECMWF Reanalysis v5[25] [ERA5] data layers) to understand the regional change and the processing of CMIP5, NOAA, and academic literature through known climate data downscaling models. This is used to identify predictive climatic hazards and scenarios, creating a unique representation of a 'climate grid.' The establishment of a spatial relationship with National Grid asset location and vulnerability data enables the Company to calculate an individual risk score for each feature.

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[23] https://www.nationalgrid.com/document/152071/download

[24] https://www.nationalgridus.com/Our-Company/New-York-Climate-Resiliency-Plan

[25] Hersbach H, Bell B, Berrisford P, et al. The ERA5 global reanalysis. *Q J R Meteorol Soc*. 2020; 146: 1999–2049. https://doi.org/10.1002/qj.3803; https://www.ecmwf.int/en/forecasts/dataset/ecmwf-reanalysis-v5

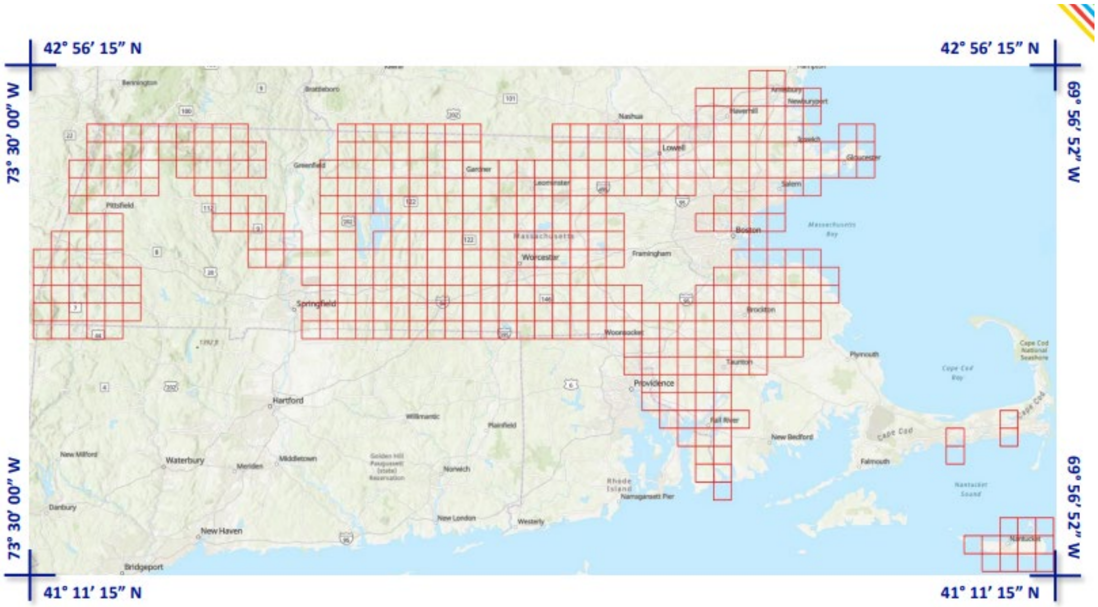
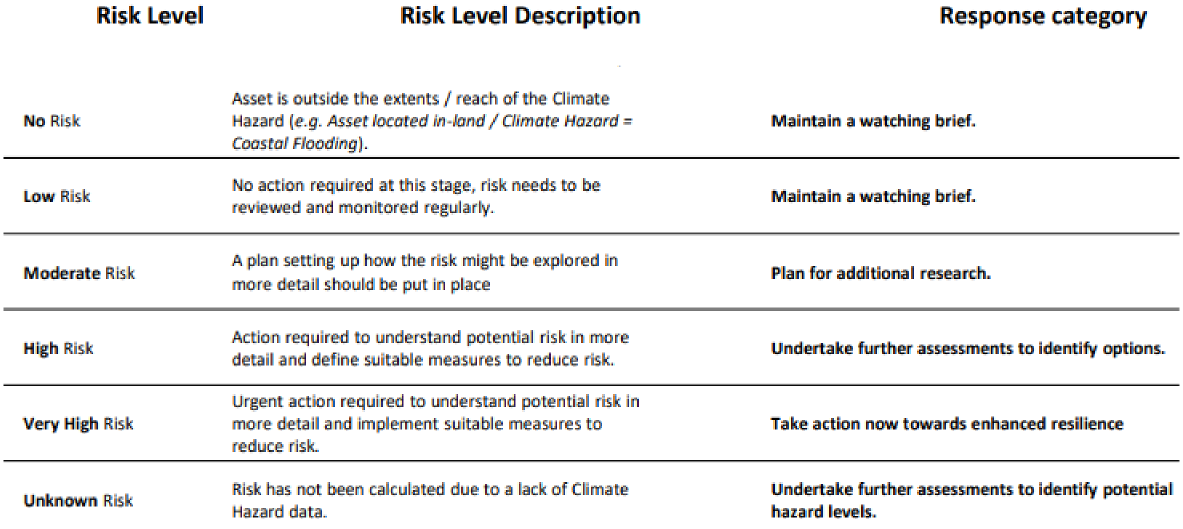


Figure 3: National Grid's Climate Change Risk Tool (CCRT) analytic grid for Massachusetts climate assessments



Risk Level	Risk Level Description	Response category
No Risk	Asset is outside the extents / reach of the Climate Hazard (*e.g. Asset located in-land / Climate Hazard = Coastal Flooding*).	**Maintain a watching brief.**
Low Risk	No action required at this stage, risk needs to be reviewed and monitored regularly.	**Maintain a watching brief.**
Moderate Risk	A plan setting up how the risk might be explored in more detail should be put in place	**Plan for additional research.**
High Risk	Action required to understand potential risk in more detail and define suitable measures to reduce risk.	**Undertake further assessments to identify options.**
Very High Risk	Urgent action required to understand potential risk in more detail and implement suitable measures to reduce risk.	**Take action now towards enhanced resilience**
Unknown Risk	Risk has not been calculated due to a lack of Climate Hazard data.	**Undertake further assessments to identify potential hazard levels.**

Figure 4: CCRT Asset risk level descriptions

National Grid will continue to build the CCRT with more granular enhancements, including more refined geographic details, to enable more planning capabilities for short- and medium-term needs and long-term climate risks.

3.2.2 Wind, Icing, and Coastal Flooding Risk Tool (WICT)

The WICT consists of two separate datasets and can focus on one at a time or show them both side by side. The first dataset includes wind and icing hazards, and the other features coastal flooding.

National Grid worked with the Massachusetts Institute of Technology's ("MIT") Joint Program on the Science and Policy of Global Change to forecast weather conditions over the Company's service territory for the years

2025 – 2041 in hourly, ≤3km^2 granularity. The MIT report, published in June of 2021,[26] along with the applied statistical analytics that followed, is National Grid's data source for wind and icing risks on the Company's distribution assets in this assessment.

From 2020-2022, National Grid analyzed the 65 TB dataset provided by MIT using extreme events methodology to identify 1-in-10-year (10% annual probability) wind speeds and wind gusts and 1-in-10-year (10% annual probability) radial icing levels that the Company's circuits will likely face in the future. This analysis helps prioritize projects, re-consider design standards for transmission and distribution networks, and allows the Company to work with stakeholders to influence standards in the broader region.

For this CVA, National Grid has applied the analyzed dataset from the MIT study in the WICT. The WICT, similar to the CCRT, allows National Grid to view where climate change hazards are projected to occur in the future and shows National Grid's electric distribution infrastructure's exposure to these risks.

Along with the MIT wind and icing data, the WICT includes coastal flooding risks per the Massachusetts Coast Flood Risk Model ("MC-FRM") from the Massachusetts Office of Coastal Zone Management ("CZM").[27] The WICT includes coastal flooding events with a 1% annual coastal flood exceedance probability ("ACFEP")–otherwise known as the once in a 100-year storm—for 2030, 2050, and 2070. The Massachusetts website states that the data "includes sea level rise, dynamic future storm surge scenarios, and current worst-case hurricane surge and flood zone models [which] were developed by the National Oceanic and Atmospheric Administration (NOAA), Woods Hole Group (WHG), U.S. Army Corps of Engineers, and Federal Emergency Management Agency (FEMA)."[28]

The WICT overlays the wind, icing, and coastal flood hazards with distribution asset maps to allow visibility into which assets are likely to be at risk of experiencing the hazard, acting as a screening tool for future analysis. The WICT does not consider individual asset resilience or asset hardening and is not a predictor of which assets will experience damage from the climate hazard. National Grid, however, does review individual asset risks on a site-specific basis, especially at the Company's worst-performing sites.

4.0 Climate Vulnerability Assessment

Based on the geography of National Grid's Massachusetts service territory, the prevalence of associated climate threats, and the severity of their impact on electric distribution infrastructure, four climate hazard categories were selected for this CVA. As noted in Section 2.1, these major climate hazards agree with the outcomes of recent Massachusetts climate change studies.

Major Climate Hazards
Rising Temperatures
Changes in Precipitation
Coastal Flooding
Severe Weather

Formulated from the risk assessment method explained in section 3.2 and Figure 2, each of these hazards is further examined along with asset vulnerability and exposure probabilities to assess the overall risk. There are some compounding impacts on electric distribution assets from multiple hazards, especially concerning wind events that occur in conjunction with other climate hazards. For example, ice accretion on vegetation can make

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

[27] Massachusetts Office of Coastal Zone Management, Sea Level Rise and Coastal Flooding Viewer

[28] Massachusetts Office of Coastal Zone Management, Sea Level Rise and Coastal Flooding Viewer

trees heavier and more brittle which can make them more susceptible to damaging overhead infrastructure when also experiencing high winds.

The following sections in this chapter assess the vulnerabilities of National Grid's distribution infrastructure, considering the impacts of climate change for each of the four main hazards to estimate overall risks.

4.1 Rising Temperatures

The following sub-sections review rising temperature hazards, asset vulnerabilities to rising temperatures, and the results from the risk assessment accounting for potential exposure and risks of electric distribution assets due to increasing temperatures.

4.1.1 Rising Temperature: Climate Hazard

According to the World Meteorological Organization, the planet has been warming by two-tenths of a degree every decade, with 2023 being about 2.61°F (1.45°C) warmer than the pre-industrial average.[29] As laid out by the Commonwealth of Massachusetts, chronic warm-weather hazards have been increasing, and Massachusetts has witnessed a 3.5°F (1.94°C) increase in average temperatures since the early 1900s and the number of days above 90°F (32°C) and warmer nights are increasing.[30] The last eight years have been the warmest on record and will continue to increase in frequency and intensity as global temperatures continue to rise. For example, Figure 5 shows that in a high emission scenario, Worcester could see an additional 3.5°F (1.95°C) increase in average maximum daily temperature between 2020 and 2050. Warm-weather hazards tend to occur across large geographical areas and are likely to impact the regional electric system.

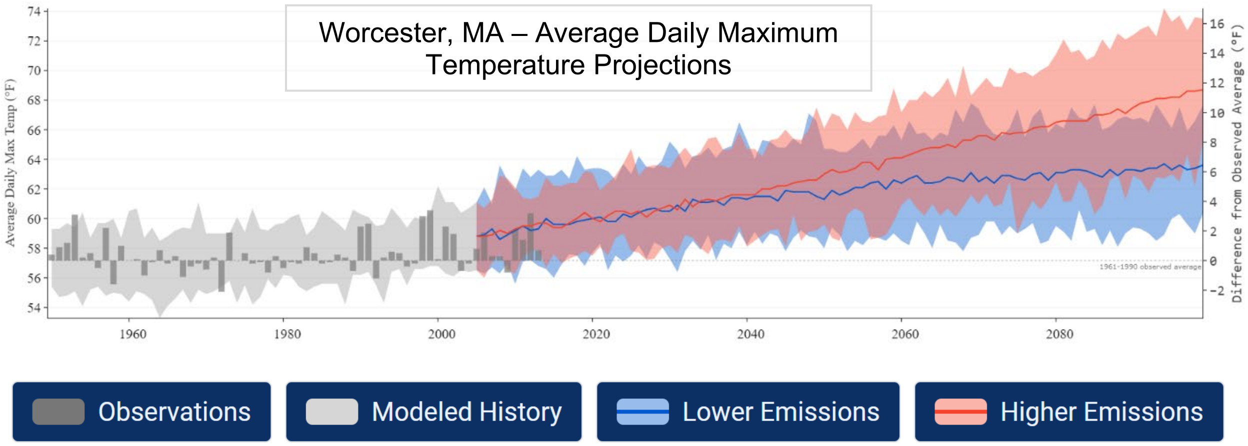

Figure 5: Worcester, MA average daily maximum temperature projections using CMIP5 forecasts from the U.S. Climate Resilience Toolkit Climate Explorer. Blue is a lower emission projection and red is a higher emission projection; lines are weighted means.[31]

Warm-weather wind events, specifically those associated with storms, remain a high concern for electric infrastructure and are considered in the severe weather section (Section 4.4.3) of this CVA.

4.1.2 Rising Temperature: Asset Vulnerability

High temperatures can have direct negative impacts at the asset level, and vulnerabilities can also be found indirectly at the operational level (primarily resulting in the need to de-rate equipment) with potential knock-on effects that cannot be overlooked. High air temperature events can both increase the degradation of equipment in real-time and indirectly lead to increased loading and further strain due to higher customer

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[29] World Meteorological Organization, State of the Global Climate 2023, 2024

[30] Commonwealth of Massachusetts Extreme Heat Resource Guide, 2024.

[31] The Climate Explorer, NOAA Climate Program Office and the National Environmental Modeling and Analysis Center (NEMAC) at the University of North Carolina Asheville. https://crt-climate-explorer.nemac.org/

demand. Essentially, high ambient temperatures can lead to more electricity flowing through equipment that may already be stressed—such as when customers turn on their air conditioning on a hot summer day.

Increasing ambient temperature has the most significant impact on the ratings of oil-filled equipment such as transformers and voltage regulators. The resulting vulnerabilities include increased potential for outages, decreased electrical capacity, and decreased life expectancy of equipment. Thermal ratings, which establish thresholds for acceptable equipment loading without incurring an unacceptable loss of life, are based on assumed ambient temperatures and load cycles. Increasing ambient temperatures combined with flatter load cycles (from a combination of increasing overnight temperatures and increased overnight electrical demand, e.g., from electric vehicles and battery charging) will challenge traditional ratings assumptions and may lead to the identification of lower thermal ratings. These lower ratings will reduce the amount of demand a given piece of equipment can serve, at the same time that higher ambient temperatures are increasing that demand.

> *High temperature periods also include a human safety factor. Personnel safety and health could be at risk, and routine business operations could be impacted as a result.*

Heat waves present the most risk when in combination with other adverse effects. Many heat dispersion tactics lose efficiency as temperatures and humidity increase. Heat waves are also likely to increase residential and industrial cooling energy demand. Power demand from residential, commercial, or industrial consumers is influenced by a wide range of factors including temperature, humidity, population levels, urbanization, industrialization, and electrification levels. In Massachusetts, peak power demand is expected to increase in the summer months as temperatures grow warmer and the need for cooling increases. Peak load is more sensitive to temperature increases than average demand, introducing risks to capacity margins. The Massachusetts 2050 Clean Energy and Climate Plan forecasts peak electric demand switching from the summer to the winter in the mid-2030s.[32] However, it is unlikely that Massachusetts will experience exposure to extreme heat during winter high-load events, and the increased summer load during heat waves will remain the largest heat-related concern for equipment capabilities.

Underground cables on National Grid’s distribution system are either directly buried or in conduit. Above average temperatures or dry soil conditions during heat waves could affect direct buried cable ratings by increasing ground temperature and soil resistivity, thereby limiting the heat transfer to the soil. Under high temperatures and high loads, the thermal rating of cables is reduced in manhole/duct installations, due mostly to the increased cable loading producing more heat.

4.1.3 Rising Temperature: Exposure and Assessment Results

Rising temperature hazards were reviewed for increasing intensity from forecasted climate change. The warm-weather hazards reviewed in this assessment are the following:

1. **Heat waves:** Maximum daily temperature above 90°F (32°C) and minimum daily temperature above 70°F (21°C) for 3 consecutive days.
2. **High Air Temperature:** Days above 95°F (35°C).

4.1.3.1 Heat waves

The CCRT was used to identify assets at high risk of exposure to heat waves, ‘High’ risk indicates 2.66 – 4.11 occurrences per year where the maximum daily temperature is above 90°F (32°C) and minimum daily temperature is above 70°F (21°C) for 3 consecutive days. The following tables provide the assets at risk and the rate of change for both the 2°C scenario and the 4°C scenario.

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[32] Commonwealth of Massachusetts Clean Energy and Climate Plan for 2050, 2022

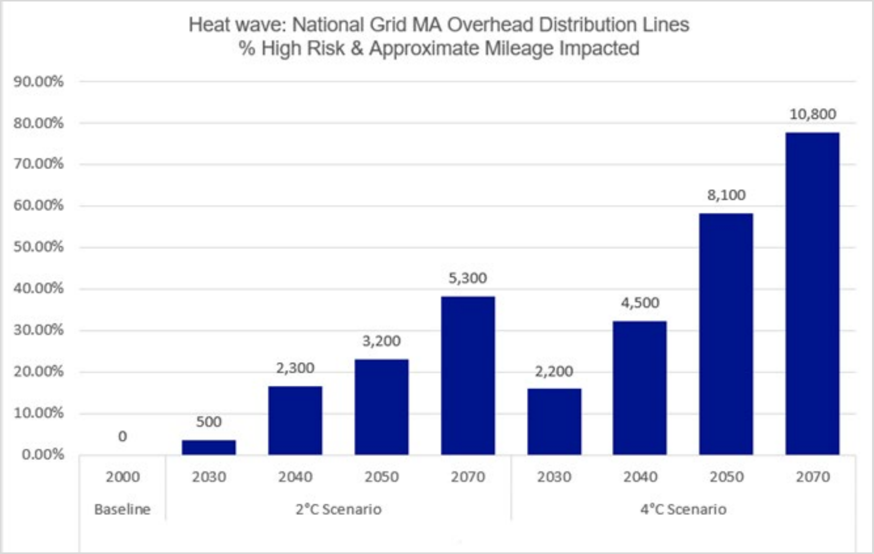

Figure 6: Results from CCRT on National Grid's Massachusetts overhead distribution line equipment risk of exposure to heat waves in % of total overhead line equipment and miles of overhead line infrastructure exposed.

Overhead distribution lines are expected to have significant exposure to heat waves in both the 2° and 4° scenarios, with over 38% of lines at risk of being impacted by 2070 in the 2° scenario, and 78% of lines at risk in the 4° scenario over the same time period.

When heat waves occur with other adverse weather conditions such as high humidity or low wind, the risk of electric infrastructure impacts can increase.[33] The combination of heat waves with drought can increase wildfire risks. Heat waves will also increase residential and industrial cooling energy demand, which increases asset loads along with customer dependency on a resilient electric system.

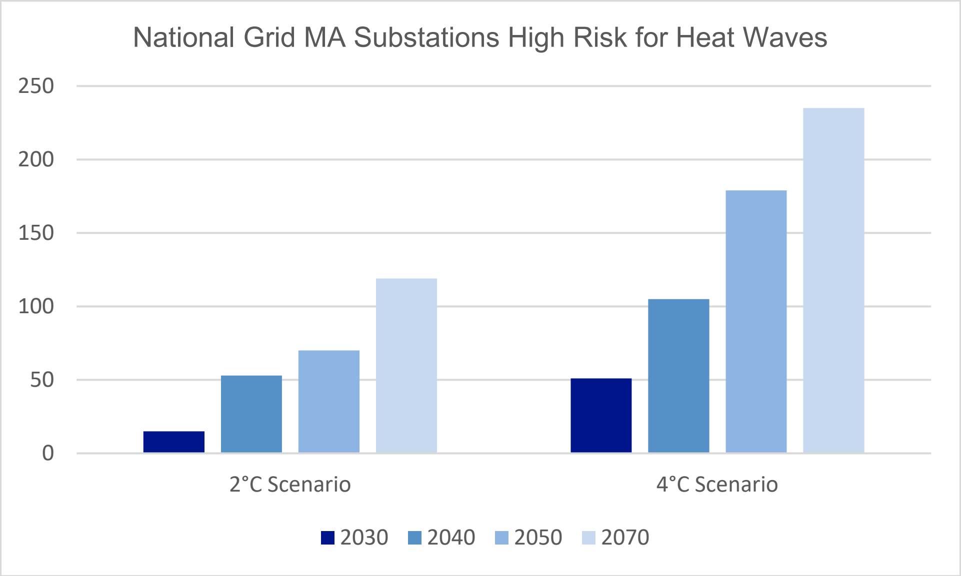

Figure 7: Risk analysis from the CCRT on the impact of heat waves on National Grid's distribution substations in Massachusetts

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[33] EPRI, Climate READi, READi Insights: Extreme Heat Events and Impacts to the Electric System, 2022

Substation assets—specifically power transformers and circuit breakers—are expected to experience a significant volume of high risk due to heat waves in both the 2° and 4° scenarios. More significant exposure is expected in the 4° scenario, with nearly 18% of substations at high risk by 2030, and 81% of substations exposed by 2070. As noted in Figure 8 below, the highest impacts of heat waves are expected in the eastern and southern areas of Massachusetts, with stations in the Berkshires less at risk of impact from heat waves.

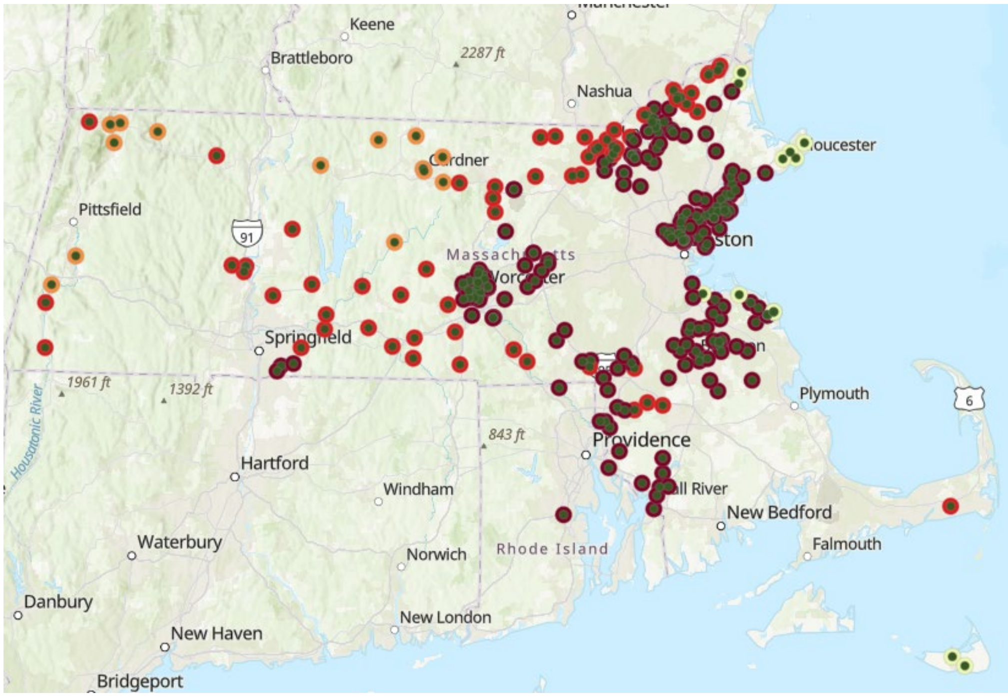

Figure 8: CCRT screen share of substation heat wave exposure, for the 4° Scenario in 2050. Maroon indicates high risk, red indicates moderate risk, and orange indicates low risk. Yellow indicates a lack of current data.

4.1.3.2 High Air Temperatures

The CCRT was used to identify assets at risk of exposure to high air temperatures. ‘High’ risk indicates 2.16 – 3.41 days per year above 95°F (35°C). The following tables provide the assets exposed and the rate of change for both the 2° scenario and the 4° scenario.

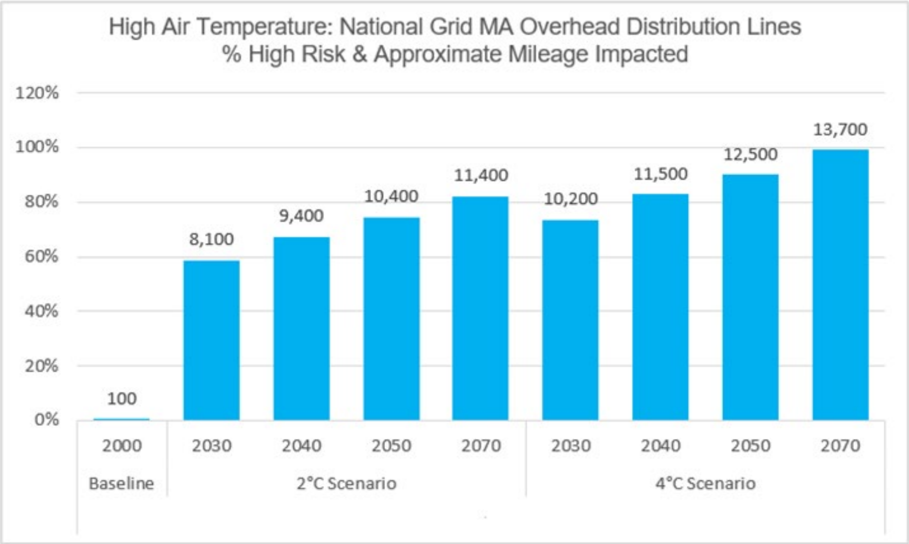

Figure 9: Results from CCRT on National Grid's Massachusetts overhead distribution line equipment risk of exposure to high temperature in % of total overhead line equipment and miles of overhead line infrastructure exposed.

Overhead distribution lines are expected to have significant exposure to high air temperatures in both the 2° and 4° scenarios, with 82% of lines experiencing high temperatures by 2070 in the 2° scenario, and 99% of lines in the 4° scenario over the same time.

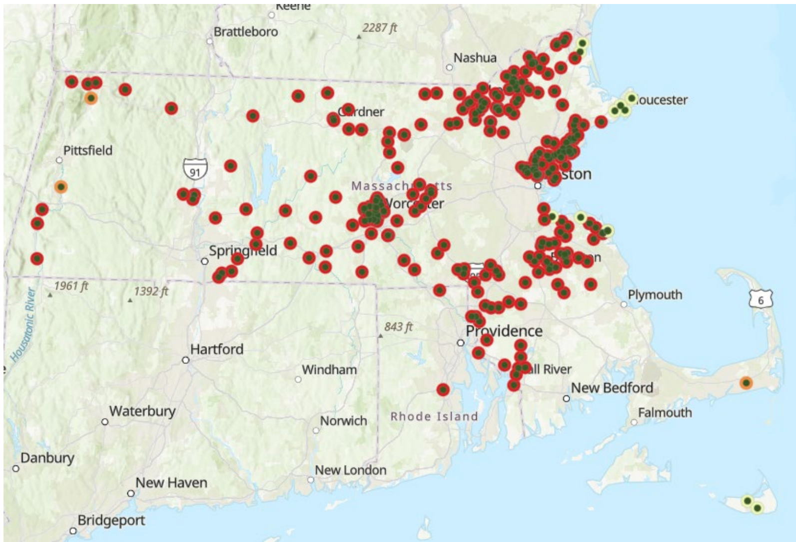

Figure 10: High Temperature exposure to National Grid's MA distribution substations, 4° Scenario, 2050. Red signifies moderate risk and orange is low risk. Yellow indicates a lack of current data.

While the output of the CCRT indicates a growing frequency of higher temperatures, it has been recognized that the ambient temperatures used in the initial climate hazards scenario are within ambient temperatures specified in equipment standards and rating methodologies, which suggests there will be less risk to these assets from this hazard. Additionally, there are instances where the ambient temperature exceeds the high-end of the temperature threshold considered in this study. These particularly high temperatures that exceed asset ratings must also be considered when determining asset risk.

4.1.4 Rising Temperature Risk Rating

From this assessment, the estimated risk rating related to high temperature is moderate for substations and overhead equipment. In a 4° scenario, many of the Company's assets will experience extreme heat and heat wave exposure; however, with updated standards and maintenance practices, these risks can be mitigated. Underground cables are less impacted by temperature swings given the insulating nature of the surrounding earth, and their risk to rising temperatures is low-to-moderate from 2030 through 2070 (data not shown in this CVA). This results in a low designation for underground cable equipment risk.

Table 2: Asset risk matrix for rising temperature hazards

Climate Hazards	Electric Distribution Asset Category		
	Substation	Overhead Equipment	Underground & Pad-Mount Equipment
Rising Temperature	M	M	L

4.2 Changes in Precipitation

According to the Massachusetts Climate Change Assessment, [34] annual precipitation may remain steady in the coming decades, but the water cycle is projected to intensify, with a greater amount of precipitation occurring in shorter time windows. Seasonal water cycle changes such as increased precipitation in the winter and decreased precipitation in the summer are expected. Heavy rain events can result in flooding, and decreased rain can result in dry and drought conditions, both of which can carry risks to electric infrastructure. Refer to the Wildfire and Related Hazards callout box for more details relating to drought.

The following sub-sections review hazards related to changes in precipitation, asset vulnerabilities related to precipitation changes, and the results from the risk assessment accounting for potential exposure and risks of electric distribution assets due to precipitation changes.

4.2.1 Changes in Precipitation Hazard

The Commonwealth and leading climate scientists agree that flooding risks will rise over the next few decades with increased likelihoods of extreme precipitation events.[35] Such events can cause fluvial/riverine flooding, which is flooding along rivers from excessive rainfall, and pluvial flooding, which is flooding in areas without adequate rainfall drainage independent of the overflow from bodies of water. In the second half of this century, seasonal changes to precipitation cycles may be more divided with increased precipitation in the winter and decreased precipitation in the summer, as shown in Figure 11 taken from the 2022 Massachusetts Climate Change Assessment Report.

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[34] Commonwealth of Massachusetts, 2022 Massachusetts Climate Change Assessment, Volume II, Statewide Report

[35] Commonwealth of Massachusetts, 2023 ResilientMass Plan: 2023 MA State Hazard Mitigation and Climate Adaptation Plan

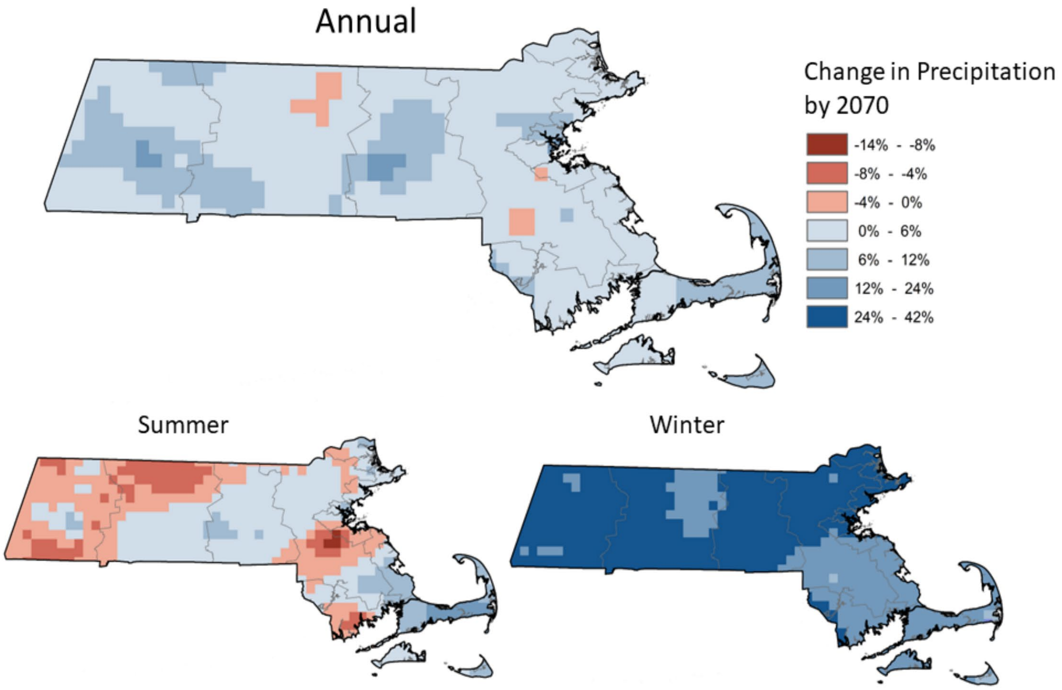

Figure 11: Map of projected seasonal changes of precipitation in 2070. Source: 2022 Commonwealth of Massachusetts Climate Change Assessment; data from Localized Constructed Analogs repository. The projection for 2070 is for a 20-year era centered on 2070.[36]

Fluvial/riverine flooding—from snowmelt, intense precipitation events, and changes in precipitation locations and river pathways—was reviewed as part of this assessment. The Massachusetts Climate Change Assessment indicates less frequent and more intense precipitation events.[37] Inland extreme flood events already occur and will persist within the Company's service territory, and substation sites located near rivers will continue to be reviewed for flood risk. National Grid will continue research on regional climate models to specify any rivers or watersheds that may pose new risks.

Pluvial flooding and Future Surface Water Flooding (SWF) risks are other possible flood-related hazards, and they are more challenging to project at long timescales. Current SWF forecasts are published about a week to a month in advance. The same storm occurring just miles apart could have very different impacts, and SWF can occur in areas not experiencing any extreme precipitation at the time of the flood. Higher resolution forecasts are needed to better understand this hazard, as well as embedding local topography into projections.

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[36] Commonwealth of Massachusetts, 2022 Massachusetts Climate Change Assessment, Volume II, Statewide Report

[37] Commonwealth of Massachusetts, 2022 Massachusetts Climate Change Assessment, Volume II, Statewide Report

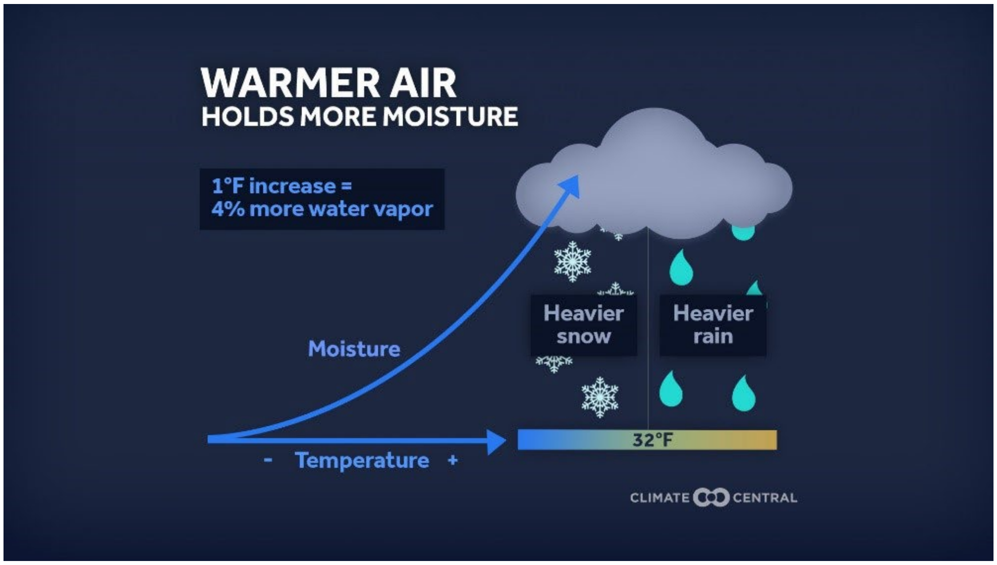

Figure 12: Climate Central Warm Air Moisture Schematic[38]

While temperatures are projected to increase, warmer air holds more moisture, as shown in Figure 12, potentially resulting in more precipitation. The Northeast US has witnessed this change, and more rain has been falling in winter months compared to snow; this trend is expected to continue into the 21st century.[39] Winter rain events can lead to hazardous conditions and ice accretion on trees and overhead structures. When snow does fall, it will likely be heavier and denser, which can be more damaging to infrastructure.

4.2.2 Changes in Precipitation and Asset Vulnerability

Precipitation flood risks can flood electric system infrastructure and adjacent vegetation. Polluted river and surface flooding can accelerate equipment corrosion, which is a secondary climate hazard to flooding. Flooding poses a significant threat to the vulnerability of electric distribution assets, making it a critical consideration in the Company's efforts to enhance infrastructure resilience.

Inland flooding and precipitation changes are mainly linked to electric asset vulnerabilities from equipment submersion. Inland flooding can also cause soil instability and erosion which increases vulnerabilities in pole and tree foundations and can unearth cables if severe. In National Grid's Massachusetts distribution system, many of these risks are present today. River flooding will continue to be a major hazard in specific locations, and the Company will continue to analyze this exposure.

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[38] Climate Central, Shifting Snow in the Warming U.S., Warm Air Moisture Schematic.https://www.climatecentral.org/climate-matters/shifting-snow-in-the-warming-u.s

[39] University of Massachusetts, Massachusetts Wildlife Climate Action Tool. https://climateactiontool.org/

Figure 13: Adams, MA substation inland flooding in 2023

Increased precipitation in the winter can freeze on and around infrastructure. Frozen water on the power system can have adverse effects on distribution structures, as the added weight can cause line sag, line failure, or other consequences that could result in asset damages and outages. Heavy snow and ice accumulation on trees can cause trees or tree branches to fall on overhead conductors and poles causing electrical faults and equipment damage, and vegetation damage from heavy ice and wind is even more prevalent when combined with wind.[40]

Underground distribution infrastructure is moderately impacted by increased precipitation. If installed and sealed as designed, underground cables, conduits, and other underground electrical infrastructure are less vulnerable to flooding events. Under normal conditions, manholes are often filled with water and their equipment is designed to be submersible. However, there remains a slight risk of water infiltration which could lead to corrosion, insulation damage, or short-circuiting which could result in service disruptions or costly repairs.

4.2.3 Changes in Precipitation Risk Exposure and Assessment Results

To better understand National Grid's exposure to precipitation, the CCRT was used to analyze river flooding risk. The increase in winter precipitation not only raises the risk of flooding but also heightens the possibility of snow and ice accumulation on the electrical distribution system. The WICT was utilized to assess radial icing risks.

4.2.3.1 River Flooding

River flooding in the CCRT looks at the frequency of occurrence of riverine flooding and exposure due to an increase in extreme rainfall precipitation. To estimate the frequency of flood event days, a one-day maximum precipitation threshold was set at 25 mm (1 inch).

River flooding can be due to snowmelt, intense precipitation events, and changes in precipitation locations and river pathways. This hazard brings the risk of equipment submersion and the secondary hazards of soil instability/erosion which can cause weaknesses in foundations and could potentially unearth cables if severe.

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[40] EPRI Climate READi, Technical Report: Climate Vulnerability Considerations for The Power Sector: Transmission and Distribution Infrastructure, 2024

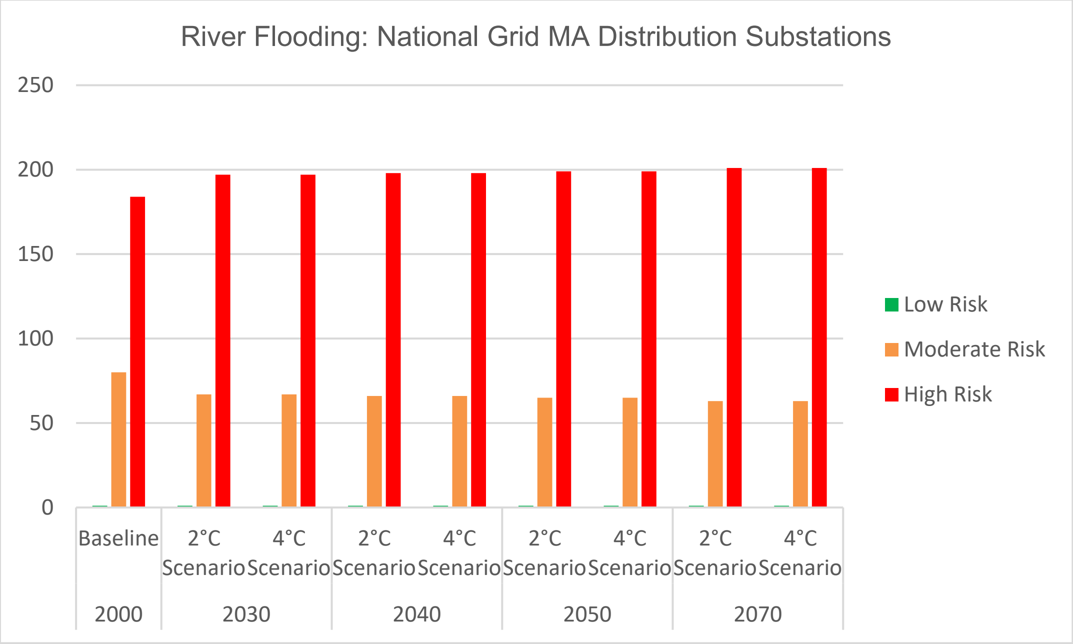

Figure 14: CCRT model outputs of number of distribution substations at risk of inland flooding

A portion of substation assets will be exposed to river flooding in both the 2° and 4° scenarios. These risks are already present today, and current models indicate slight increases between 2030 and 2070.

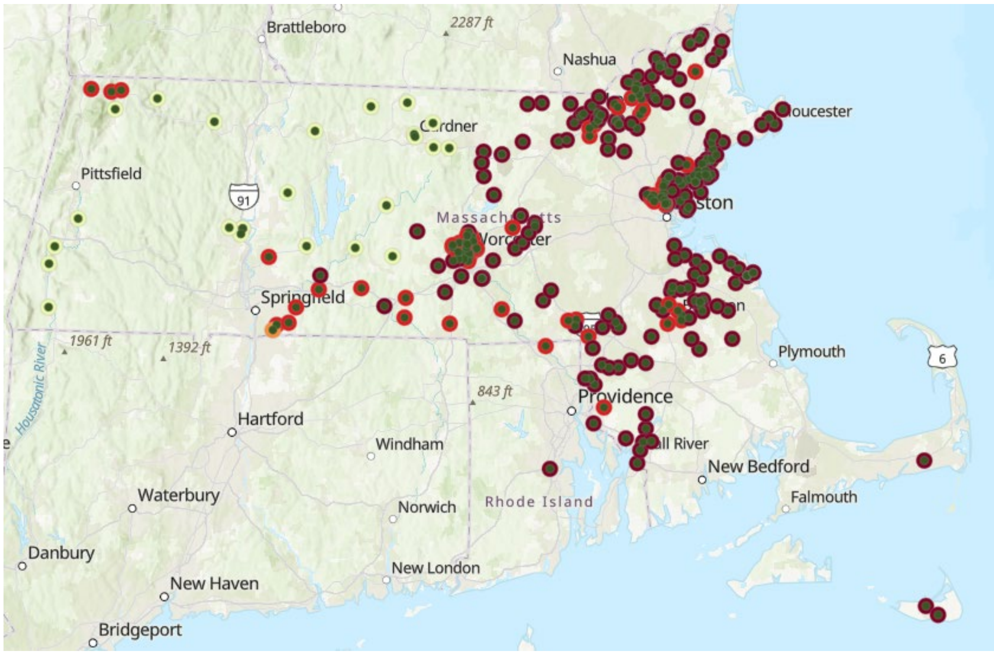

Figure 15: CCRT screen share of distribution substations at risk of precipitation-related flooding in 2050 in the 4° scenario. Maroon is high risk, red is moderate risk, and orange is low risk. Yellow indicates a lack of current data.

The highest river flooding risks are projected to manifest in the eastern half of Massachusetts, with assets in the western portion of the state less exposed. The CCRT does not currently include geospatial characteristics such as substation elevation, but National Grid engineers consider these additional factors when developing risk mitigations.

As seen in Figure 16, the majority of overhead distribution lines will experience moderate exposure in the 4° scenario from 2030 to 2070, with a small amount (~320 miles) shifting from low exposure to moderate exposure over that time period. Similar to the overhead distribution lines, Figure 17 shows the majority of underground distribution lines will experience moderate exposure in the 4° scenario from 2030 to 2070, with a small amount (~100 miles) increasing from low exposure to moderate exposure.

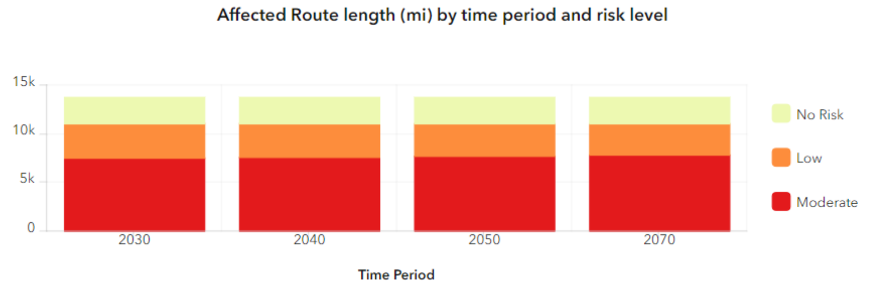

Figure 16: CCRT data of National Grid MA overhead distribution lines exposed to river flooding 2030-2070, 4° scenario.

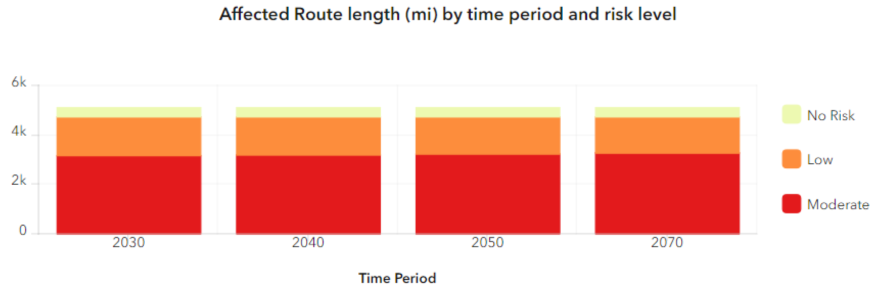

Figure 17: CCRT data of National Grid MA underground distribution lines exposed to river flooding 2030-2070, 4° scenario.

It is important to note that the exposure and vulnerability of assets to flooding can vary based on factors such as the severity and duration of flooding, the elevation of the assets, and the adequacy of protective measures in place. National Grid will continue to fine-tune asset exposure projections to determine individualized asset flood mitigation plans. Assessing and addressing the vulnerabilities of these assets is crucial to minimize the impact of flooding on the reliability of the Company's electrical distribution systems.

4.2.3.2 Radial Icing

As described in Section 3.2.2, to assess icing risks on distribution assets, National Grid leveraged a study conducted by MIT[41] and converted the results to a 10-year Mean Recurrence Interval ("MRI") of radial icing events over the years 2025-2041. The Company overlaid these results with National Grid's distribution assets in the WICT. The WICT was used to determine the ice accumulation exposure and risk to overhead distribution assets.

Figure 18 depicts an output from the WICT, filtered for future climate change radial icing risks of greater than 0.5 inches of radial icing overlaid on a terrain map of Massachusetts. Distribution lines currently follow a design standard to withstand 0.5 inches of radial icing. This map shows the greatest future icing

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[41] Komurcu, M. and S. Paltsev (2021): Toward resilient energy infrastructure: Understanding the effects of changes in the climate mean and extreme events in the Northeastern United States. *Joint Program Report Series Report 352*, June, 16 p. (http://globalchange.mit.edu/publication/17608). MITJPSPGC_Rpt352.pdf

risk projections predominantly in the Berkshires and hill towns, with some risk in the Greater Connecticut River Valley and Central regions of the state. Only a small area contains a risk of greater than 0.75 inches of radial icing. Increasing the current design standard from 0.50 inches to 0.75 inches could allow distribution lines to withstand projected events in nearly 90% of risk areas for MA, which is a design adaptation that National Grid could consider when developing a resilience plan.

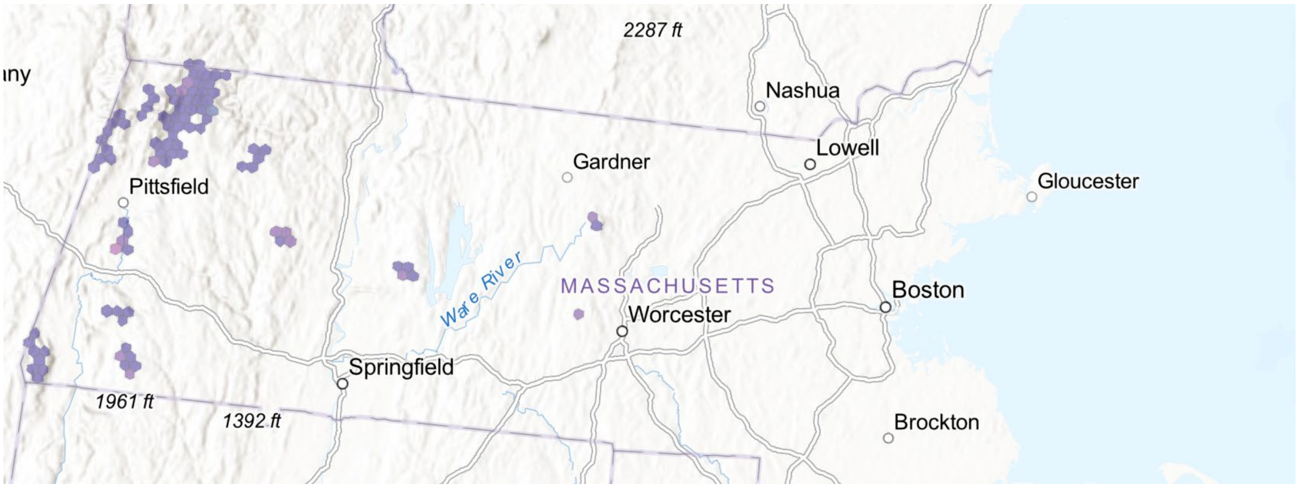

Figure 18: National Grid areas at risk of radial icing over 0.50 inches from 2025-2041, WICT output

4.2.4 Changes in Precipitation Risk Rating

Based on this assessment, electric distribution assets are at moderate to high risk of precipitation-related climate hazards. Substations located in or near areas prone to inland flooding are at a high risk of flood damage now and in the future. Overhead equipment and adjacent vegetation in specific regions of the state are at moderate risk of snow and ice accumulation during winter precipitation events along with soil degradation from either over-saturation or drought conditions. Components of the distribution underground system have a moderate risk of flooding, specifically above-ground pad-mounted devices that are not elevated above the flood plain.

Table 3: Asset risk matrix for changes in precipitation hazards

Climate Hazard	Electric Distribution Asset Category		
	Substation	Overhead Equipment	Underground & Pad-Mount Equipment
Changes in Precipitation (including Inland Flooding, and Icing)	H	M	M

4.3 Coastal Flooding

Massachusetts's climate models are projecting a rise in sea level that increases the risk of asset exposure to coastal flooding near the shoreline, expanding further inland over time.[42] Water infiltration can significantly impact substation equipment and above-grade components of underground distribution line systems, resulting in physical and electrical failure and accelerated corrosion.

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[42] Massachusetts Office of Coastal Zone Management, Massachusetts Coast Flood Risk Model

The following sub-sections review hazards related to changes in coastal flooding, asset vulnerabilities related to coastal flooding, and the results from the risk assessment accounting for potential exposure and risks of electric distribution assets due to coastal flooding.

> *Flooding presents a significant environmental risk to electric infrastructure, particularly in substations. In the spring of 2010, a series of heavy rain events caused historic flooding in the state of Rhode Island. Eight substations in the Company territory were completely flooded and subsequently had to be removed from service. The impacts of this event included significant customer outages and loss of high-value substation equipment. The Company recognizes the threat that floods pose to substations located in the Commonwealth.*

Figure 19: Flooded National Grid Substation

4.3.1 Coastal Flooding Hazard

Coastal flooding can result from a combination of factors including rising average sea level, tides, storm surge, and surface waves. Storm surge is an added effect on top of astronomical tides, caused by pressure and wind combinations pushing water towards coastal areas. The Massachusetts 2022 Climate Assessment, using the RCP 8.5 GHG emission scenario, projects over 20 inches of relative sea level rise between 2020 and 2050 and nearly double that between 2020 and 2070[43]. The data in the Climate Assessment suggest that by 2050, a 1% annual probability event could flood over 88,000 acres of Massachusetts with over a foot of water, which is over two times the area of what Massachusetts has experienced historically (an additional 50,000 acres/78 square miles).[43]

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[43] Commonwealth of Massachusetts, 2022 Massachusetts Climate Change Assessment

4.3.2 Coastal Flooding Vulnerability

According to the Massachusetts Coastal Zone Management models, climate change will continue to increase sea levels and the frequency and intensity of severe weather events,[44] resulting in the potential for coastal flooding and its associated impacts on electrical systems. Many of the assets that are vulnerable to inland flooding are also vulnerable to coastal flooding and sea level rise.

When it comes to flooding, various types of electric distribution assets can be impacted, while others may be less susceptible. The assets that are more likely to be affected by flooding include:

- **Substations**. Power transformers and control houses are two of the most critical components of the substation, as well as switchgear, batteries, and other pieces of important equipment with electronics. If water levels rise above a critical threshold, water can damage electrical equipment, control systems, and substation buildings, leading to service interruptions and potential safety hazards.
- **Switchgear and Control Cabinets**: Electrical switchgear and control cabinets, which house critical control and protection devices, are often located at ground level or in low-lying areas. Flooding can damage these components, leading to operational issues and potential safety concerns.
- **Pad-mounted equipment**: Pad-mounted equipment (often air-insulated), including transformers and switchgear, is susceptible to flooding and can be impacted if water levels rise above the height of the equipment or if the enclosures are not adequately sealed. Floodwaters can damage electrical components, compromise insulation, and lead to equipment failure.

On the other hand, certain electric distribution assets are less vulnerable to flooding:

- **Overhead Power Lines**: Overhead power lines, which are elevated above ground level, are generally less vulnerable to flooding. However, they can still be impacted indirectly if flooding causes trees or debris to fall onto the lines or if floodwaters erode the ground beneath the supporting structures. Accelerated corrosion and damage from debris is a risk but through regular inspection and maintenance cycles, this risk can be effectively managed.
- **Underground Electrical Infrastructure**: If underground infrastructure is built to standards, it is less vulnerable and should not be impacted by flooding events. Saltwater contact from sea-level rise, storm surges, and coastal humidity is corrosive and can lead to increased conductivity concerns for transformers and pad-mounted electrical cabinets. National Grid standards incorporate stainless steel cabinets to reduce this impact along with standards that minimize the risk of water contact in the first place such as elevating equipment. Brine from saltwater exposure can collect and degrade pad-mount equipment, but proper sealing and regular inspection and maintenance can help manage this risk.[45]

Through regular inspection and maintenance cycles, many of these risks can be effectively managed. In addition to the direct impacts of flooding on electrical infrastructure, there are indirect impacts such as customer and employee safety concerns and limited access to equipment if roads are impassable or deemed unsafe from flooding; however, this CVA is currently focused on the distribution system assets themselves and not these indirect impacts.

4.3.3 Coastal Flooding Exposure and Risk Assessment

National Grid is utilizing the Massachusetts Coast Flood Risk Model ("MC-FRM") to estimate the risk of coastal flooding to the Company's electric distribution assets.[46] The MC-FRM datasets were added to the WICT and overlayed with substations, pad-mount equipment, and utility poles. Utility poles should be able to withstand broad flooding while substations and pad-mount equipment are at a higher risk of impacts from flooding if adaptation measures are not implemented.

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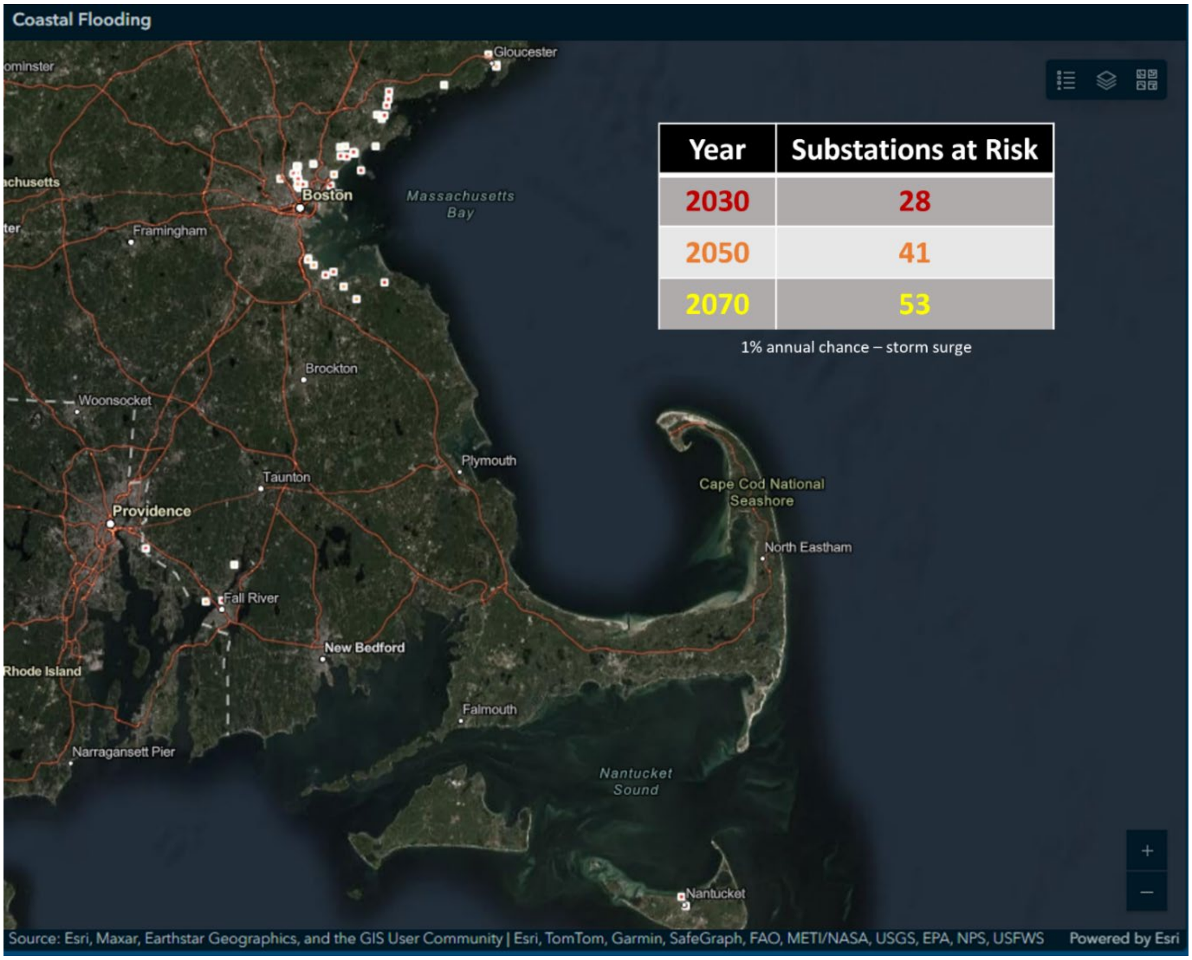
[44] Massachusetts Office of Coastal Zone Management, Massachusetts Coast Flood Risk Model

[45] EPRI Climate READi, Technical Report: Climate Vulnerability Considerations for The Power Sector: Transmission and Distribution Infrastructure, 2024

[46] Massachusetts Office of Coastal Zone Management, Massachusetts Coast Flood Risk Model

4.3.3.1 Substation Flood Risks

Shown in Figure 20 is an output from the WICT showing substations at risk from coastal flooding. The WICT identifies National Grid substations at risk of a 100-year return period flood, which has a 1% probability of occurring or being exceeded in any given year. As illustrated in Figure 20, in this scenario 28 sites are projected to be at risk of flooding in 2030, an additional 13 in 2050, and 12 more in 2070.



Year	Substations at Risk
2030	28
2050	41
2070	53

1% annual chance – storm surge

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community | Esri, TomTom, Garmin, SafeGraph, FAO, METI/NASA, USGS, EPA, NPS, USFWS

Figure 20: Screen capture of WICT showing National Grid's cumulative substations at risk in 2030, 2050, and 2070.

Zooming into specific regions shows details of the MC-FRM outputs and substation locations. Figure 21 shows an example of a grouping of substations at risk in the Mystic River region. In this example, the event is flooding neighborhoods, businesses, and access roads surrounding the substations, increasing safety risks for residents, local industry, and electric infrastructure restoration crews. Even if these substations could remain energized, careful consideration would be needed to determine if electricity should flow to the flooded surrounding area.

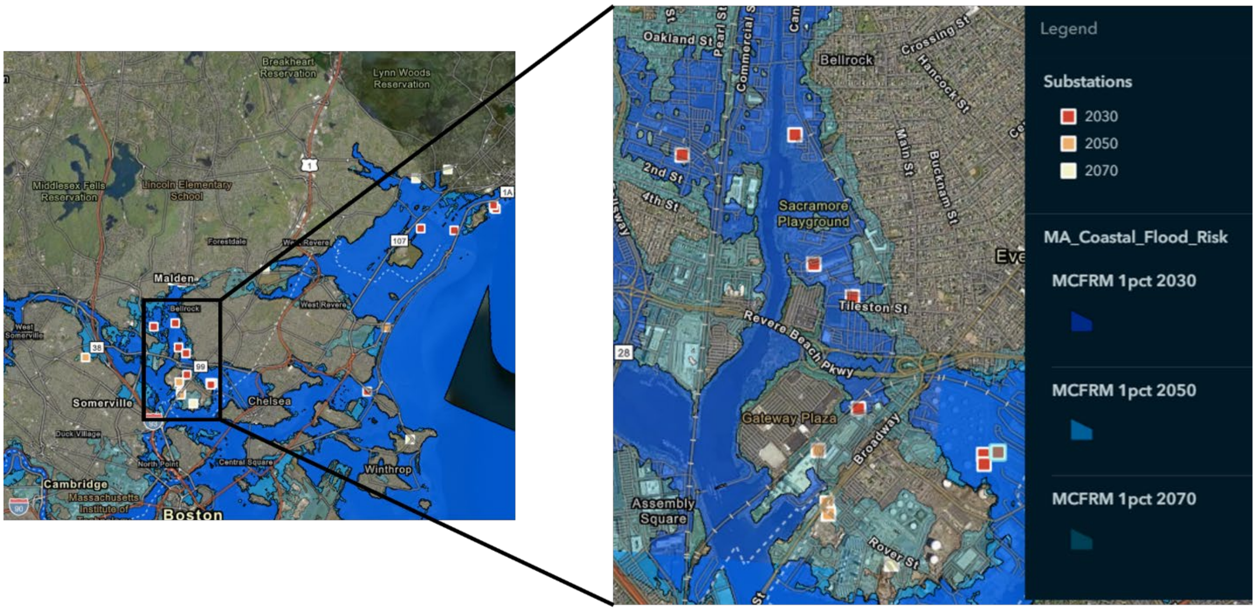


Figure 21: Example of WICT showing National Grid's substation coastal flooding risk.

National Grid currently reviews substations where there is a 1% probability of the base flood elevation (BFE) being equaled or exceeded each year per FEMA probabilities. The 500-year flood elevation also needs to be considered for substations that are in these mapped areas. Substations located within the 500-year flood elevation have a 0.2% chance of being flooded within a given year. In these flood-risk substations, building structures and sensitive equipment (e.g., transformers, control panels, switch handles, etc.) are located to some extent above these determined flood elevations. The guidance for determining elevations at which these buildings and sensitive equipment are elevated is provided in National Grid's standard *Design Basis Manual* for New England substations.[47] New England coastal substations account for an additional one foot of water elevation resulting from an assumed sea level rise. If a municipality has a detailed Town/City-wide study or report that predicts a higher elevation of sea level rise, that value is utilized.

System impacts from a flood event could include substation removal from service and a high probability of damage to critical equipment such as transformers, circuit breakers, and relays. Customer outages would likely occur while the substation equipment is not available.

Mitigation measures include:

- Immediate response actions such as the installation of timber walls and floodstop barriers (rapidly deployable earth-filled barriers), flood barriers, and supplemental flood risk reduction elements such as pumps, plugs, and generators to displace water inside substations from general rainfall and potential flood barrier leaks.
- Further evaluations of flood risk that resolve system performance concerns, including interactions with external agencies such as submitting a Conditional Letter of Map Revision ("CLOMR") to FEMA.
- Incorporation of flood mitigation measures into planned infrastructure development projects at the identified substations. These measures are intended to reduce the risk of damage during a flood event, enhancing the Company's substations' resiliency to this potential climate change impact. Flood mitigation efforts have been implemented at dozens of substation locations and many additional projects are planned.
- Regarding corrosion concerns for equipment, National Grid has implemented standards for transformers with stainless steel tanks in coastal areas.

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[47] Note: The guidance in this company standard document is based on the direction provided in ASCE 24 Flood Resistant Design and Construction. ASCE 24 is referred to in ASCE 7 Minimum Design Loads and Criteria for Building and Other Structures – the paramount load standard used for structures abiding by the International Building Code.

Figure 22: Substation equipment in Lowell, MA raised 6.5' above grade as a flood mitigation measure.

National Grid is considering strengthening its flood mitigation design criteria to account for anticipated future flood levels that exceed the current standards for all planned projects, as well as evaluating existing flood mitigation measures.

4.3.3.2 Pad-Mount Underground Infrastructure

In general, the underground system is designed to be submersible. The above-ground components of underground systems (e.g., pad-mount transformers and switches) are the most vulnerable to coastal flooding. See Figure 23 for an example area from the WICT of potential coastal flood risks on pad-mount equipment in an area of Quincy. In total, National Grid has ~1,300 pad-mounted equipment assets that may be at risk of a 1% annual probability storm surge flood event in 2030 with an additional 719 and 522 by 2050 and 2070, respectively.

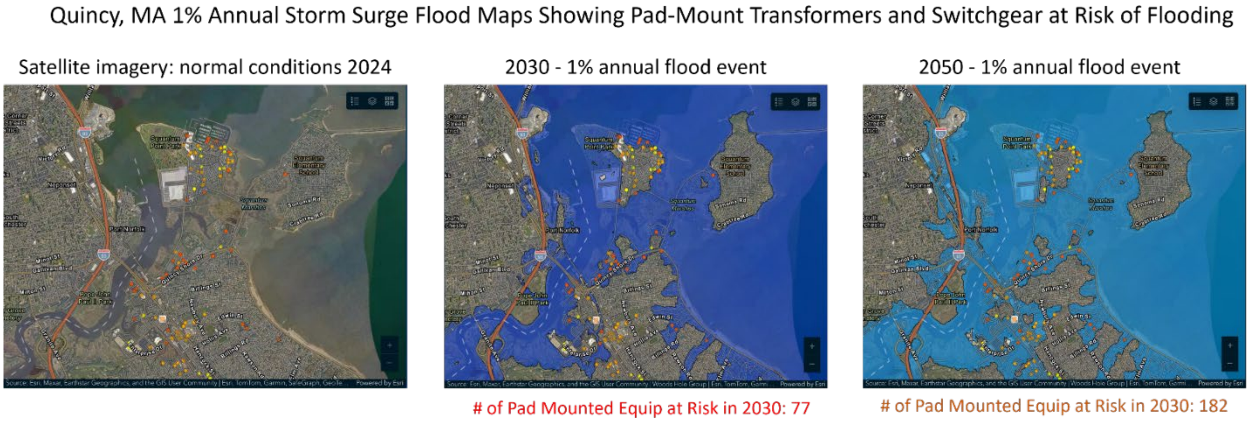


Figure 23: Example from WICT of National Grid's pad-mounted equipment flood risks in a coastal section of Quincy, MA. In this area, 77 underground pad-mount equipment sites are at risk of a 1% annual probability flood event in 2030 and an additional 105 sites are at risk in 2050, for a total of 182 sites.

To address coastal storm impacts on pad-mounted equipment, the primary mitigation action under consideration is to apply the coastal design storm hardening standard further inland which specifies the use of specific materials and equipment types that are more resistant to corrosion and the requirement to increase the elevation of electric equipment (e.g., transformers and switches). Submersible designs are also being considered but they tend to not be as cost-effective or easy to maintain. National Grid will continue to study Massachusetts coastal flood projections to determine if these design standards need to be extended to additional coastal zones by using the WICT and other CZM and Office of Climate Science data.

Figure 24: Elevated pad-mounted equipment in Salisbury, MA

4.3.3.3 Distribution Poles

The WICT can also overlay overhead distribution poles with coastal flood risks, as seen in an example in Figure 25Figure below on the right. The image on the left shows today's dry land coverage and overhead distribution lines.

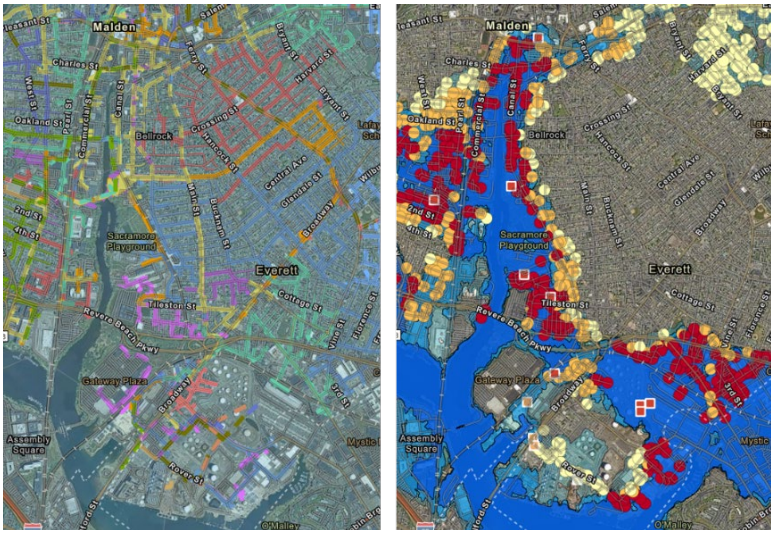
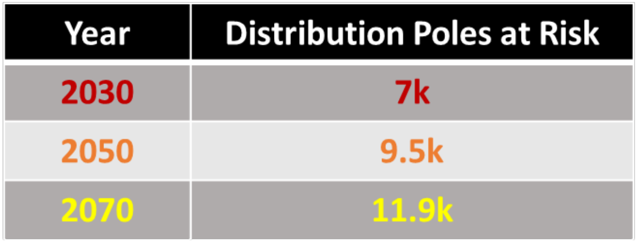


Figure 25: WICT map showing overhead distribution infrastructure and poles at risk of flooding. The red dots are poles that are at 1% annual risk of coastal flooding in 2030, Orange is 2050, and Yellow is 2070.

In total, current data suggests that a 1% annual probability coastal storm event would result in 7,000 distribution poles at risk of water flooding in 2030. In 2050 and 2070, an additional 2,500 and 2,400 poles are at risk, respectively, totaling approximately 11,600 flooded poles in a 1% storm event in 2070.

Table 4: Cumulative Distribution Poles at Risk from Flooding by Year



Year	Distribution Poles at Risk
2030	7k
2050	9.5k
2070	11.9k

1% annual probability – storm surge

Poles can be sensitive to water events like long-term floods that are slow to recede—or heavy and persistent precipitation—because the soil holding the pole in place can become unstable or soil erosion can occur. This long-duration soil saturation can reduce the pole's ability to withstand wind events which increases the risk of poles tilting or falling. Nearby trees are also sensitive to prolonged saturated soil, which can destabilize their roots and increase the risk of falling onto overhead equipment.

4.3.4 Coastal Flood Risk Rating

Similar to inland flooding, coastal flood risks vary from moderate for overhead and underground equipment to high risk for substations.

Table 5: Risk matrix for coastal flooding hazards

Climate Hazard	Electric Distribution Asset Category		
	Substation	Overhead Equipment	Underground and Pad-Mount Equipment
Coastal Flooding	H	M	M

4.4 Severe Weather

The following sub-sections review hazards related to changes in severe weather including snowstorms and cold weather, hurricanes, and high winds. Details are included on asset vulnerabilities related to severe weather in Massachusetts. The results of the risk assessment account for potential exposure and risks of electric distribution assets for the two main hazards of freeze/thaw and high winds.

4.4.1 Severe Weather Hazards

Severe weather hazards were reviewed for increasing intensity from forecasted climate change. The severe weather hazards analyzed are the following:

1. **Cold Weather Hazards**
    a) **Cold Weather:** Number of days per year when maximum daily temperatures are below 32°F (0°C).
    b) **Winter Compound Events/Snowstorms:** Number of days per year when both high winds and high precipitation are above the respective thresholds, maximum daily wind gusts above ~60

    mph, and precipitation over 1 inch in the same day.
    c) **Freeze Thaw:** Number of days per year when temperature cycles above and below freezing, maximum daily temperatures above 32°F (0°C), and minimum daily temperature below 32°F (0°C), on the same day.
2. **Hurricanes:** A type of storm called a tropical cyclone, which forms over tropical or subtropical waters with winds greater than 74mph.
3. **High Winds:** Wind gusts over 40 mph; extreme wind gusts are over 76 mph.

Although all the above-mentioned hazards were considered for Massachusetts in this CVA, the most significant risks to electric distribution infrastructure are from wind-related hazards, including those below the hurricane and extreme wind thresholds noted above. National Grid has experienced impacts from cold weather and freeze/thaw events, and those are also explored further in this section.

4.4.1.1 Snowstorms and cold-weather hazards

The National Oceanic and Atmospheric Administration's ("NOAA") National Centers for Environment Information tracks the Regional Snowfall Index ("RSI") using the Northeast Snowfall Impact Scale ("NESIS") which considers the area impacted, the amount of snow, and number of people in the path of the storm. For example, 'extreme' storms in the past have caused over 10 million power outages. Trends from the highest-impact snowstorms from 1956 – 2022 are shown below in Figure 26.[48]

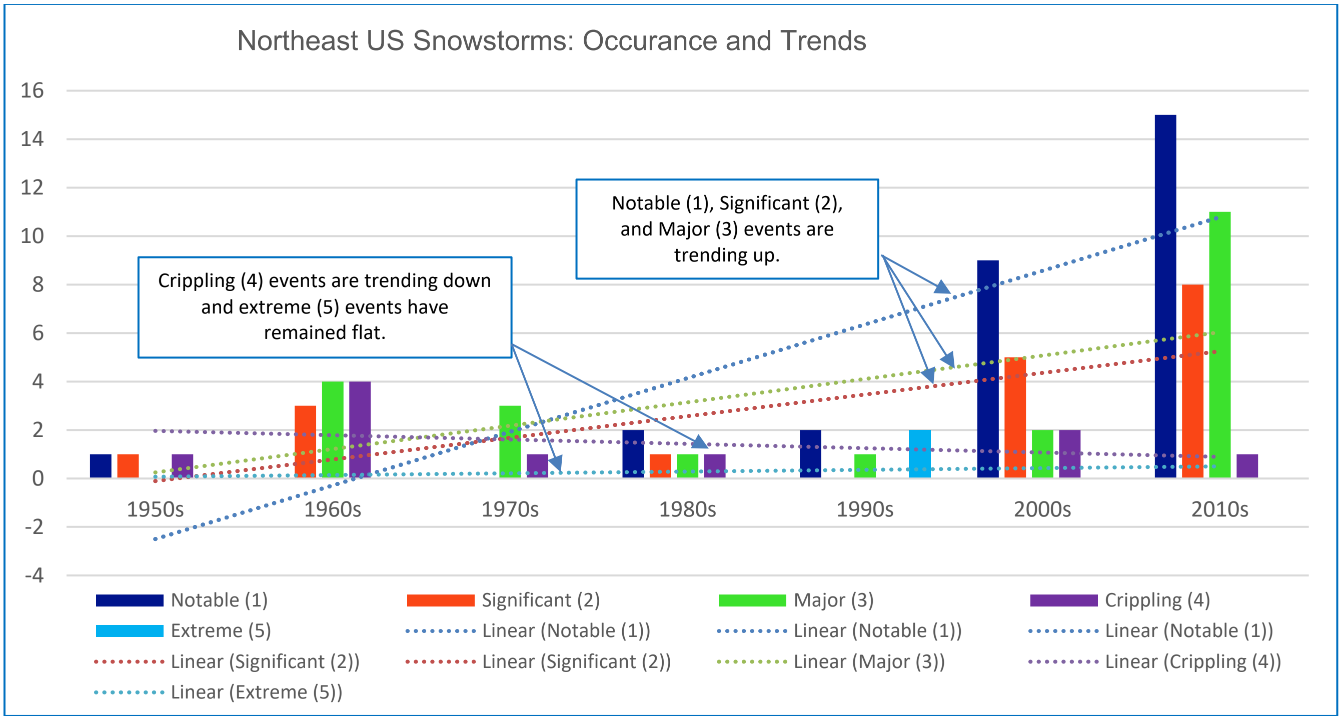


Figure 26: Northeast snowstorm historical events, dotted lines represent linear trends for each event type[49]

'Notable,' 'Significant' and 'Major' events have increased over the decades, and 'Crippling' events have declined. 'Extreme' events have mostly remained flat as only two events occurred in the 1990s.

According to leading climate scientists at the Intergovernmental Panel on Climate Change ("IPCC"), average temperatures will continue to increase globally, resulting in a declining risk for cold-weather hazards such as low-temperatures (days below 10°F [-12°C]), freeze/thaw cycles, and winter compound

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[48] The Northeast Snowfall Impact Scale (NESIS) | Regional Snowfall Index (RSI) | National Centers for Environmental Information (NCEI) (noaa.gov)

[49] Ibid

events. National Grid will remain vigilant of these hazards as they remain prominent even with declining risk. Increased winter precipitation is discussed in Section 4.2.

4.4.1.2 Hurricanes

According to NOAA and the U.S. Environmental Protection Agency, global oceans have been remarkably warmer than they have been historically, and the North Atlantic Basin has been experiencing record-high sea surface temperatures.[50,51] Hurricane severity is likely to increase because of high sea surface temperature, sea level rise, and atmospheric changes. These combined effects are likely to result in stronger (i.e., Category 3-5) hurricanes forming over the Atlantic, but the degree of intensity increase is uncertain. The frequency of hurricanes will still be driven by the oscillation between La Niña (increased hurricane activity) and El Niño (decreased hurricane activity) phases.

Since 1878, about six to seven hurricanes have formed in the North Atlantic each year and roughly two hurricanes make landfall in the US each year. Due to the low historic frequency of annual events, there is a small sample size, and it is more challenging for models to make accurate projections of hurricane activity, but many climatological and economic trends illustrate the positive correlation between increasing severe weather and hazardous impacts.

Figure 27 below illustrates tropical cyclone (hurricane) activity in the North Atlantic from 1949 to 2019, suggesting an increase in hurricane risk. It is important to reflect on historical trends to understand the directional change to expect in the northeast in addition to the impacts of climate change while also considering that the trajectory of hurricanes can be quite variable.

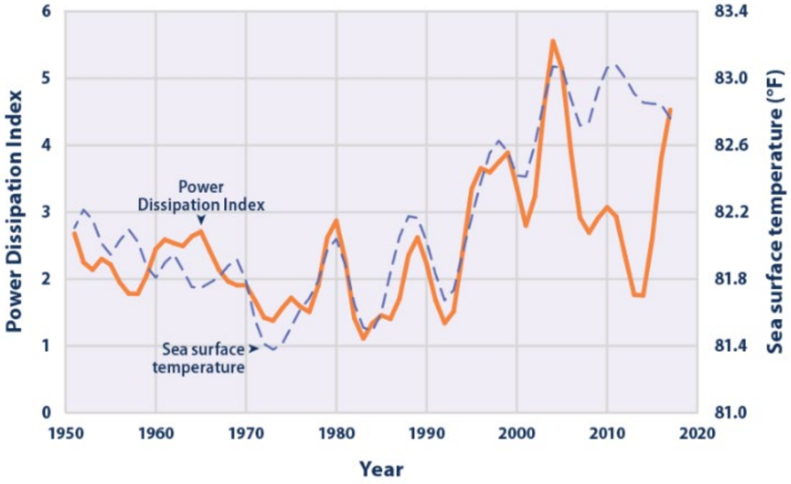

Figure 27: North Atlantic Tropical Cyclone Activity According to the Power Dissipation Index, 1949-2019[52]

A main impact of hurricanes is coastal and inland flooding. Asset vulnerabilities to flooding are covered in Sections 4.2 and 4.3. Another main impact of hurricanes is wind, and every hurricane in 2024 experienced increased wind speeds due to warmer ocean temperatures because of climate change.[53] High wind analysis is discussed in the following section and includes wind events from hurricanes, non-hurricane tropical cyclones, and non-storm related wind gusts.

4.4.1.3 High Wind

National Grid obtained hourly wind data using dynamically downscaled projections of wind speeds for the near future with the support of MIT. This analysis found only small attributable changes in mean wind

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[50] https://www.ncei.noaa.gov/access/monitoring/monthly-report/global/202413#ohc
[51] https://www.epa.gov/climate-indicators/climate-change-indicators-sea-surface-temperature
[52] Climate Change Indicators: Tropical Cyclone Activity | US EPA
[53] Human-caused ocean warming has intensified recent hurricanes, Daniel M Gilford et al 2024 Environ. Res.: Climate 3 045019

speeds and no significant changes in wind directions when comparing the near future (2025-2042) to historical time periods (2006-2020).[54] However, in certain regions, the magnitudes of the extreme wind speeds (defined as the 95th percentile) increase, especially at higher land elevations and along the coast. Many reports on climate change's impacts to wind focus on wind events related to increased storms, and at this time there are limited additional materials that isolate wind changes outside of these storm events.

4.4.2 Severe Weather and High Wind Asset Vulnerabilities

4.4.2.1 Cold Weather Vulnerabilities

Although cold weather hazards are projected to decline overall, there remains a risk that an extremely cold temperature event could occur. In general, distribution assets most vulnerable to cold-temperature-related hazards are those that are vulnerable to winter storms/compound events and freeze/thaw cycles. Porcelain and cement materials can be vulnerable to freeze/thaw cycles if they are not designed appropriately to withstand expanding moisture from freezing. A major risk of severe cold-weather events relates to fuel supply and electric generation, which are beyond the distribution infrastructure scope of this analysis but remain highly concerning when considering a predominantly electric-heat-dependent future. Even though cold-weather hazards may decline, ensuring the Company's customers stay warm in the winter is one of the Company's utmost concerns.

4.4.2.2 Hurricane Vulnerabilities

Today, the larger risk to electric assets from hurricanes is high winds, as this is a significant threat to distribution assets. In the future, because of the expanding tropics (warming of mid-latitudes), the latitude at which a hurricane is the strongest is expected to move northerly, and therefore the risk of experiencing more intense wind speeds in the Northeast is growing. High winds from storms can directly damage overhead lines, but the greater risk is likely from vegetation and its impact on overhead distribution infrastructure as it contacts lines, structures, or nearby equipment. Overhead distribution lines have the highest vulnerability to extreme wind from storm events which can cause line damage, including downed poles, broken conductors, and sagging lines.

4.4.2.3 High Wind Vulnerabilities

Overhead distribution infrastructure can show vulnerability during periods of long sustained winds and extreme wind gusts. Distribution poles—and the equipment and devices attached to distribution poles—should be built and secured to withstand their regional expected wind speeds per design standards.[55] In Massachusetts, the greatest risk to these assets in wind events is from distribution lines' proximity to vegetation, and with higher average annual temperatures and longer growing seasons, an increase of vegetation growth into conductors could occur between pruning cycles. With an estimated tree population density of 165 trees per mile,[56] the Company's electric system across the Commonwealth is vulnerable to harsh conditions during high wind events, which are becoming both more common and more severe in some locations due to climate change. These events can cause substantial damage to the system and cause interruptions that can last for multiple days.

To address these vegetation issues, the Company has moved away from a time-based pruning cycle to a condition-based maintenance pruning program. The Company is using satellite imagery to detect changes in growth patterns and calculate clearances between vegetation and power lines along with data analytics to determine which circuits should be pruned each year. Additionally, the Company's Enhanced Vegetation Management ("EVM") Program seeks to increase clearances between vegetation and power lines, and in some cases, remove all branches that hang over the wires to prevent outages during weather events.

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

[55] The National Electrical Safety Code® (NESC®) Section 25 contains details and requirements related to ensuring conductor and pole construction is designed to withstand each location's expected wind and icing loads.

[56] National Grid, "Change in the Utility Forest: An assessment of changes in tree conditions over ten years," Available externally in the near future.

The Company's design standards for distribution poles are prudently fit for purpose based on today's needs. However, as forecasted storms and wind speeds increase, these standards will need to adapt to ensure the system is hardened and more resilient to this hazard.

4.4.3 Severe Weather Exposure and Risk Assessment

The assessments relevant to National Grid and Severe Weather are below. In this CVA, wind is the focus of severe weather risks. Cold-temperature hazards, including freeze/thaw events and compound winter events, either had low data confidence or were determined to not increase overall asset risks due to climate change.

4.4.3.1 Cold-weather related risk assessment

The CCRT was used to determine the exposure and risk from winter compound/snowstorm and freeze/thaw events. Climate science regarding the Winter Compound Event hazard shows a high uncertainty level but it was still reviewed as part of this assessment. The CCRT indicated there is minimal to no change in risk for the modeled assets. The Winter Compound Event hazard has a high uncertainty level, and this climate hazard will continue to be monitored. Freeze/Thaw is defined as the number of days per year when temperature cycles above and below freezing on the same day. Maximum daily temperatures above 32°F (0°C) and minimum daily temperature below 32°F (0°C) on the same day, and results from the risk analysis in the CCRT are shown in the following figures.

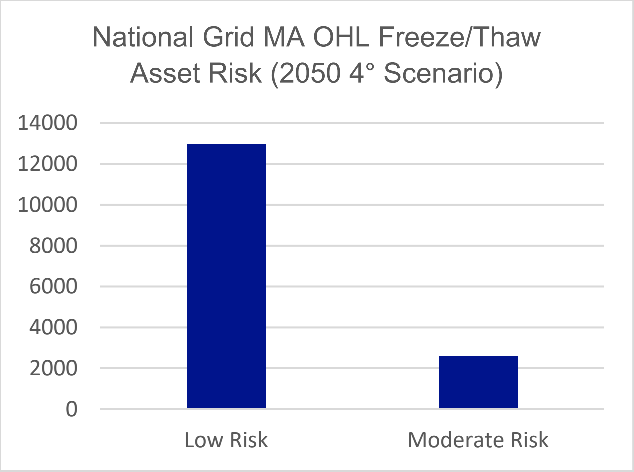

Figure 25: Distribution Overhead Freeze/Thaw Cycle (2050, 4° Scenario)

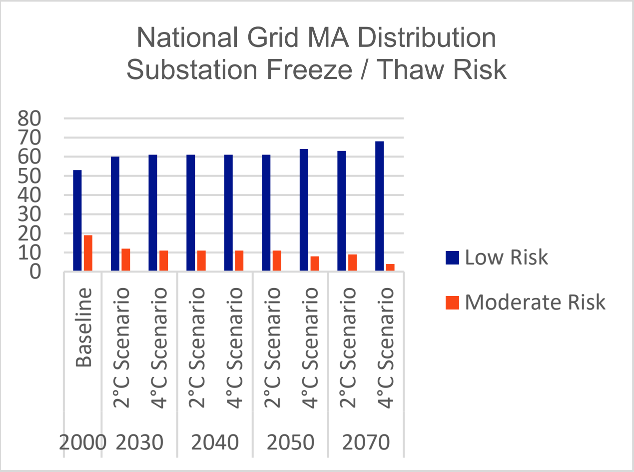

Figure 29: Distribution Substation Freeze/Thaw Risk, 2030-2070, 2° and 4° Scenario

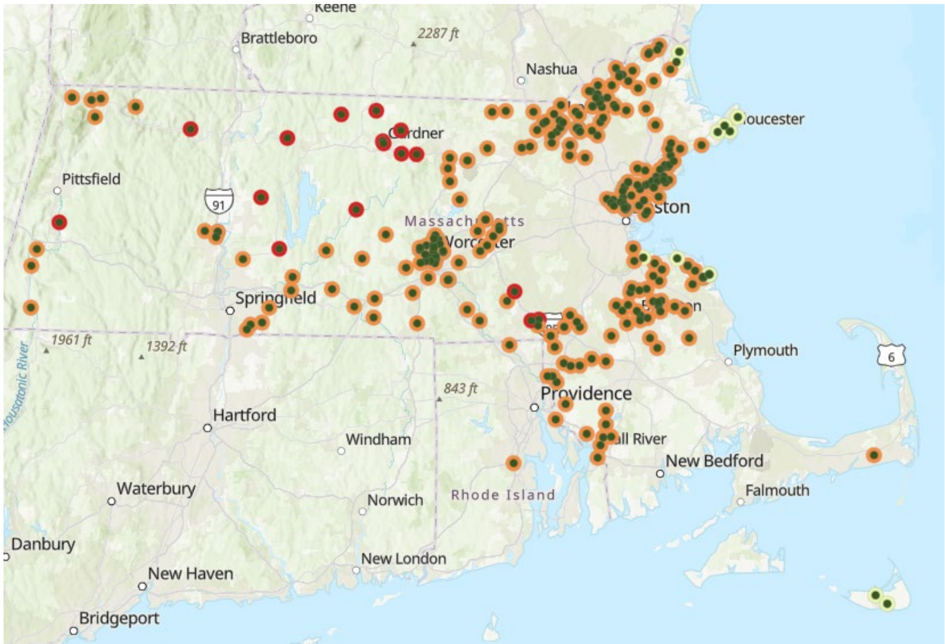

Figure 30: Export from CCRT of freeze/thaw exposure risk levels of distribution substations in Massachusetts in 2050 in the 4° scenario. Red is moderate risk and orange is low risk. Yellow indicates a lack of current data.

The ‘Freeze/Thaw Cycle’ climate hazard risk either declined or was not applicable for all assets modeled in the CCRT. Even so, freeze/thaw events are a concern for the electric overhead distribution system. To mitigate this risk, National Grid can replace more vulnerable ceramic equipment with more resilient materials such as glass; replacements have already occurred on many at-risk assets. This hazard is not expected to increase from climate change and is predominantly classified as lower risk.

4.4.3.2 Wind related risk assessment

Projected exposure and risks from wind were analyzed using the WICT to determine National Grid’s distribution asset exposure based on MIT’s climate change model’s projected outcomes. Below is an output from the WICT showing 1-in-10-year (10% annual probability of occurrence) wind speeds over 75mph. These areas include parts of the Boston Harbor, North and South Shore, Eastern Inland, and Nantucket. Similar to radial icing concerns, the Western border of the state is showing the highest risk of exposure and contains areas that may experience wind speeds over 100mph.

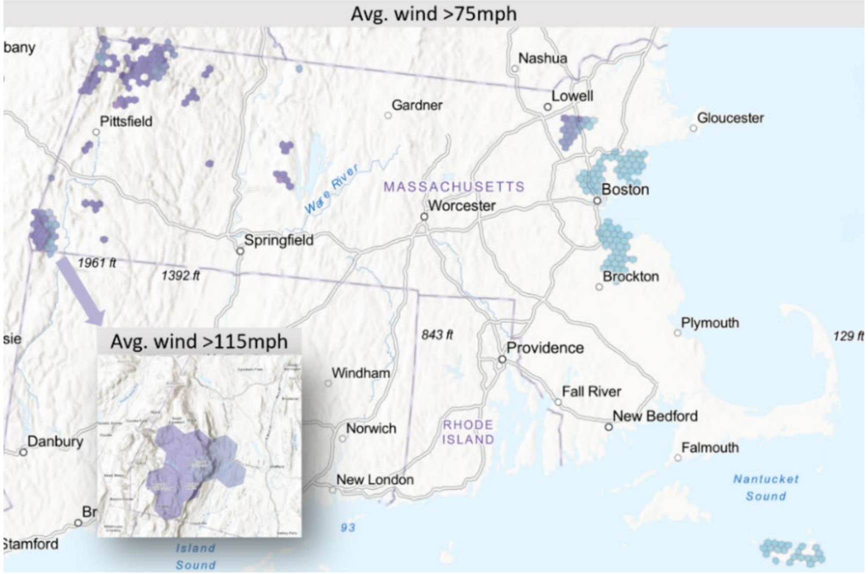

Figure 31: 10% annual occurrence of wind speeds over 75mph per the MIT study and National Grid analysis. The model predicts that the southwestern area of the state could experience the highest average wind speeds between now and 2041.

Current overhead distribution asset standards per IEEE NESC 250C[57] anticipate wind speeds of 90 to 110 mph in different sections of the state for MRI 100-yr wind gusts, and poles greater than 60ft are now built to withstand wind gusts up to 120mph. Distribution lines are designed for 0.5 inches of radial icing concurrent with a 40mph wind. The impact of increasing wind speed and radial icing is under review and acceptance of this standard would likely result in taller, higher-class (stronger) poles.

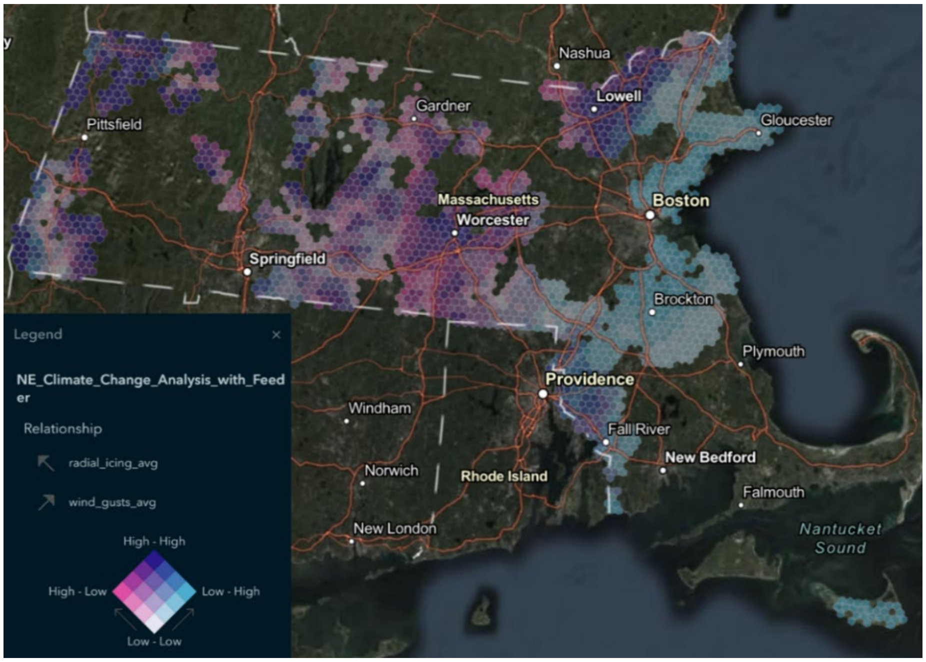

Figure 32: Output from WICT for areas at risk of wind speeds over 40mph through 2041, 10% annual probability.

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[57] IEEE Standards Association, 2023 National Electrical Safety Code® (NESC®)

As a member of EPRI's Climate READi,[58] the Company knows that National Grid is aligned with other utilities in deploying hardened overhead designs in specific regions that could experience extreme wind impacts. These improvements include using stronger poles, improving pole-top designs, and implementing new pole-setting strategies, such as setting poles deeper or with backfills to support the higher forces experienced at the pole top. The Company is also adding break-away conductors and break-away spacer cable brackets. As discussed in Section 4.4.2, high winds and icing events bring along the larger risk of tree contact with the overhead distribution system, and tree-related damages cause most of the overhead distribution system impacts during these events. Optimized vegetation management activities have proven to positively impact the reliability of the electric network. Tree wire, anti-cascading structures, and Fault Location Isolation and Service Restoration (FLISR) schemes can further minimize the impact when tree contact does occur.

Targeted undergrounding eliminates the risk of vegetation contact entirely. Although wide scale undergrounding may carry higher costs and it is not always feasible, targeted undergrounding can protect system performance during a significant wind event, and the improved reliability benefit and customer long-term value may outweigh the higher upfront cost. Distribution undergrounding opportunities are often best suited in congested areas of the system, near substations, and in highly populated areas. Underground infrastructure near substations improves the reliability and resilience for the highest number of customers compared to undergrounding portions of circuits further from substations. Additionally, as this analysis suggests, undergrounding solutions in areas that have projected high exposure to high winds may be considered in resiliency planning.

4.4.4 Severe Weather Risk Rating

Although the vulnerability of cold weather events (such as freeze/thaw) to overhead equipment is moderate, the exposure is low in most regions of the state and is expected to continue to decrease as the climate becomes warmer. These factors result in a low-risk ranking for cold-weather-related hazards. Wind events, on the other hand, may increase with increasing hurricanes and other storms, especially at the coast and the western mountain regions of the state. These high-wind events can cause major damage to the overhead distribution infrastructure and surrounding vegetation. For these reasons, high wind and severe wind events are noted as a high risk.

Table 6: Severe weather and wind risk, including cold-weather-related hazards. Since current climate change projections anticipate overall reductions in cold-weather events, these risks are all rated low for future increased impacts and this row is omitted in the final Risk Matrix.

Climate Hazard	Electric Distribution Asset Category		
	Substation	Overhead Equipment	Underground and Pad-Mount Equipment
Cold Weather Events	L	L	L
High Wind and Severe Events	L	H	L

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[58] EPRI Climate READi, https://www.epri.com/research/sectors/readi

Wildfire and Related Hazards

Wildfire

Historically the probability of significant wildfires in the Commonwealth has been low, but with increasing extreme events across the US, it is an emerging risk under review. In 2024, National Grid's Massachusetts service territory experienced twice as many Red Flag Warning[59] days compared to 2023 (impacted by drought conditions), and further trends of this hazard have not yet been analyzed. While precipitation is expected to increase in future years, the precipitation is expected to fall more intensely during shorter periods, meaning there will likely be longer periods of seasonal drought. The Company is reviewing this risk and has developed a wildfire response plan (which was utilized for the 2024 fire season, to include several exercises with state and local fire officials). National Grid will continue risk assessments, mitigation efforts, and collaborations with other utilities and state and local agencies to learn best practices and better understand appropriate mitigation plans regarding wildfires. Fire response is already part of the Company's Emergency Response Plans (ERPs), and ERPs include training, exercises, communication strategies, and external engagements such as those with local fire departments.

Wildfire risk mitigation considers best practices from peer utilities, including other northeast utilities, and those with more wildfire experience, such as utilities in California. Vegetation management programs, inspection and maintenance programs, and storm hardening programs (e.g., tree wire and targeted undergrounding) are significant components of published leading wildfire mitigation plans to help mitigate wildfire risk. The Company will continue to review these best practices and will implement mitigation measures appropriate for the geographical risk level.

Figure 33: Wildfires and Electrical Infrastructure[60]

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[59] The National Weather Service issues a Red Flag Warning when fire conditions are ongoing or expected to occur shortly (https://www.weather.gov/safety/wildfire-ww)

[60] https://www.energy.gov/gdo/articles/protecting-our-electric-grid-wildfire

Drought

According to ResilientMass, droughts are expected to become more frequent in Massachusetts with climate change.[61] Prolonged high air temperatures and lack of precipitation can result in drought conditions and soil baking.[62] Dry conditions risk generating floods at lower precipitation levels than in normal soil conditions. These two effects each have the potential to increase soil instability and erosion, which could create structure instability and uncover underground cables. Rain acts as a natural cleaning method for above-ground equipment and long periods of no rain can increase dirt, dust, and debris accumulation on equipment which can degrade some materials with abrasion and insulation deficiencies.[63] Drought can also impact the grounding performance of electrical systems which has implications for lightning performance and wildfire risks. In 2022, Massachusetts experienced significant and critical drought in every region of the state. That same year the state witnessed about twice as many wildfires in August compared to the monthly average.[64] A similar trend was witnessed in October of 2024 when weather conditions resulted in extremely high off-season wildfire occurrences with the entire state at risk.[64]

Lightning

Current data on lightning forecasting and climate change is often provided with low-confidence disclaimers. This hazard is difficult to predict, but the consequences of the hazard are better known. Direct or indirect lightning strikes can result in voltage surges, which may lead to circuit outages and/or damage to electrical equipment such as distribution cables, distribution transformers, and substation power transformers. Lightning strikes can also be an ignition source for fires leading to property and equipment damage and the potential for fire-related injuries and fatalities. Along with direct equipment damage and potential failure, lightning can also cause vegetation fires. If these fires occur in dry or drought-like conditions, lightning brings with it a risk of uncontained wildfires. In the past decade, lightning has ranked among the top ten causes of outages in National Grid's distribution system, contributing to nearly 5,000 outages. Lightning is one of the largest causes of wildfires on a global basis. To mitigate these impacts, the electric grid is equipped with devices such as lightning arrestors and static and ground wires as well as standards to ensure the proper grounding of equipment.

5.0 Summary of Climate Vulnerability Assessment

5.1 Asset Risk Matrix

Below is a table that summarizes the climate vulnerability assessments described in Section 4. Some climate change-related risks are currently estimated to be low from current analyses. These include either hazards that will not likely increase from the future projected climate changes or they may be hazards that do not suggest increased vulnerability to distribution assets. They still may be a risk to electric infrastructure, but their specific climate change-related risks are either minimal or unknown. Table 7 displays a simplified risk matrix to summarize the expected likelihood of increased risks from climate change on three major distribution asset classes while considering the severity and prevalence of hazards. For more details on how the results in this table were determined, refer to the risk result sections in Section 4.

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[61] Commonwealth of Massachusetts, 2023 ResilientMass Plan: 2023 MA State Hazard Mitigation and Climate Adaptation Plan, Appendix 5

[62] Evaporation of moisture from climate change's rising temperatures can increase drought severity. Anthropogenic warming has ushered in an era of temperature-dominated droughts in the western United States | Science Advances, 2024.

[63] EPRI's Technical Report Climate Vulnerability Considerations for the Power Sector: Transmission and Distribution Infrastructure, 2024

[64] Commonwealth of Massachusetts Department of Fire Services, Massachusetts Wildland Fires Spiked 1,200% in October | Mass.gov, 2024

Table 7: Distribution Asset Climate Change Related Risk Matrix: Red (R) represents high risk, yellow (M) represents moderate risk, and green (L) represents lower risk.

National Grid’s MA distribution assets climate change risk estimates for 2050

Climate Hazards	Electric Distribution Assets		
	Substation	Overhead Equipment	Underground & Pad-mount Equipment
Rising Temperatures	M	M	L
Changes in Precipitation	H	M	M
Coastal Flooding	H	M	M
Severe (and wind) Events	L	H	L

As illustrated in Table 7, current analyses show the highest risk of infrastructure impacts may come from substation flooding (both inland and coastal) and overhead infrastructure high wind events. Flooding hazards also show moderate risks to non-substation distribution infrastructure, especially in some regions by the coastline and rivers. Rising temperatures have moderate risks of impacting substations and overhead equipment, especially regarding oil-filled equipment during periods of sustained high temperatures and increased loads.

5.2 Summary and Next Steps

This CVA advances National Grid’s understanding of the potential technical risks posed by climate change to the Company’s electrical infrastructure and provides examples of measures to enhance system resilience to continue providing safe and reliable electric service to customers even in the face of worsening climate conditions. National Grid evaluated the potential impacts of climate change hazards outlined in the ResilientMass Plan, such as high temperatures, changes in precipitation, coastal flooding, and severe weather. By evaluating the vulnerabilities of the Company’s assets to these future climate threats, National Grid can develop effective resilience strategies, prioritize actions to harden infrastructure, adapt to changing environmental conditions, and minimize customer disruptions.

As previously stated, this CVA is a stepping-stone in the ongoing improvement of reliability and resiliency activities. Ultimately, the CVA will transition to the development of a comprehensive climate vulnerability and resilience plan, in accordance with MA legislative and regulatory requirements. Moving forward, it is important to involve a diverse range of subject matter experts, both internally and externally, in further analysis. By collaborating with experts from various fields such as climate science, engineering, construction, and risk assessment, the Company can gain additional insights into the vulnerabilities and potential solutions, contributing to the robustness of National Grid’s assessments. Another important consideration in National Grid’s upcoming analysis will be the potential climate change risks to National Grid’s electric infrastructure in Environmental Justice Communities (“EJCs”) and recommended mitigation measures so that resiliency planning is equitable across our service territory.

In conclusion, this climate vulnerability assessment is one component of National Grid’s resiliency planning and provides the Company with a technical foundation for prioritizing actions and strengthening infrastructure to mitigate the risks of climate change to our electric system. From here, the Company will begin developing a comprehensive climate vulnerability and resilience plan to continue to fortify the electrical grid, reduce vulnerabilities, and provide safe, reliable and resilient electric service to the communities we serve.