Climate Vulnerability Assessment (CVA)

March 2026

EVERSOURCE



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Introduction

As the largest energy delivery company in New England, Eversource recognizes the urgent need to mitigate climate risks by executing on greenhouse gas (GHG) reduction targets, adapting our infrastructure and operations to an increasingly unpredictable environmental landscape and supporting our region's clean energy goals.

Climate change is a defining challenge of the 21st century, affecting ecosystems, infrastructure and communities worldwide. Rising temperatures, shifting weather patterns and the increased frequency of extreme weather events have underscored the urgency for comprehensive adaptation and mitigation efforts.

For Eversource, these changing conditions require a robust, multilayered approach to both mitigate our environmental footprint and adapt infrastructure to withstand the stresses of a less predictable climate. Eversource is committed to addressing these challenges proactively, investing in resiliency measures that enhance the reliability of energy services while supporting community well-being.

The impacts of climate change on the New England region are increasingly apparent and affect Eversource's service area of Connecticut, Massachusetts and New Hampshire in distinct ways. Although each state faces unique climate-related challenges, they share common threats that demand a unified and regionally informed approach.

While we have already made strong progress reducing our operational (Scope 1 and 2) greenhouse gas (GHG) emissions by nearly 30% since 2018, we expanded our targets in 2025 to reduce these emissions by 45% by 2035.

We are also looking longer term with the introduction of a target to achieve Net Zero emissions by 2050 which includes Scope 1 and 2 as well as the Scope 3 emissions associated with our customers' energy use - the most significant and challenging portion of our overall GHG footprint.

We empower our customers to make informed decisions around energy consumption and take part in the clean energy transition by reducing their own carbon footprints through energy efficiency measures and the interconnection of renewable generation.

Our climate adaptation and mitigation strategies are closely aligned with a complex regulatory landscape, which includes federal, state and local policies. The evolving nature of climate policy in the United States means that utilities like Eversource must remain flexible and proactive, anticipating changes in policies that will impact their operations and environmental obligations. This is especially true in the New England region, where we operate.

The climate challenges facing New England are diverse and interconnected, requiring a sophisticated and adaptable response from Eversource. By addressing both broad regional impacts and state-specific needs, Eversource can implement climate adaptation and mitigation strategies that are comprehensive, effective and aligned with regulatory

expectations. Through a clear understanding of climate risks, we are well-positioned to anticipate future challenges, protect our infrastructure, and continue delivering safe and reliable energy to our customers in the face of an uncertain climate future, while collaborating with regulators to balance affordability with the necessary investments for a sustainable energy transition.

Executive Summary

Eversource completed its tri-state Climate Vulnerability Assessment (CVA) in early 2025. This report includes the projections of six (6) climate hazards, relevant to the Company's territory, namely:

1) Sea Level Rise
2) Storm Surge
3) Precipitation
4) Rising Temperatures
5) Drought and
6) Wind.

The Company also assessed temperature-driven increased demand as part of its CVA. The Company's study looked at the projected values of these hazards in 2030, 2050 and 2080 under multiple scenarios corresponding to varying levels of greenhouse gas emissions and associated global temperature rise. The Company utilized multiple sources for climate futures where available and cross referenced these projections with historical data.

This report also quantifies the projected impact of each hazard to Company assets. Specifically, in this report, the Company devised novel spatial analytics to quantify the asset types and population of assets impacted by each climate hazard, consistent with least-regrets planning methods so as to balance performance and affordability. The steps include a qualitative analysis of which asset types are impacted by each hazard (for example, wind does not impact substation assets but impacts overhead conductors and poles). Based on the projected values of the climate hazard at each asset's location, the Company can determine the level of the need to mitigate and differentiates based on vulnerability and adaptive capacity as well as acute versus chronic hazards. Further, this report includes sensitivity analyses on the impacted assets across multiple scenarios.

The sensitivity analyses results on impacted assets per climate hazard show a wide range of impacted assets, and therefore it indicates that in order to ensure least regrets planning for resilience and climate adaptation, climate projections should be high-confidence, high-fidelity.

Current State of the Distribution System

The CL&P service territory is shown in Figure 1 below. The total service area covers 4,400 square miles, or 87 percent of the total area in Connecticut. Situated within this service territory are 149 communities including large urban centers such as Hartford, Stamford and Waterbury; suburban settings surrounding these cities; and rural settings located throughout the state.

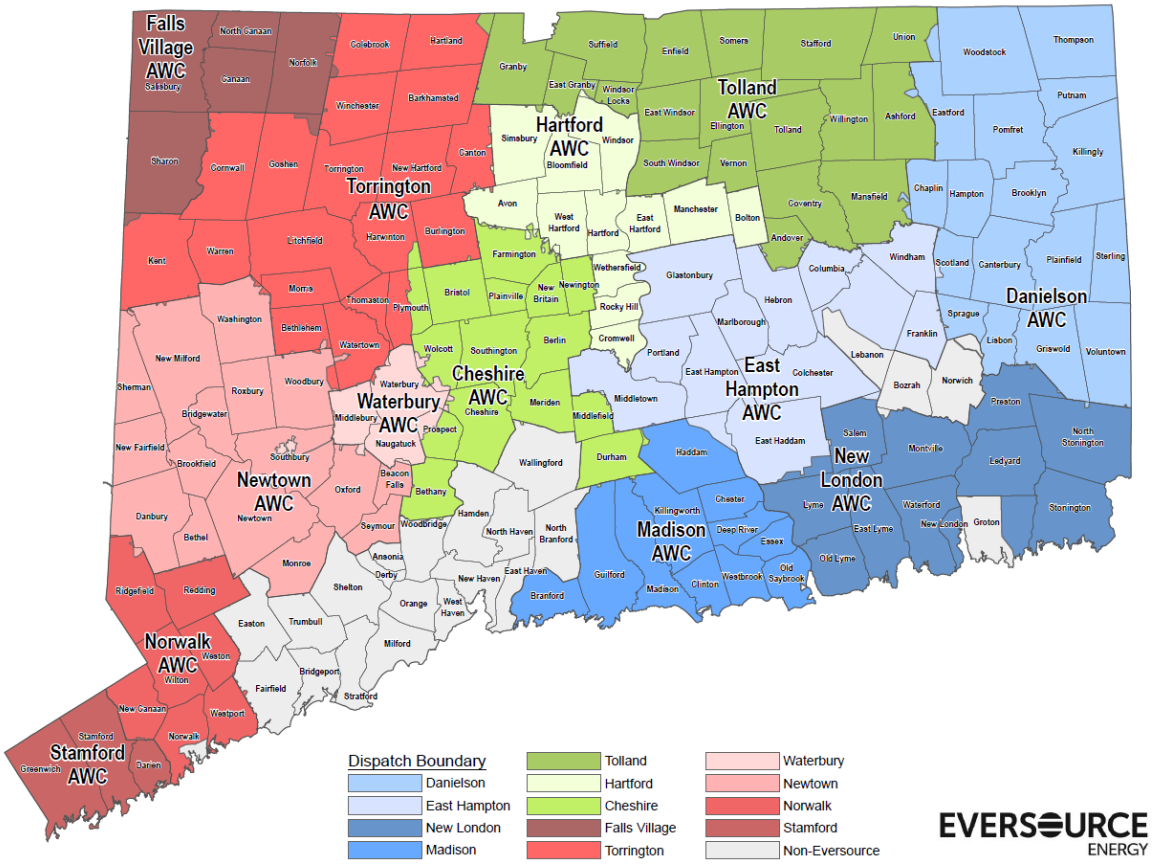


Figure 1. Service territory map

The CL&P service territory includes heavily treed areas, shoreline areas, and hilly terrain. Weather conditions can be severe and, from time to time, include ice and snowstorms, heavy winds, hurricanes, thunderstorms, flooding and occasional tornadoes.

CL&P's electric transmission system consists of approximately 1,678 circuit miles of overhead transmission and 143.7 miles of underground transmission. The Company has 22 transmission substations, 100 distribution substations supplied from its transmission system and 57 substations supplied from its distribution system.

CL&P's distribution system consists of approximately 16,700 circuit miles of overhead primary construction and 7,130 circuit miles of underground primary construction, including both direct-buried and underground duct and manhole primary construction. Primary distribution voltages range from 4.16kV to 34.5kV with the majority of circuits operated at 4.8kV, 13.2kV, 13.8kV and 23kV. The Company uses approximately 294,777 distribution transformers to supply its customers.

CL&P's electric system serves approximately 1.3 million customers and had a 2025 coincident peak load of 4,966 MW. Although it is possible that abnormal population or customer-class growth in specific areas could challenge the capacity of the distribution system and negatively affect reliability, the Company does not anticipate such conditions to develop in 2026. The Company has developed a number of distribution system load-relief projects planned for completion prior to the 2026 summer load peak.

CL&P's service territory is organized into three Divisions, with 12 Area Work Centers ("AWC") and one Electric Field Organization ("EFO") satellite work center,

- Central Division AWCs:
  - Cheshire
  - Hartford
  - Tolland
- Eastern Division AWCs:
  - Danielson
  - East Hampton
  - Madison
  - New London
- Western Division AWCs:
  - Newtown
  - Norwalk
  - Stamford
  - Torrington
  - Waterbury

Climate Vulnerability Assessment (CVA)

In late 2022, Eversource commenced its first tri-state climate vulnerability assessment (CVA). The study was set up in three stages: (i) climate change assessment (climate hazard projections), (ii) engineering risk assessment focuses on the qualitative risk assessment by asset type, and (iii) optimal climate adaptation plan with mitigations for specific assets. This report tackles stages (i) and (ii).

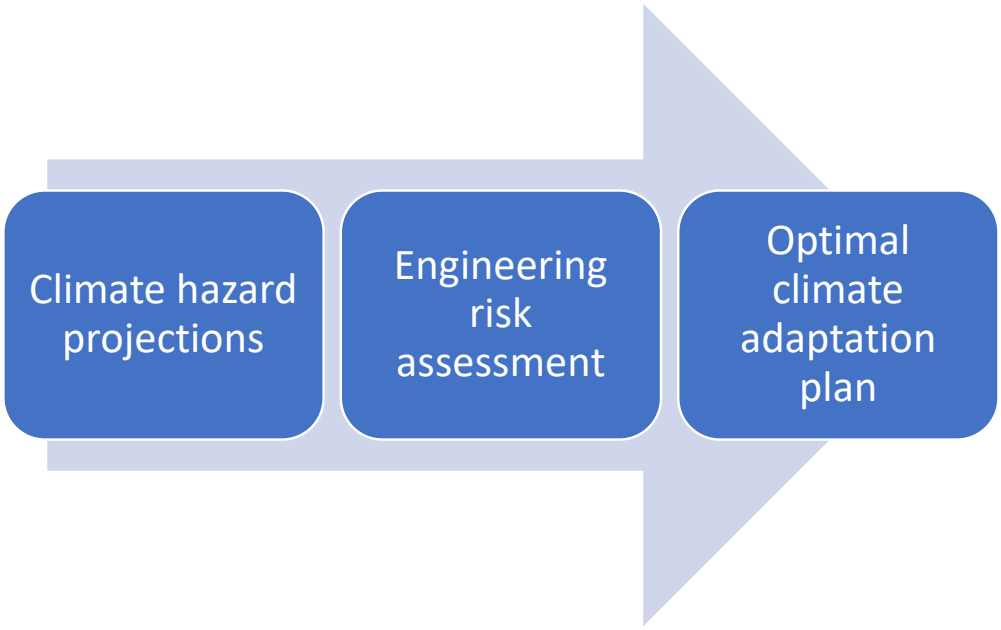


Figure 2. Phases of the Climate Vulnerability Assessment (CVA)

In 2023, the climate change assessment was completed with projections of various climate hazards relevant to the New England area. We are currently utilizing the results of this study to determine whether our plans, operations and standards may need to be updated. This calculated approach to system planning is necessary to enhance our ability to maintain a safe, reliable and resilient grid in the face of climate change.

The climate vulnerability study used best available global climate change projections that were then downscaled into a 6km-by-6km grid. This downscaling is critical to enable the association of projections over a certain threshold and their impact on assets. The projections can go out to 2080 with intermediate steps in 2030 and 2050.

The primary climate hazards that were studied are six:

1) Temperature
2) Drought
3) Precipitation

4) Wind
5) Sea level rise
6) Storm surge

Temperature-driven demand increase was also examined.

Each hazard may require multiple variables to be squarely described and characterized. The table below shows the variables whose projections describe plausible futures for the aforementioned six hazards.

Table 1. List of studied climate hazards and variables used to quantify each studied climate hazard

Hazard	Climate Variables
Extreme Temperature	1. Annual 50th, 90th and 95th percentile daily maximum temperature 2. Annual 5th, 10th, 50th, 90th and 95th percentile daily average temperature 3. Number of days above 90th and 95th percentile daily maximum temperature 4. Number of days above 90th and 95th percentile daily average temperature 5. Frequency of two and three consecutive day heat waves with daily maximum temperature over 90th and 95th percentiles 6. Frequency of two and three consecutive day heat waves with daily average temperature over 90th and 95th percentiles 7. Annual longest heat wave duration over 95th percentile daily maximum temperature 8. Annual longest heat wave duration over 95th percentile daily average temperature 9. Number of days below 5th and 10th percentile daily minimum temperature 10. Annual warmest daily maximum temperature 11. Annual coldest daily minimum temperature
Energy Demand	12. Proxy for May-September Weighted Temperature-Humidity Index (WTHI) 13. October-April Heating Degree Days 14. May-September Cooling Degree Days

Heavy Precipitation	15. Annual maximum 1- and 5-day precipitation 16. Days per year with precipitation exceeding 1, 2, and 3 inches
Drought	17. Annual maximum consecutive dry days
Sea Level Rise	18. Local sea level rise projections under low and high scenarios 19. Sea level rise flooding depth and extent under low and high scenarios
Storm surge	20. Category 1, 2, and 3 hurricane storm surge depth and extent
Wind	21. Days exceeding the 95th percentile daily average windspeed 22. Average annual windspeed

Global Climate Science Models

Global climate change models are complex mathematical representations of the Earth's climate system based on fundamental scientific principles. They are designed to capture the dynamics and interactions of the main components of the climate system: atmosphere, oceans, land surface and vegetation, sea ice and land ice[1].

It is important to note that all climate models, and all of the hazard and variable values that are used in this study are projections and not predictions or forecasts. Mathematically, this represents the fact that global climate change models show what could happen in the future and not necessarily what will happen in the future.

These climate models are developed under common sets for assumptions. These assumption sets or trajectories or scenarios are called Shared Socioeconomic Pathways (SSP). Since anthropogenic greenhouse gases are the primary cause of recent global warming, SSPs represent scenarios of projected socioeconomic and technological changes and are used to develop emission scenarios. Two climate change scenarios were used for the forecasts; the Shared Socioeconomic Pathways (SPP) 2-4.5 and SSP5-8.5. The former assumes that at a federal level GHG emissions stay at current levels until 2050 and that start to reduce, but not reaching net zero by 2100. The former (SSP5-8.5) assumes GHG emissions keep increasing and triple by 2075.

The following figure shows how global temperature rise scenarios relate to the aforementioned SSPs. In 2050, SSP2-4.5 corresponds to a 2°C global temperature rise, while SSP5-8.5 is closer to 2.5°C. By 2080, the range of the two SSPs widens; SSP2-4.5 is related to 2.5°C of global temperature rise while SSP5-8.5 is closer to 4°C of global temperature rise.

[1] https://www.agci.org/projects/climate-portal-guide/additional-information

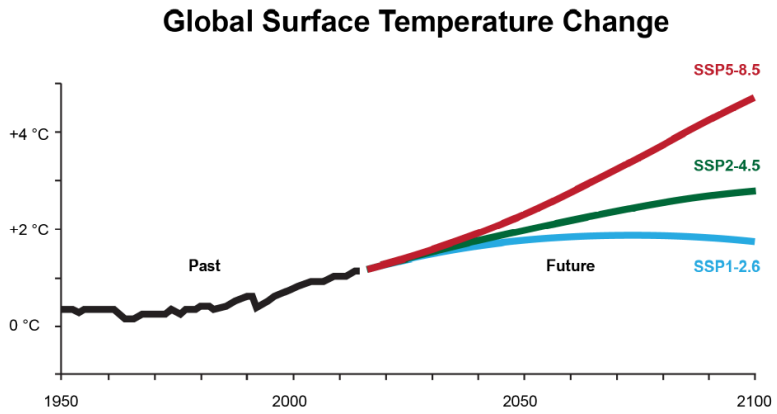


Figure 3. SSP relationship to global temperature rise across time[2].

The sea level rise and global temperature change are related through complex relationships, although sea level rise models are presented as distinct from the projections under SSP2-4.5 and SSP5-8.5. Per NOAA, 2 feet of sea level rise is increasingly likely between 2020 and 2100 if global temperature rise is under 3 degrees Celsius.

Therefore, in this study, a 2 feet sea level rise scenario is related to 2050 and a 3 feet sea level rise scenario is related to 2080. In NOAA's Sea Level Rise Viewer, the coarse sea level rise scenario refers to feet above Mean Higher High Water (which is the average of the higher high water height of each tidal day).

There can be various climate models developed under the same SSP and therefore, percentiles can be calculated for each SSP. In our study, projections use a common set of 23 models under SSP2-4.5 and SSP5-8.5. Our study includes calculation of 10th, 25th, 50th, 75th and 90th percentiles for each SPP scenario and each variable. Mathematically, 90th percentile represents the right tail of the probability distributions, where 90% of the samples have a lower value. The 90th percentile of the SSP5-8.5 is highlighted in the upcoming results, as it represents a worst case or a perceived ceiling of the projections. The results also highlight the 90th percentile of SPP2-4.5, as a more middle-of-the-way scenario to contrast with that worst case. The 50th percentile represents a value that is higher than 50% of the samples.

[2] https://climatedata.ca/resource/understanding-shared-socio-economic-pathways-ssps/

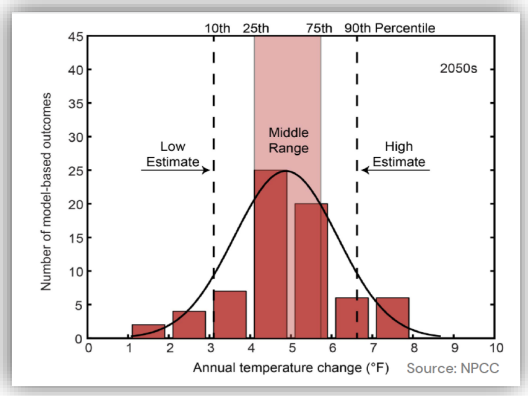


Figure 4. Percentiles of climate change modeling.

The results that follow in this document focus on the year 2050 as a best-case look-ahead horizon, that gives the utility enough time to act and is not that far into the future where confidence in the projections is reduced.

The study employs statistical downscaling, called LOCA2, to create more granular projections at the 6km-by-6km scale. Statistical downscaling leverages coarse global scale climate models with observed weather data of higher resolution to create high resolution projections, assuming that the present-day relationship between local variables and large-scale features will also hold in the projected future climate[3].

The existing LOCA2 does not directly address all variables that were included in our study as potential relevant hazards in our tri-state territory, like humidity. To address this, Multivariate Adaptive Constructed Analogs (MACA) statistically downscaled global climate models were used. MACA is downscaled to a 4km-by-4km resolution. Wind projections are formulated using 34 NEX-GDDP Global Climate Models across SSP2-4.5 and SSP5-8.5. Therefore, the granularity of the results is different, with the wind results being reported at an approximately 25km spacing.

[3] https://journals.ametsoc.org/view/journals/hydr/21/12/jhm-d-19-0275.1.xml

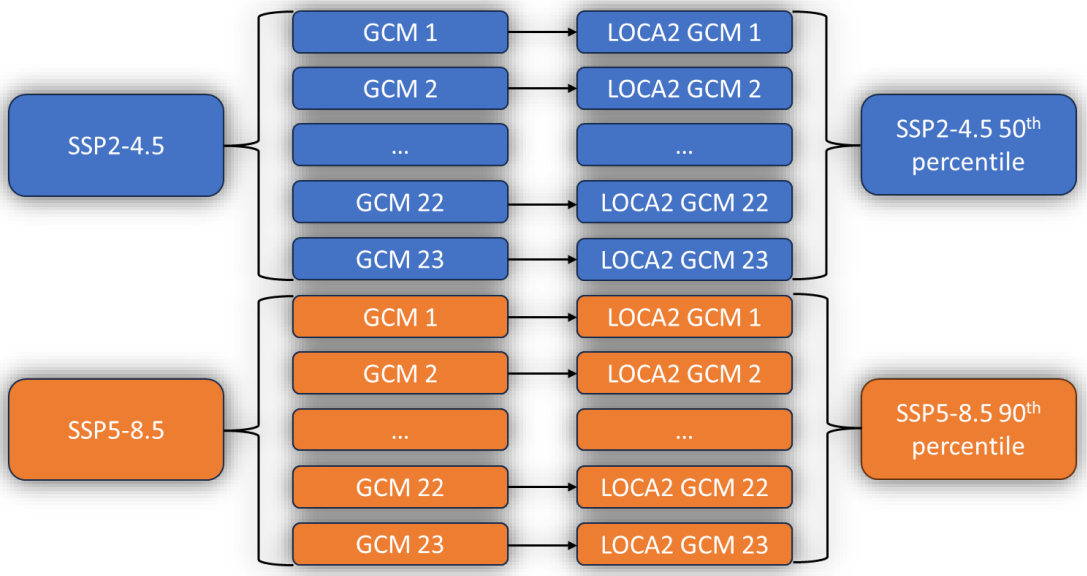


Figure 5. SSP scenarios and percentiles of focus

Climate Hazard Projections

In what follows, we highlight results from the climate study focused on the year 2050 and showcasing SSP2-4.5 90th percentile and SSP5-8.5 90th percentile. The following tri-fold figures are organized as follows: from left to right the historically observed values of the variable, the projected value under SSP2-4.5 90th percentile for 2050 and the projected value under SPP5-8.5 90th percentile for 2050. The two-fold figures show the evolution of a variable's projection across time (years are on the horizontal axis), with SSP2-4.5 shown on the left and SPP5-8.5 shown on the right. The different percentiles within each scenario are plotted in the same graph for comparison.

Temperature

A warming climate is overall projected for our territory. This is showcased through increased annual hottest daily temperatures and longer and more frequent heat waves. The following graph shows how the temperatures are projected to change in a generic warming climate scenario.

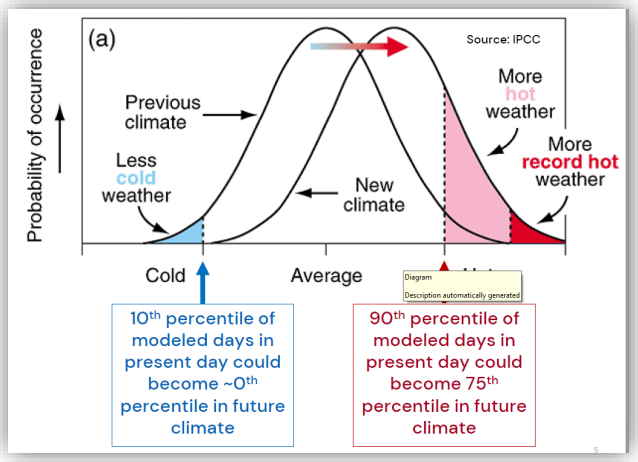
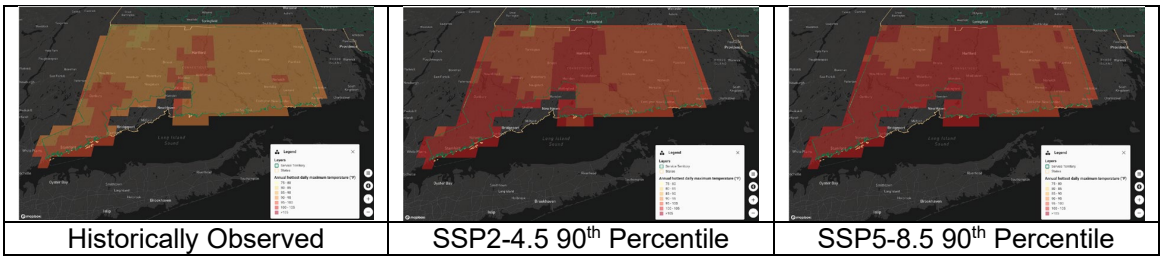


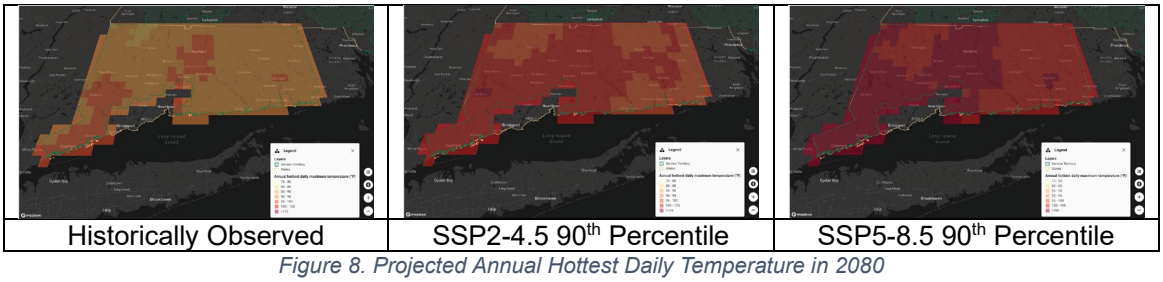
Figure 6. Generic depiction of Probability Density Function of temperature in a warming climate

Figure 7 shows that the hottest daily temperature increases almost uniformly under both scenarios. The Hartford area and the Norwalk – Stamford area have the hottest daily temperature under SSP2-4.5 90th percentile in 2050. It is mostly the east of the state that is relatively cooler than the rest of the state under SSP2-4.5 90th percentile in 2080, while all areas in our tri-state footprint have an increased hottest daily temperature under SSP5-8.5 90th percentile by 2080.



Historically Observed	SSP2-4.5 90th Percentile	SSP5-8.5 90th Percentile

Figure 7. Projected Annual Hottest Daily Temperature in 2050



Historically Observed	SSP2-4.5 90th Percentile	SSP5-8.5 90th Percentile

Figure 8. Projected Annual Hottest Daily Temperature in 2080

Figure 9 shows the evolution of the annual average maximum temperature in Hartford for SSP2-4.5 and SSP5-8.5 across years. Under SSP5-8.5, not only are the projected temperatures higher, the range of the projections also widens with time and compared to SSP2-4.5 based projections.

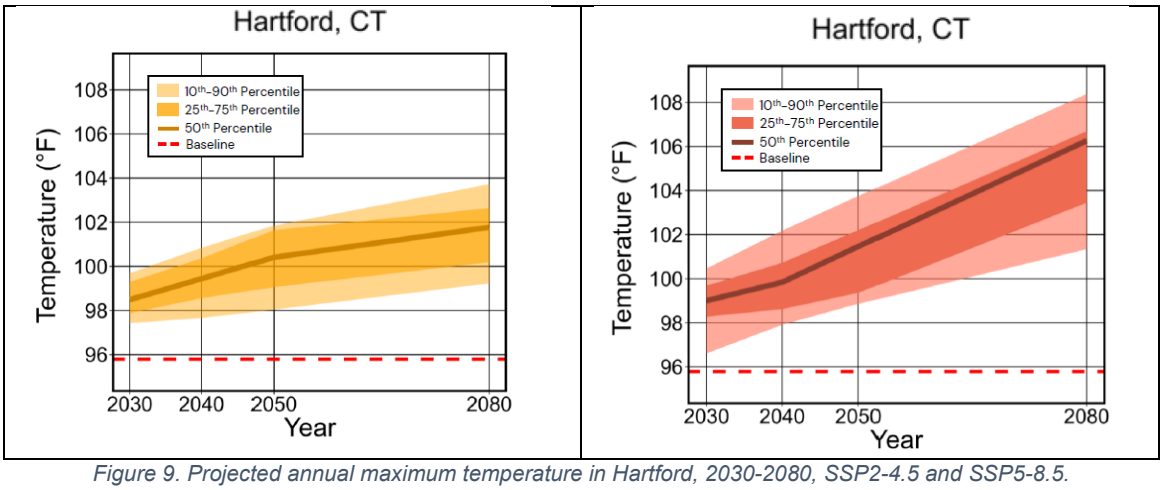
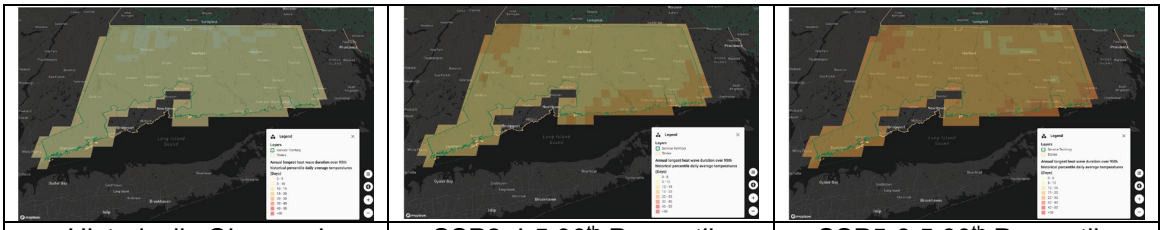


Figure 9. Projected annual maximum temperature in Hartford, 2030-2080, SSP2-4.5 and SSP5-8.5.

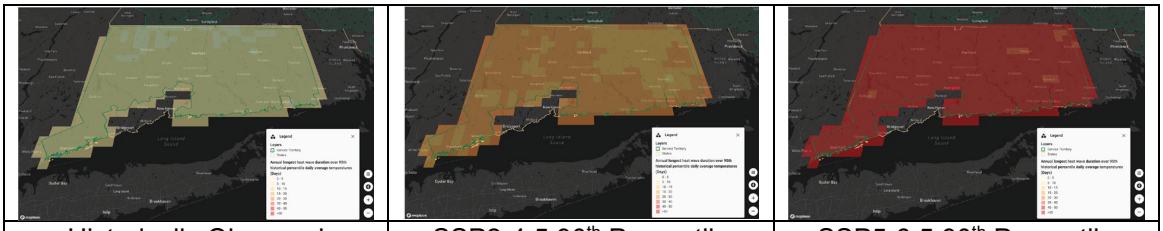
Figure 10 and Figure 11 shows the annual longest heatwave in 2050 and 2080, respectively, while Figure 12 and Figure 13 show the total number of days in a year with hottest daily temperature above the 95th percentile. While the duration of the longest heat

wave seems to have a moderate and uniform increase across both scenarios in 2050 and 2080, the increase under SSP4-8.5 90th percentile in 2080 is very significant and covers the entire state without spatial variations.



Historically Observed	SSP2-4.5 90th Percentile	SSP5-8.5 90th Percentile

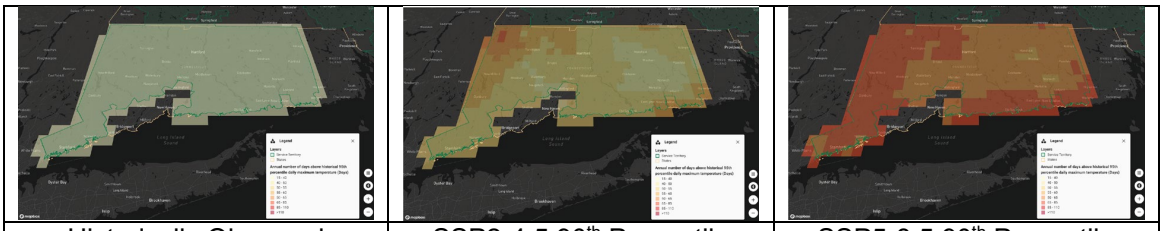
Figure 10. Projected Anunal Longest Heat Waves in 2050



Historically Observed	SSP2-4.5 90th Percentile	SSP5-8.5 90th Percentile

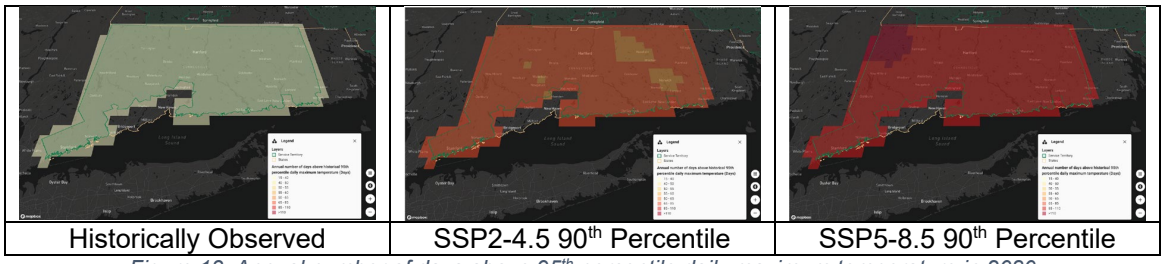
Figure 11. Projected Annual Longest Heat Waves in 2080

Annual days above 95th percentile exhibits low spatial variation under all scenarios in both 2050 and 2080. Under SSP5-8.5 90th percentile, the entire state reaches the peak projected value.



Historically Observed	SSP2-4.5 90th Percentile	SSP5-8.5 90th Percentile

Figure 12. Annual number of days above 95th percentile daily maximum temperature in 2050



Historically Observed	SSP2-4.5 90th Percentile	SSP5-8.5 90th Percentile

Figure 13. Annual number of days above 95th percentile daily maximum temperature in 2080

The following figure shows the number of 3-day heat waves above 95th percentile across time for the two scenarios used.

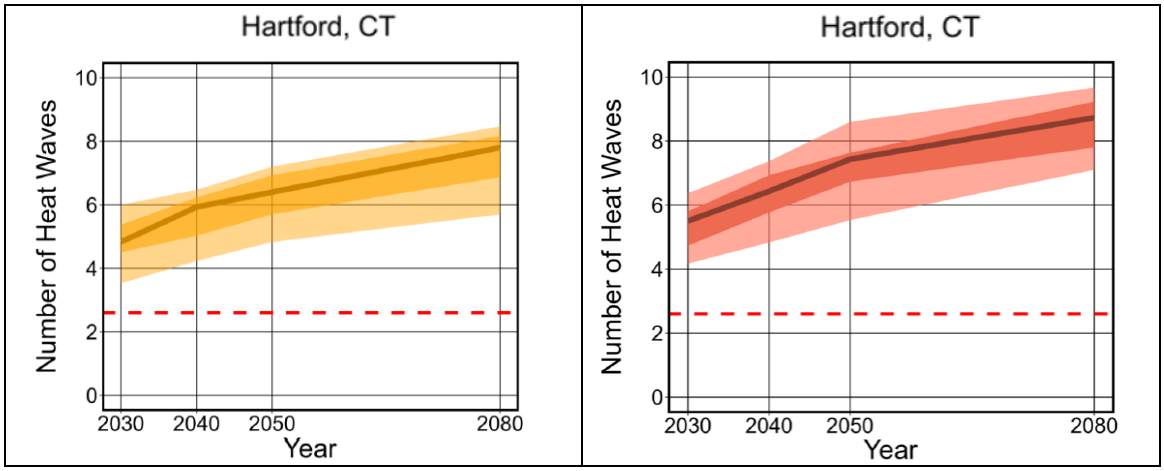
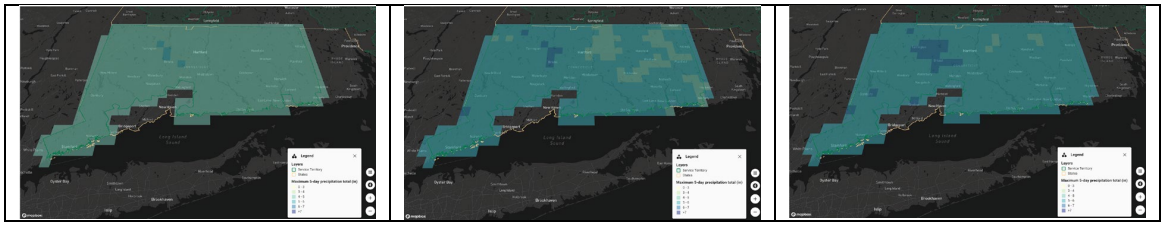


Figure 14. Projected annual number of 3-day heat waves in Hartford, 2030-2080, SSP2-4.5 and SSP5-8.5.

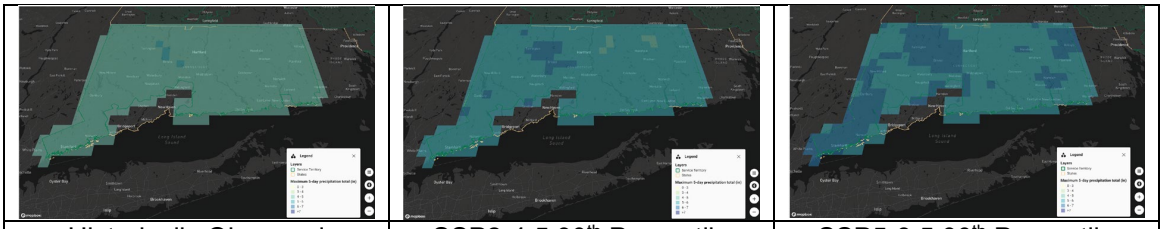
Precipitation

Maximum 5-day precipitation is projected to uniformly increase across our territory by 2050. Higher precipitation pockets exist around Torrington under all scenarios. By 2080, the Stamford – Norwalk area also reaches the maximum projected precipitation value. Similar qualitative results can be associated with Figure 17, that showcases the projected annual number of a days with precipitation more than 3 inches.



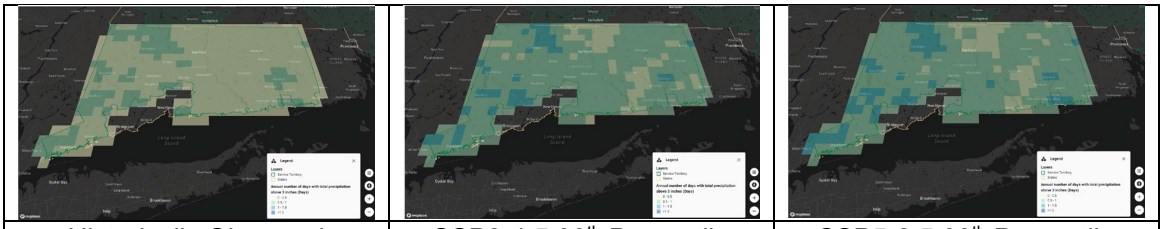
Historically Observed	SSP2-4.5 90th Percentile	SSP5-8.5 90th Percentile

Figure 15. Maximum 5-day precipitation total in inches in 2050



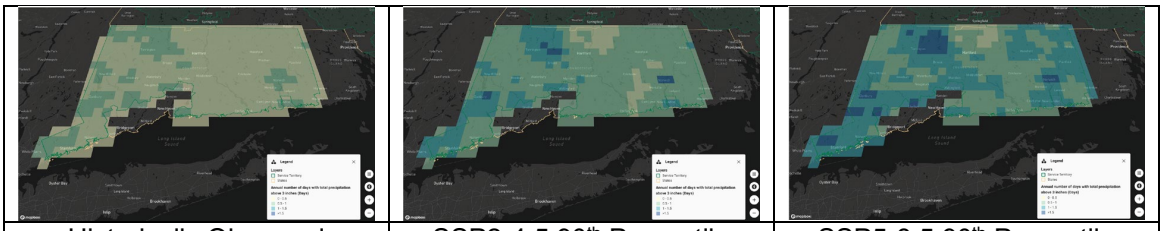
Historically Observed	SSP2-4.5 90th Percentile	SSP5-8.5 90th Percentile

Figure 16. Maximum 5-day precipitation total in inches in 2080



Historically Observed	SSP2-4.5 90th Percentile	SSP5-8.5 90th Percentile

Figure 17. Annual number of days with precipitation above 3 inches in 2050

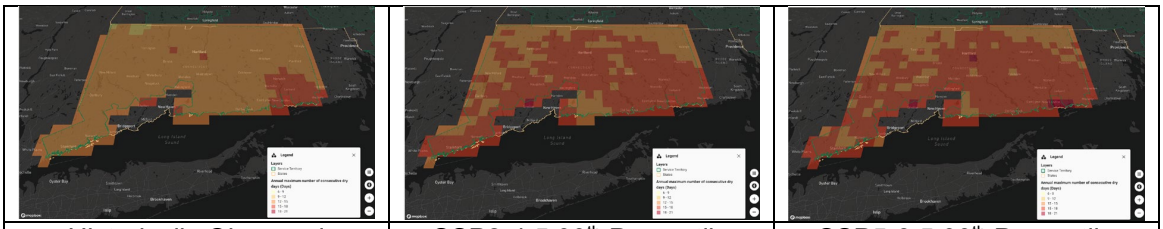


Historically Observed	SSP2-4.5 90th Percentile	SSP5-8.5 90th Percentile

Figure 18. Annual number of days with precipitation above 3 inches in 2080

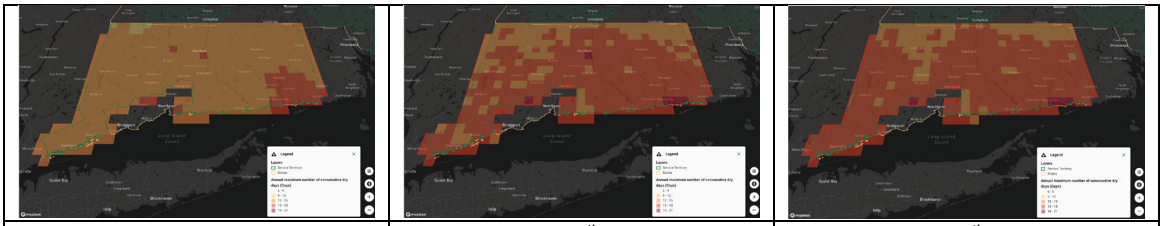
Drought

Figure 19 shows the projected annual maximum number of consecutive dry days. In 2050, significant spatial changes and value changes are projected under SSP2-4.5 90th percentile, while areas with prolonged drought become even more under SSP5-8.5 90th percentile. In conjuction with the results shown above for precipitation, especially under SSP5-8.5 90th percentile is indicative of a projected future of extremes, where both prolonged drought periods and intense concentrated precipitation are plausible.



Historically Observed	SSP2-4.5 90th Percentile	SSP5-8.5 90th Percentile

Figure 19. Annual maximum number of consecutive dry days in 2050

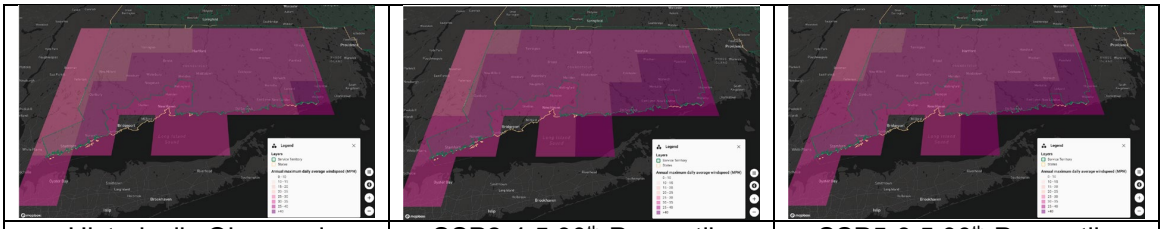


Historically Observed	SSP2-4.5 90th Percentile	SSP5-8.5 90th Percentile

Figure 20. Annual maximum number of consecutive dry days in 2080

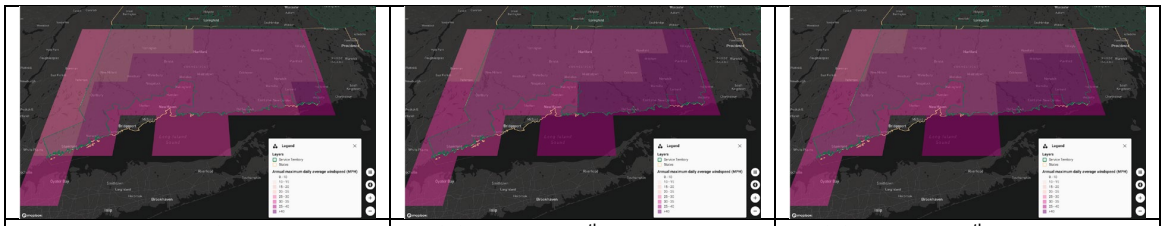
Wind

As will be shown below, the downscaled projections for wind variables are coarser than the projections for temperature, precipitation and drought. There are no significant variations in the projected values for 2050 compared to the observed values under both future scenarios. However, as discussed in detail below, the critical input variable for impacts to the vegetation and wires during wind events is wind gust and not wind speed. Therefore, these projections should not be used to project the levels of threat and vulnerability in 2050.



Historically Observed	SSP2-4.5 90th Percentile	SSP5-8.5 90th Percentile

Figure 21. Annual maximum daily average windspeed (mph) in 2050



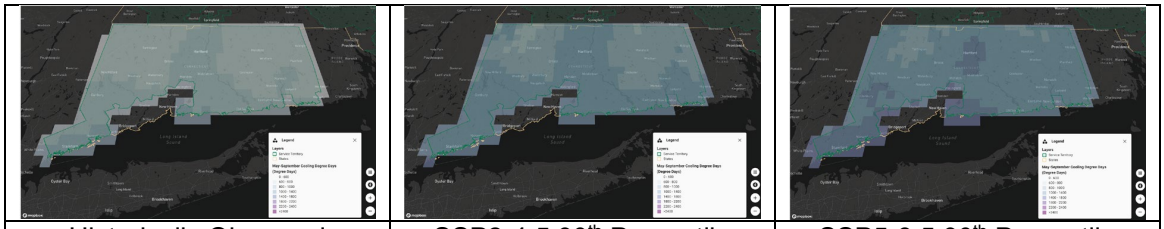
Historically Observed	SSP2-4.5 90th Percentile	SSP5-8.5 90th Percentile

Figure 22. Annual maximum daily average windspeed (mph) in 2080

Temperature-driven demand

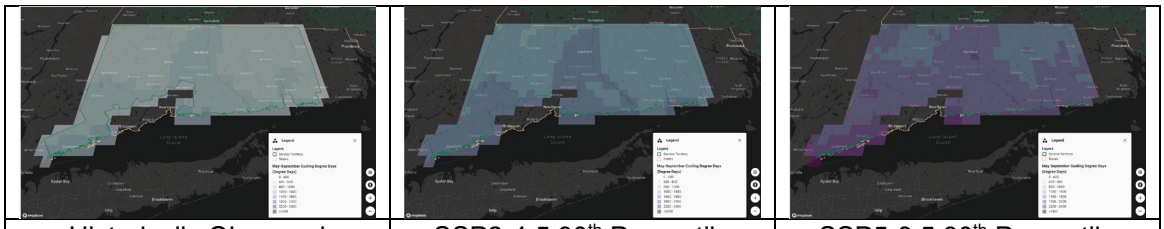
Climate change is projected to warm winter temperatures and reduce the overall frequency and intensity of cold snaps. However, climate change does not preclude the occurrence of cold snaps, particularly through the medium-term, and some evidence shows that complex processes amplified by climate change could worsen some cold snaps, such as polar vortex events.

Nonetheless, the heating degree days are projected to decrease in the northern part of our territory including New Hampshire and Western Massachusetts. The annual number of days below historical 5th percentile of minimum temperatures is also projected to decrease across the three states. Cooling days increase and spread more covering with peak values around Stamford - Norwalk.



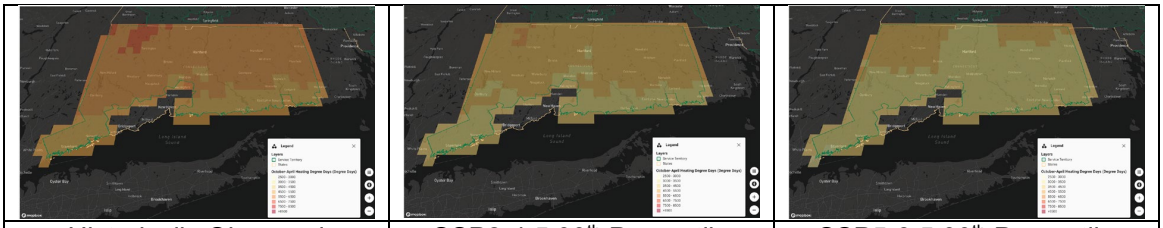
Historically Observed	SSP2-4.5 90th Percentile	SSP5-8.5 90th Percentile

Figure 23. May- September cooling degree days in 2050



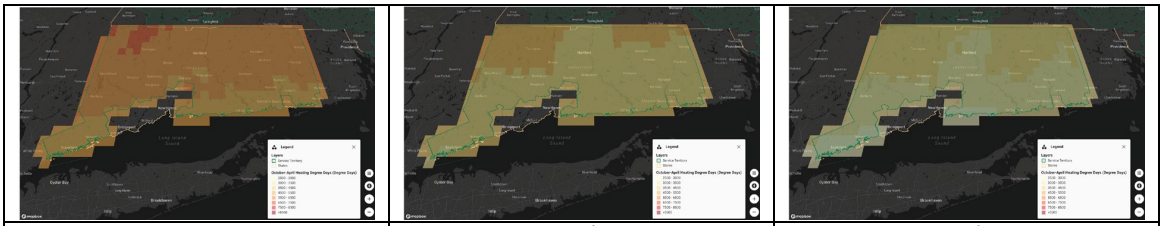
Historically Observed	SSP2-4.5 90th Percentile	SSP5-8.5 90th Percentile

Figure 24. May- September cooling degree days in 2080



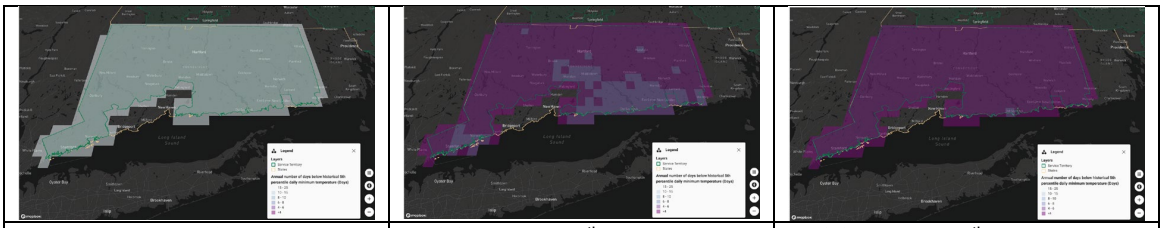
Historically Observed	SSP2-4.5 90th Percentile	SSP5-8.5 90th Percentile

Figure 25. October- April heating degree days in 2050



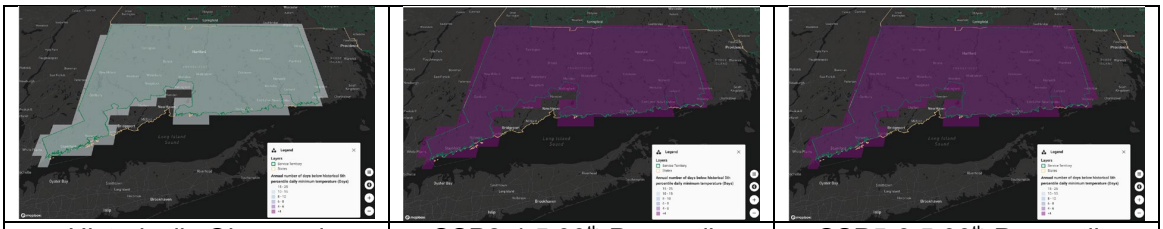
Historically Observed	SSP2-4.5 90th Percentile	SSP5-8.5 90th Percentile

Figure 26. October- April heating degree days in 2080



Historically Observed	SSP2-4.5 90th Percentile	SSP5-8.5 90th Percentile

Figure 27. Annual number of days below historical 5th percentile of daily minimum temperature in 2050



Historically Observed	SSP2-4.5 90th Percentile	SSP5-8.5 90th Percentile

Figure 28. Annual number of days below historical 5th percentile of daily minimum temperature in 2080

Sea Level Rise

The source of the Seal Level Rise projections is the National Oceanic and Atmospheric Administration (NOAA)'s Seal Level Rise Viewer. The viewer can be found at https://coast.noaa.gov/slr/#/layer/slr/2/-

7840455.758856021/5136701.092987982/10/satellite/184/0.8/2050/interHigh/midAccretion .

The sea level rise and global temperature change are related through complex relationships, although sea level rise models are presented as distinct from the projections under SSP2-4.5 and SSP5-8.5. Per NOAA, 2 feet of sea level rise is increasingly likely between 2020 and 2100 if global temperature is under 3 degrees Celsius. SSP2-4.5 is linked to 2 degrees Celsius higher temperatures in 2050 and SSP5-8.5 is linked to 2.5 degrees Celsius by 2050.

Therefore, in this study, a 2 feet sea level rise scenario is related to 2050 and a 3 feet sea level rise scenario is related to 2080. In NOAAs Sea Level Rise Viewer, the coarse sea level rise scenario refers to feet above Mean Higher High Water (which is the average of the higher high water height of each tidal day).

Storm Surge

For storm surge, the projections used are from NOAA's Sea, Lake and Overland Surges from Hurricanes (SLOSH) tool. Based on historical data, we focus on Hurricane 1 for this study, since Hurricanes 2 and 3 have historically occurred very infrequently. The SLOSH tool can be found at https://experience.arcgis.com/experience/203f772571cb48b1b8b50fdcc3272e2c .

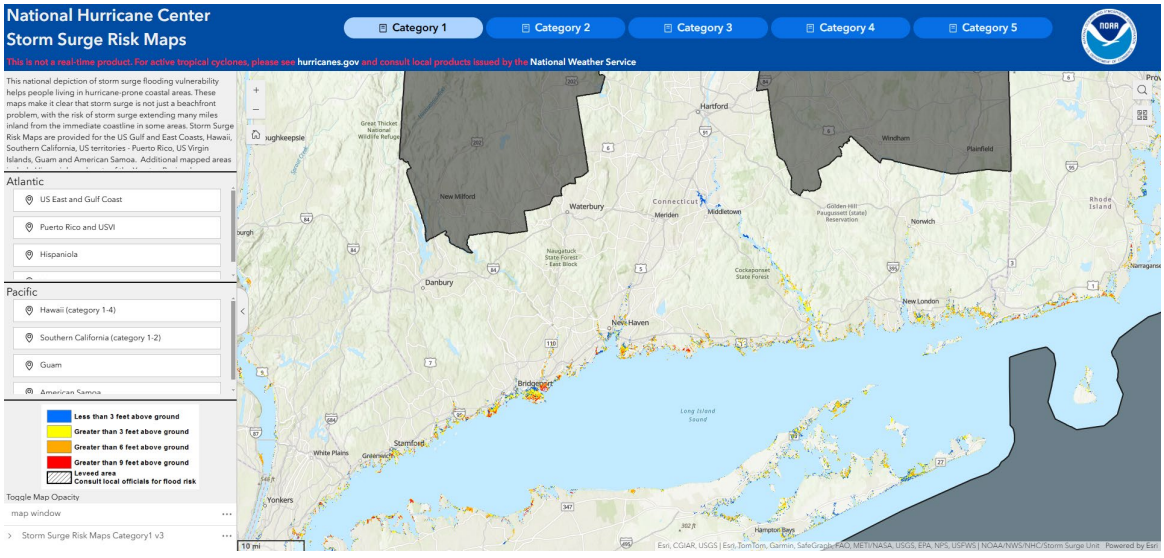


Figure 29. NOAA's SLOSH projections for a Category 1 Hurricane around Connecticut

Extreme Events

Global Climate Models are limited in their ability to resolve these types of extreme weather events due to the small spatial and time scales at which the events occur, as well as the shortness of the historical record relative to the rarity of the events. In addition, droughts, tropical cyclones, ice storms, and cold snaps are particularly difficult to resolve in climate models given the complex and rare environmental and meteorological conditions that promote their formation. To address this, as part of this study, two extreme weather event scenarios were developed. These extreme scenarios supplement projections from climate models and provide a stress-test and broader understanding of potential future climate hazards in Connecticut, Massachusetts, and New Hampshire in support of Eversource's climate resilience planning.

While the narratives reveal the extent to which extreme events may worsen due to climate change, the current understanding of the climate science behind these events does not provide specific probabilities of occurrence.

Each narrative is supported by a suite of underlying climate information including (1) recent historical analogs for each event, (2) a review of recent scientific research related to each event, and (3) climate model projections, as appropriate. Analogs help constrain a historical baseline for each event type, while forward-looking climate research and projections characterize potential future change. The sections below provide an overview of this information and the corresponding narrative for the two HILL events of interest.

Scenario 1: Major Ice Storm followed by a Cold Snap

Background

Ice storms occur when the vertical temperature profile of the atmosphere meets specific environmental conditions. Freezing rain typically occurs during temperature inversions, as warm air moves over colder, shallow air. In New England, a typical ice storm may occur when a warm air mass travels from the south (originating near the Mississippi Valley or Gulf of Mexico) and intersects cold air from southern Quebec and northern New England as it travels towards the north (Robbins & Cortinas, 2002; Jones & Mulherin, 1998; DeGaetano, 2000). This leads to freezing rain, as the warm and dense air from the south is forced to rise over the cooler, less-dense arctic air.

Extratropical cyclones, one type of intense winter storm and regionally and commonly referred to as nor'easters, are low-pressure systems driven by the convergence of cold polar air from Canada and warm air over the Atlantic Ocean. As a result, nor'easters occur most frequently during the cold season between November and April, when the temperature contrast between these air masses is greatest. Nor'easters can be accompanied by rainfall or frozen precipitation, including snowfall, sleet, and freezing rain. Some of the strongest nor'easters with frozen precipitation achieve blizzard conditions when winds persistently gust more than 35 mph or visibility is reduced to one-quarter mile

due to heavy or blowing snow. In addition, nor'easters are often followed by intensely cold northwest winds as storm systems exit the region to the northeast.

Extreme cold events, often referred to as cold snaps, generally occur in New England when anomalously cold, polar air from Canada extends farther south into Vermont, New Hampshire, Massachusetts, and even as far south at Connecticut due to an unstable polar vortex or from northerly atmospheric circulation (winds) in the wake of a passing winter storm. An unstable polar vortex results from sudden stratospheric warming in the Arctic, which splits or weakens the vortex, allowing polar air to extend farther south into the Northeast US.[4]

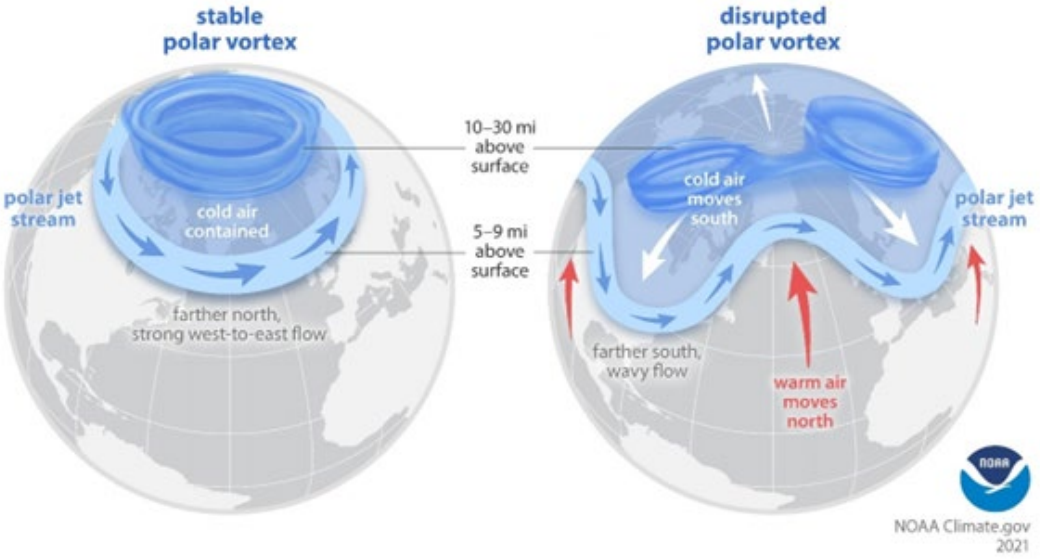


Figure 30. Demonstration of stable and unstable polar vortex[5]

More intense cold snaps can result in temperatures as high as 30-40°F below average, particularly in northern New England, with the daily minimum temperatures during cold spells ranging from 0 to -30°F depending on the location and timing. Extreme cold following an ice storm can exacerbate the impacts of the ice storm, preventing ice accumulation from melting and prolonging storm impacts.

Historical Information

Major Ice Storm

Connecticut, Massachusetts, and New Hampshire experience ice storms on an annual basis, recording an average of approximately 3-6 days with freezing rain per year between 1948 and 2000 (Changnon & Karl, 2003). While freezing rain is relatively

[4] Understanding the Arctic polar vortex. https://www.climate.gov/news-features/understanding-climate/understanding-arctic-polar-vortex

[5] *https://www.climate.gov/media/11999*

common during winter months in the service area, the most significant ice storms are exceedingly rare. These storms have produced total ice accumulations of up to 4 inches, lasting from a few hours to upwards of five days, leading to short-term (a few hours) and long-term impacts (1+ weeks) after storms pass, especially when followed by a prolonged cold spell (DeGaetano, 2000).

The 2008 ice storm, which occurred on December 11-12, 2008, might have been the most impactful to the service territory in terms of area impacted. Widespread areas of ice up to 0.25–1 inch were observed across most of southern New Hampshire, Massachusetts and northwestern Connecticut, with local amounts of up to 1.5 inches in higher elevations near Pittsfield, MA, and southern New Hampshire.[6] The ice storm prompted both Massachusetts and New Hampshire to declare states of emergencies. In New Hampshire ice accretions of 0.5–1 inch across central and southern New Hampshire led to over 400,000 experiencing power outages.[7]

Another recent significant ice storm that impacted the area was the January 1998 Northeastern Ice Storm, which occurred from January 4-10, 1998. The storm led to upwards of 2-3 inches of ice accumulation in New Hampshire, with 1-3 inches reported in Wolfeboro, NH, and damage to trees covering over 800,000 acres across the state.[8] The ice accretion led to power outages for over 1 million people across northern New England, taking weeks to recover in some areas.[9] Polar air was drawn into the region in the wake of the passing storm, leading to overnight temperatures in the single digits and prolonging the impacts of the storm for days in portions of New Hampshire.

Cold Snap

Extreme cold events are relatively common in New England. Cold snaps can cause minimum temperatures well below zero across the service territory, particularly in New Hampshire and Massachusetts. The coldest temperature recorded in Boston, Massachusetts was -18°F in 1934; within the last ten years, the coldest temperature was -9°F.[10] In Hartford, Connecticut, the record lowest temperature recorded was -26°F in 1961; within the last ten years, the coldest temperature was -12°F.[11] The lowest

[6] December 2008 Ice Storm. National Weather Service. https://www.weather.gov/media/box/science/December_2008_Ice_Storm.pdf

[7] Storm froze New Hampshire with thick blanket of ice 14 years ago Sunday. WMUR. https://www.wmur.com/article/weather-archives-ice-storm-of-2008/30188089

[8] Saturday marks 25 years since freezing rain fell for more than 80 hours, coated New Hampshire in ice. WMUR. https://www.wmur.com/article/new-hampshire-great-ice-storm-1998/42410010#

[9] New England marks 20 years since record Ice Storm. NBC Boston. https://www.nbcboston.com/news/local/new-england-marks-20-years-since-ice-storm/127941/

[10] *Boston - lowest temperature for each year*. Boston MA Lowest Temperature Each Year - Current Results. (2023). https://www.currentresults.com/Yearly-Weather/USA/MA/Boston/extreme-annual-boston-low-temperature.php

[11] Hartford - *lowest temperature for each year*. Hartford CT Lowest Temperature Each Year - Current Results. (2023).https://www.currentresults.com/Yearly-Weather/USA/MA/Boston/extreme-annual-boston-low-temperature.php https://www.currentresults.com/Yearly-Weather/USA/CT/Hartford/extreme-annual-hartford-low-temperature.php

temperature recorded in Manchester, New Hampshire was -29°F, which has occurred three times in history, most recently in 1984.[12] Within the last ten years, the record lowest temperature in Manchester was -12°F, which occurred in both 2023 and 2016.[12] Often accompanying the cold snaps are stronger than average winds, and wind chill values can appear well below 0°F for large portions of the service area during a significant event. Even if no precipitation (or no significant precipitation) occurs with extreme cold events, the below average temperatures and strong wind fields can cause many issues, including loss of power during times of high energy demand.

Future Projections

Major Ice Storm

Overall, despite high uncertainty, models project decreasing frequency (or likelihood) of ice storms, but ice accumulation during the highest-intensity storms could increase. As temperatures warm across New England due to climate change, the number of hours of freezing rain are projected to decrease (McCray et al., 2022), as the likelihood of more extreme freezing rain events shifts farther north into Canada (Lambert & Hansen, 2011; Cheng et al., 2011). This is consistent with recent trends towards a gradual northward migration of the rain-snow transition zone across the United States (Easterling et al., 2017). In addition to the poleward shift of ice storms, frequencies are more likely to decrease during shoulder seasons (spring and fall) and increase during winter months, particularly in more northern regions, such as New England (Klima & Morgan, 2015).

One study investigated projected changes to extreme ice loads used to design infrastructure over North America using a multi-member initial-condition ensemble of a Global Climate Model (GCM) under the RCP 8.5 scenario (Jeong et al., 2019). Warming upper-level and surface temperatures over North America could lead to increased freezing rain ice accumulation at latitudes above 40°N in North America, or those north of Philadelphia's latitude. The increases, however, are predominantly driven by the highest latitudes above 50°N in the cooler climates of Canada, consistent with a northward shift in the likelihood of freezing rain events Canada (Lambert & Hansen, 2011; Cheng et al., 2011; Easterling et al., 2017). Interestingly, atmospheric ice thickness caused by freezing rain on vertical surfaces is projected to increase at a greater rate relative to freezing rain on horizontal surfaces. This is due to projected increases in surface wind speed during the cold season, leading to greater ice loading on the sides of infrastructure and vegetation (Jeong et al., 2019).

It is important to emphasize that the findings highlighted here are drawn from a limited subset from existing scientific literature, summarizing the current state-of-the-science on ice storms and climate change. Projections for the influence of climate change on ice

[12] *Manchester NH Lowest Temperatures by Year*. Extreme Weather Watch. (2023).https://www.extremeweatherwatch.com/cities/manchester-nh/lowest-temperatures-by-year

storms and winter extratropical cyclones are difficult to resolve and remain highly uncertain due to the specific atmospheric conditions required for ice storms relative to other high-impact hazards (IPCC, 2021). From a physical science perspective, winter storms are highly sensitive to a range of underlying factors, including sea surface temperatures, jet stream activity and land/atmosphere heat exchange, which remain difficult to incorporate into climate models. Thus, large uncertainty associated with future changes in winter storms remains. However, focused studies using regional downscaled climate models can help approximate their direction and magnitude of future change (Colle et al., 2013, 2015).

Cold Snap

Climate change is projected to warm winter temperatures and reduce the overall frequency and intensity of cold snaps. However, climate change does not preclude the occurrence of cold snaps, particularly through the medium-term, and some evidence shows that complex processes amplified by climate change could worsen some cold snaps, such as polar vortex events.

Climate change is causing the Arctic to warm more quickly than lower latitudes (a phenomenon referred to as arctic amplification), which reduces the temperature gradient between high and mid latitudes. Some studies suggest that polar vortex events over the northeastern US may occur more frequently due to reduced sea ice and snow cover in the Arctic weakening the confinement of the polar vortex (e.g., Zhang et al., 2018; Overland et al., 2018; Cohen et al., 2021). One such study proposed that extreme cold air outbreaks, possibly punctuated by widespread snow events, may become more common as high-latitude regions warm, due to resulting changes in the jet stream (Liu et al., 2012; Francis & Vavrus, 2012). A more recent study focused on polar vortex events back to the 1980s, linking changes in the climate of the Arctic to the weakening of the polar vortex encouraging outbursts of Arctic air to mid-latitudes (Cohen et al., 2021).

However, many climate scientists argue that even if cold snaps occur more frequently, there is high confidence that the Arctic is warming and, therefore, the cold air outbreaks will become warmer over time as well. Additionally, scientists argue that a longer record is needed to support research linking Arctic amplification to cold snaps. Ultimately, the relationship between the warming arctic and cold air outbreaks, particularly those affecting the northeastern United States, is still uncertain and more research is needed to improve model projections.

Future Narrative

This section describes a plausible “worst-case scenario” for midcentury in which a major ice storm followed by a cold snap impacting the Eversource service area.

In this scenario, a strong low-pressure system forms in the lower midwestern United States in mid-December and travels eastward toward New England. The low-pressure system tracks over southern New York before approaching a cold arctic air mass from

southeast Canada that extends into southern New Hampshire and Massachusetts. The relatively warm, strong low-pressure system slowly traverses eastward over southern New Hampshire and Massachusetts for nearly 2 days, leading to heavy precipitation in the form of snow (mainly over the highest elevations and northern New Hampshire), sleet, and freezing rain before exiting the region into the Atlantic Ocean. A trailing cold front brings strong winds and cold temperatures, exacerbating impacts from high ice accumulations across southern New England. A system of this magnitude could drive the following illustrative hazards and impacts across the service area:

- Freezing rain causes ice accumulations ranging from 0.5 to 3 inches across the majority of Massachusetts and southern New Hampshire over a 2-day period. Inland areas of Connecticut, including Hartford, experience ice accumulations ranging from trace amounts to 1 inch.
- The largest ice accumulations are observed in areas surrounding Manchester and Nashua in southern New Hampshire to Boston of approximately 1.5–3 inches. Smaller icing totals are observed in the Berkshires and higher elevations of New Hampshire of 0.5-1 inch due to cooler temperatures leading to snow totals over 12 inches.
    - *Current design guidelines for ice loading are set to 0.75 inches (poles for storm resiliency guidelines; combined with a 40 mph wind), 0.5 inches (conductors), and 1 inch (substations; combined with a 50 mph wind).*
- Peak wind gusts from this system reach 45 mph in inland locations near Hartford, CT, Manchester, NH, and Springfield, MA. Wind gusts are higher closer to the coast, exceeding 60 mph near Boston and 50 mph across coastal Connecticut. High winds could allow ice to accumulate over a greater surface area of assets and buildings leading to a greater ice loading, particularly if water has already frozen over surfaces.
    - *Current design guidelines for combined ice and wind loading are set for 40 mph (poles for storm resiliency guidelines) and 50 mph (substations), which is exceeded by this storm in some locations.*
- As the blocking high collapses and allows the storm to moves out of the region towards the northeast into Maine, sustained northerly winds between 20 and 30 mph on the backend of the storm draw in cooler Canadian air, leading to temperatures well below freezing across the service area. The cold snap lasts 1 week after the storm passes, prolonging the impacts in the most affected areas.
- At the cold snap's peak, lowest minimum temperatures range from -5°F in Boston to -15°F in Springfield. Higher elevations of the Berkshires experience minimum temperatures as low as -30°F. Cape Cod minimum temperatures remain above 0°F.
- In New Hampshire, lowest minimum temperatures range from -20°F near Manchester to -40°F in the higher elevations in northern New Hampshire (not including Presidential Range in White Mountains).

- In Connecticut, lowest minimum temperatures range from -15°F at inland locations near Hartford to 0°F at coastal locations near New London and Mystic.

Scenario 2: Prolonged Drought followed by a Tropical Cyclone

Background

Prolonged Droughts

Drought is a prolonged, abnormal period of dry weather characterized by warmer temperatures and/or a lack of precipitation, resulting in a significant water shortage for some activity, population, or ecological system. Drought can also result from an extended imbalance between precipitation and evaporation (US EPA, 2016). Precipitation shortages leads to a reduced moisture source into soils, while warmer temperatures act to dry out surface soils and vegetation by increasing atmospheric demand (increased potential evapotranspiration) and surface evapotranspiration, leading to more severe drought. Warmer temperatures lead to more frequent and longer-duration droughts that also increase the likelihood of fire weather and drier fuel conditions (Jones et al., 2020), impacting the magnitude, timing, and frequency of wildfires (Jia et al., 2019). Drought also weakens the health of trees due to reduced water availability, increasing the likelihood of stem breakage or uprooting under high wind-loading. Prolonged periods of increased drought stress could reduce tree health and increase the likelihood of tree mortality, leading to an enhanced risk of falling trees on nearby power lines. Warming temperatures have the potential to enhance drought severity and longevity, increasing the risk of tree mortality in the future (Adams et al., 2009; Choat et al., 2018).

Tropical Cyclones

Tropical cyclones, generally referred to as hurricanes or tropical storms in the North Atlantic basin, are rapidly rotating low-pressure systems that can lead to extreme precipitation, high winds, and coastal storm surge. These storms are classified according to their intensity and wind speed, with Tropical Storms, Category 1, and Category 5 hurricanes featuring sustained winds in excess of 39, 74, and 157 mph, respectively. Hurricane track and intensity are influenced by many factors, including near-surface and upper atmospheric conditions and sea surface temperatures. The combined influence of these factors at any given time determines how a particular storm will manifest. Tropical cyclones, however, manifest at fine spatial and temporal scales and coarse Global Climate Model projections are not equipped to adequately resolve the impacts of climate change on tropical cyclones.

Some of the most consequential impacts from tropical storms include wind damage, inland flooding from extreme precipitation, coastal flooding from storm surges, and tornadoes spawned within the rain bands of a hurricane. While wind and storm surge damage are the most common impacts of landfalling tropical cyclones, significant inland flooding can occur under specific conditions. For example, slow-moving tropical storms rotating over or near a significant moisture supply, such as the Atlantic Ocean or Gulf of

Mexico, can lead to prolonged heavy precipitation that inundates inland areas far from the center (or "eye") of the cyclone. Extreme inland flooding from tropical cyclones is rare but not unprecedented in New England. Furthermore, strong winds and tornadoes resulting from hurricanes can also be damaging, especially to overhead transmission and distribution assets.

Historical Information

Prolonged Droughts

While the Northeast US is generally a wet region that has had substantial increases in mean precipitation over past decades, it has also experienced damaging droughts and water warnings and emergencies (Krakauer et al., 2019; Huang et al., 2017). The 1960s drought impacted most of the northeastern US between 1961-1969 and is widely considered to be the worst drought on record in New England. Studies have shown that it was the most severe drought in the region in the last few centuries (Seager et al., 2012). Paleoclimate reconstructions of the New York City watershed have found that the region may have experienced repeated droughts of similar intensity, but of greater duration during the sixteenth and seventeenth centuries (Pederson et al., 2013).

In New England, the drought peaked in intensity in 1965, which was the driest year on record since the late 1800s, and from 1962-1966 34 out of 46 months experienced below average precipitation beginning in western Massachusetts before spreading eastward over the next several years. Connecticut received under 30 inches of liquid precipitation leading to water emergencies and water bans in Connecticut and Massachusetts.13 In March 1967, the Quabbin Reservoir reached a record-low capacity of 45%, significantly lower than the 79% capacity observed during a more recent drought in 2016-2017.14

From 1901-2015, there has been less frequent drought, although variability in water balance has increased and the duration and intensity of droughts that do occur has not changed significantly (Krakauer et al., 2019). Furthermore, studies have highlighted increased precipitation and reduced drought in the northeastern US in recent years (Bishop et al., 2021; Pederson et al., 2013).

According to the US Drought Monitor (USDM), New England has experienced recent droughts in 2000, 2016, 2020, and 2020, although none rival the intensity and duration of the 1960s drought (Figure 31).15 New England is also susceptible to flash droughts, rapid onset or intensification of intense dry weather periods during a relatively short timeframe

[13] 1965 Drought, New England's Worst Ever. New England Historical Society. https://newenglandhistoricalsociety.com/1965-drought-new-englands-worst-ever/
[14] 1960s drought still holds the record in region. Telegram & Gazette. https://www.telegram.com/story/news/local/east-valley/2017/02/11/1960s-drought-still-holds-record-in-region/22455516007/
Archive of Quabbin Reservoir Levels. Massachusetts Water Resources Authority. https://www.mwra.com/monthly/wsupdat/archivequabbinlevels.htm
[15] Connecticut Drought. National Integrated Drought Information System. https://www.drought.gov/states/connecticut

of 2-6 months, leading to reduced agricultural yield, water supply shortages, and reduced streamflow.16

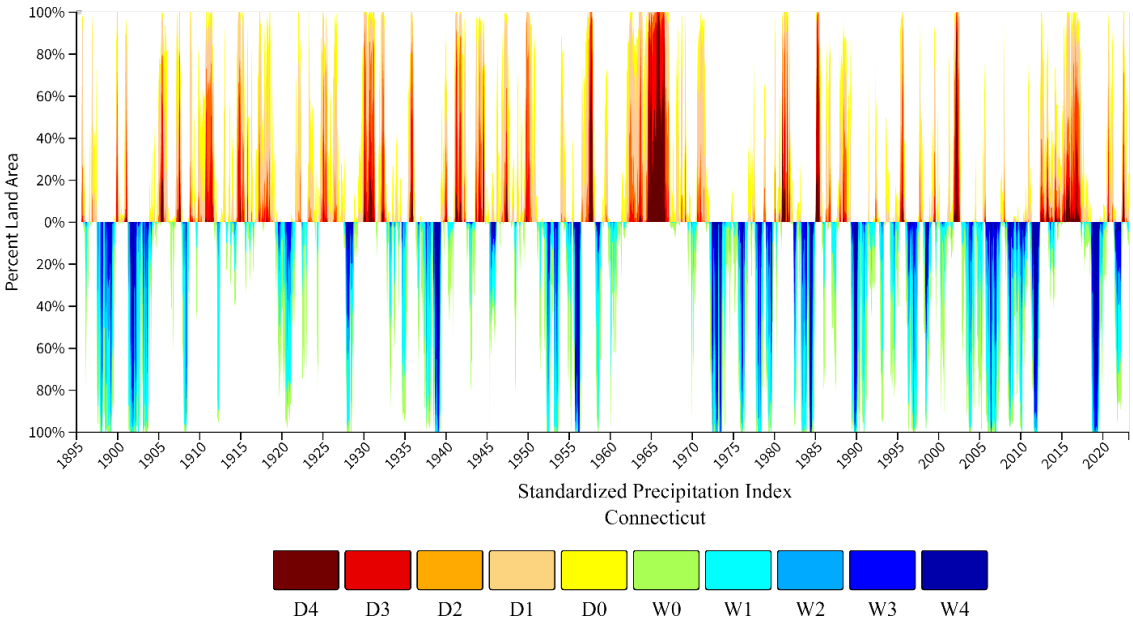


Figure 31. Weekly drought (percent land area with drought or wet conditions) in Connecticut from 1895-Present from the U.S. Drought Monitor (USDM), a national map released weekly. D0 represents abnormally dry, D1 represents moderate drought, D2 represents severe drought, D3 represents extreme drought, and D4 represents exceptional drought. Latest available data is from 5/3/2023. The 1960s and 2016-2017 droughts are prominently displayed in the plot.

Tropical Cyclones

Landfalling tropical cyclones in New England are rare relative to the coastal Gulf and southeastern US regions. Prevailing midlatitude westerly winds over land generally steer hurricanes away from the coast as storms approach the Northeastern United States and Long Island acts as a natural barrier from the worst impacts. When tropical cyclones do make landfall in Connecticut or Massachusetts, they typically approach the region from the Atlantic Ocean from the south during the warmer months of July to October, during peak Hurricane season. Overall, Connecticut has experienced 11 landfalling hurricanes (2 of which were a major category 3 intensity or higher) and Massachusetts has experienced 12 hurricanes (1 major hurricane) from 1851 to 2020, equating to one hurricane every 14-15 years.17 However, some storms have resulted in large impacts in recent years (**Error! Reference source not found.**). Impacts depend on windspeeds, rainfall intensities, hurricane track speed and direction, and size as tropical cyclones

[16] What is Flash Drought? National Integrated Drought Information System. https://www.drought.gov/what-is-drought/flash-drought

[17] How many landfalling hurricanes have hit each state? Hurricanes Frequently Asked Questions. NOAA's Atlantic Oceanographic & Meteorological Laboratory (AOML). https://www.aoml.noaa.gov/hrd-faq/#landfalls-by-state

make landfall and progress inland. For example, storm surge driven by hurricanes varies depending on storm trajectory, intensity, and timing relative to high tide.

The Great New England Hurricane of 1938 is widely regarded as one of the most significant hurricanes to impact the region. Reanalysis suggests the hurricane was of Category 3 intensity when making its initial landfall on Long Island and second landfall in Milford, CT.18 The hurricane advanced with remarkable speed inland, estimated to have traveled at 47 mph after landfall. This rapid translation speed led to widespread impacts from hurricane-intensity winds throughout New England, leading to hundreds of deaths and extensive damage to forests, homes, and crops as far north as New Hampshire.18 Damaged and downed power lines led to power outages lasting several weeks and significant fires in New London and Mystic, CT.19 Significant rainfall led to record flooding from the Connecticut River (Figure 31), destroying 8,900 buildings and damaging 15,000 and leading to 564 deaths and 1,700 injuries.19

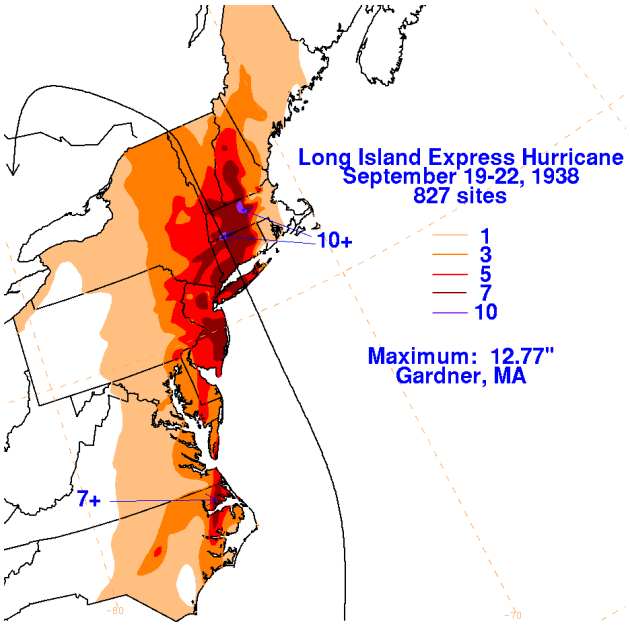


Figure 32. The Great New England Hurricane of 1938 (also known as the Long Island Express Hurricane) rainfall totals in inches, estimated by NOAA National Centers for Environmental Prediction Weather Prediction Center.

More recently, Hurricane Gloria made landfall as a Category 1 hurricane in Connecticut in 1985. At the time, Gloria was labeled as the “storm of the century” and the worst hurricane since 1938, with heavy rainfall and hurricane-force winds leading to power outages for over 700,000 residents in Connecticut for at least one week and damage to wastewater facilities in Enfield and Middletown, CT. Storm surge led to significant coastal

[18] NWS Boston – The Great New England Hurricane of 1938. https://www.weather.gov/okx/1938HurricaneHome

damage from Milford to Stonington, CT, and electrical workers experienced difficulty repairing damaged power lines due to the large amounts of saltwater on land.19

Future Projections

Prolonged Drought

The frequency and intensity of major droughts are projected to increase in the northeastern United States due to a combination of warmer temperatures leading to greater evapotranspiration and altered precipitation patterns leading to drier soil moisture (Kossin et al., 2017; IPCC, 2021). Warming temperatures increase the frequency and intensity of drought conditions, particularly during the warmest summer months. As average temperatures have risen due to climate change, the rate of evaporation from soil and transpiration from plants has also increased. Increased evapotranspiration leads to more atmospheric water availability for precipitation, but at the same time can contribute to drying over some land areas, reducing the amount of moisture in the soil (Wehner et al., 2017).

There is high confidence that heavy precipitation events in the northeastern US have increased in both intensity and frequency since 1901 (Easterling et al., 2017). However, by the end of the 21st century, the effect of higher temperatures on evaporation is expected to outweigh the increase in precipitation, especially during the summer months. This trend is expected to lead to an increased frequency of droughts, although the timing and magnitude of these drought projections are marked by relatively large uncertainty (Horton et al., 2010). Furthermore, changes in the distribution of precipitation throughout the year and the timing of snowmelt could make drought more frequent in mountainous area of Northern New England, especially since the snow season length is very likely to decrease over North America (IPCC, 2021). However, projections show that drying in the northeastern US is likely less than or more uncertain than more arid, drought-prone areas of the country, such as the western US (Cook et al., 2014).

Ultimately, there is uncertainty in model projections of drought in the northeastern US, but models are more certain about projected increases in precipitation in this region. However, climate change does not preclude the occurrence of severe droughts happening again, particularly as temperatures warm, and the water supply system in this region would be severely stressed if droughts similar to those in the past were to occur. Warming temperatures will act to increase the likelihood of severe drought should prolonged periods of reduced precipitation occur in the future.

Changes in synoptic weather patterns may also amplify future drought conditions. Westward extension of the Bermuda High (i.e., the North Atlantic anticyclone, or high atmospheric pressure system) can drive warmer and drier weather in the eastern United States, which can result in more frequent or intense drought conditions (Li et al., 2012).

[19] Hurricane Gloria: “Storm of the Century.” https://connecticuthistory.org/hurricane-gloria-storm-of-the-century/

Modeling indicates that the Bermuda High may extend northwestward more frequently in the future, potentially worsening droughts (Li et al., 2013).

Climate change increases the frequency and intensity of drought conditions, particularly during the warmer summer months, which also can influence the potential for wildfire ignition and spread in areas with dense vegetation (Pausas & Keeley, 2021; Williams et al., 2019). Looking forward, the frequency and intensity of major droughts are projected to increase due to a combination of warmer temperatures (which lead to higher rates of evapotranspiration) and changing precipitation patterns, driving greater wildfire risk, although these impacts will be most pronounced in drought-prone regions of the western US (IPCC, 2021).

Last, flash droughts may become more common as temperatures warm. The rate of drought intensification has increased globally due to increased extremes in evapotranspiration and precipitation deficit due to climate change, with most land areas experiencing large increases under a SSP2-4.5 scenario future (Yuan et al., 2023). Eastern North America, in particular, is expected to experience substantial increases in the proportion of flash droughts and drought onset speed through the end of the 21st century. This could lead to more short-term droughts in the future.

To identify areas with increased drought potential, the study team evaluated future potential drought conditions using Localized Constructed Analogs version 2 (LOCA2) statistically downscaled Global Climate Model projections (Pierce et al., 2014, 2023) (Figure 33). Specifically, we evaluated projections for future annual maximum consecutive dry days (i.e., the longest consecutive period with less than 1mm of daily precipitation), which represents short-term meteorological drought conditions.

Both the intensification of long-duration dry spells and the warming-driven increase in the potential for drought over a greater proportion of the service area in the future could increase the overall drought risk in New England by midcentury, particularly under a high-emission scenario. By 2050, projected annual maximum consecutive dry days increase from a baseline of 9–18 days to a 10–20 days based on the high-end SSP5-8.5 90th percentile scenario, with the greatest potential for long-duration dry spells in eastern Connecticut, eastern Massachusetts, and southern New Hampshire (Figure 33). Under the mid-range SSP2-4.5 50th percentile scenario, dry days change minimally (<1 day) from the baseline across the region.

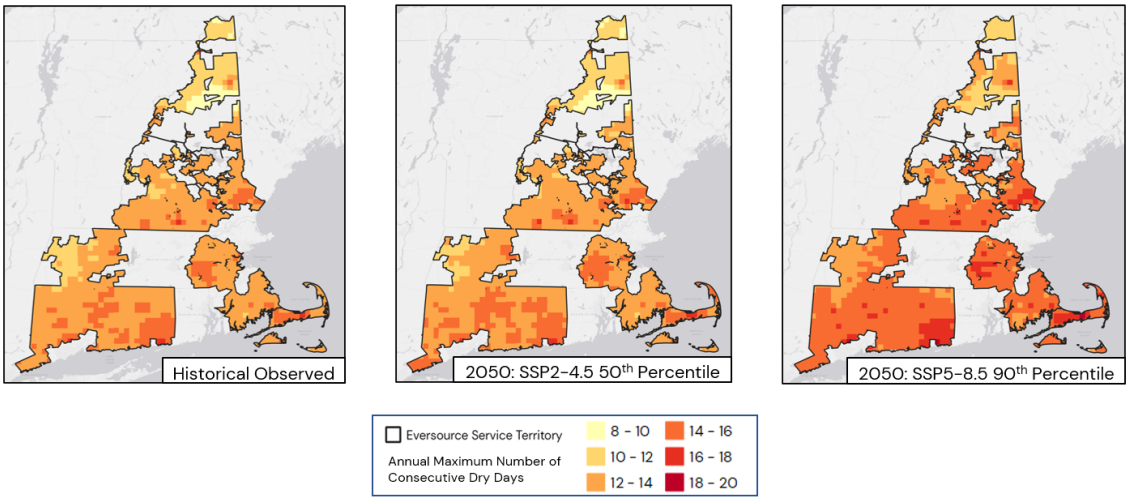


Figure 33. Localized Constructed Analogs version 2 (LOCA2) annual average maximum number of consecutive dry days for historical observed (left; 1985-2014), and 2050 (2035-2064) SSP2-4.5 50th percentile (middle) and SSP5-8.5 90th percentile scenarios (right).

Tropical Cyclones

Climate change is projected to impact many factors influencing hurricane intensity, frequency, and track, such as atmospheric and ocean temperatures. Dynamically downscaled GCMs project warming atmospheric and ocean surface temperatures could likely lead to more intense hurricanes in the North Atlantic, increasing maximum sustained wind speeds by approximately 5%, and rainfall amounts by approximately 10% to 15% relative to historical hurricanes (Knutson et al., 2013; IPCC, 2021). More intense storms bring stronger hurricane winds, storm surge, and rainfall.

GCMs project less certainty regarding changes in the frequency of hurricanes; some studies project a minor change or slight decrease in total 21st century hurricane activity (Knutson et al., 2013; Kossin et al., 2017), while others project a pronounced increase through the end of the 21st century (Emanuel, 2013). Studies generally agree that the frequency and proportion of strong (i.e., Category 4 and 5) hurricanes will increase, with one study showing a doubling of these storms by the end of the 21st century (Bender et al., 2010). The latest IPCC Assessment Report confirms these projections of a minor change or decrease in the overall frequency of hurricanes, but an increase in the frequency of strong hurricanes (IPCC, 2021). Furthermore, both future projections and historical data show a persistent northward migration of the location of hurricane maximum intensity, increasing the chances that a hurricane exceeding Category 2 status could approach the northeastern US in the future (Kossin et al., 2017). One study suggests that projected 21st-century intensification in both wind speed and rainfall could have led to a 42-64% increase in power outages across the Eversource service territory if Hurricane Sandy occurred in 2100 (Wanik et al., 2018).

Hurricane intensification has already been attributed to climate change and warming temperatures (Knutson et al., 2008), but increased precipitation rates from tropical cyclones could lead to a greater risk of inland flooding in the future. Under a scenario of 2˚C global anthropogenic warming (which aligns with 2050 warming under SSP5-8.5 or RCP 8.5), the rain rate from tropical cyclones is projected to increase by approximately 15% in the North Atlantic basin (Knutson et al., 2020). Attribution studies of strong tropical cyclones provide high confidence that anthropogenic climate change contributed to extreme rainfall amounts during Hurricane Harvey in 2017 and other intense tropical cyclones (IPCC, 2021). Several studies have estimated that the precipitation totals during Hurricane Harvey were three to ten times more probable due to climate change (Emanuel, 2017; van Oldenborgh et al., 2017; Risser & Wehner, 2017).

Sea level rise is expected to increase the risk of coastal flooding from storm surge in terms of inundation and extent by mid-century across the service territory. A 100-year storm surge event in Boston could become an 8-year event by 2050 under a high-emissions scenario (Kirshen et al., 2008). Attribution studies have also found that human-caused sea level rise exacerbated storm surge and worsened the impacts of Superstorm Sandy in 2012 (e.g., Trenberth et al., 2015; Swain et al., 2020; Strauss et al., 2021). Long-lasting storms increase the probability that storm surge could coincide with multiple high-tide cycles, increasing the potential for destructive rainfall and winds. Studies have linked these slow-moving storms to climate change (Mann et al., 2017), increasing the possibility that the factors driving stronger and more impactful storms could become more common throughout the 21st century.

Evaluating inundation depths from a Category 3 hurricane across Eversource's coastline using the NOAA Sea, Land and Overland Surges from Hurricanes (SLOSH) model,20 inundation levels could reach up to 21 feet in some locations, including Boston, MA, and Mystic, CT. Major hurricanes, such as the Category 3 hurricane demonstrated in Figure 34 are projected to become more likely by mid-to-late century in New England.

[20] https://www.nhc.noaa.gov/surge/slosh.php

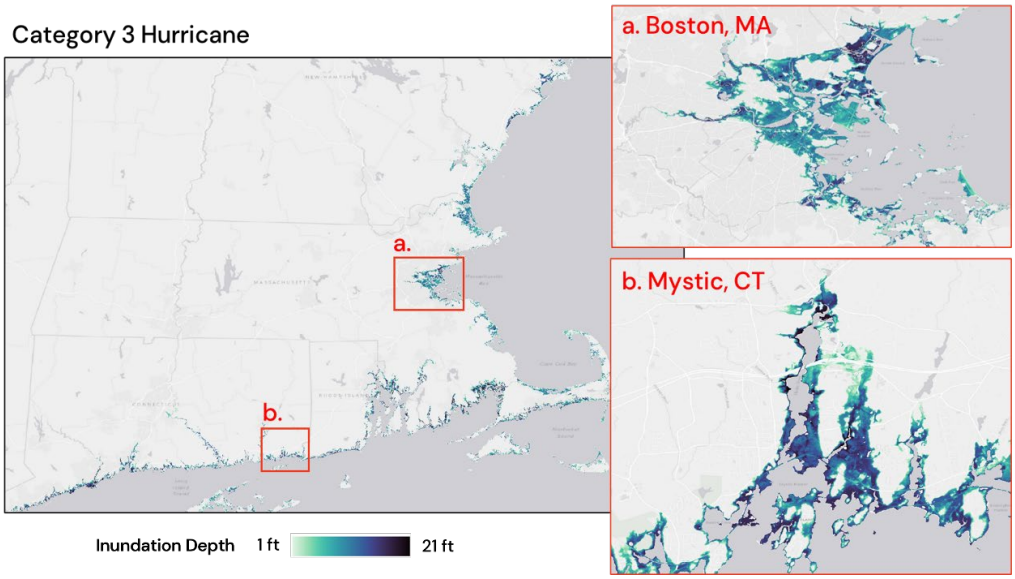


Figure 34. NOAA Sea, Land and Overland Surges from Hurricanes (SLOSH) modeled inundation maps showing maximum storm surge during a Category 3 hurricane. Insets shown for inundation levels in a) Boston, Massachusetts, and (b) Mystic, Connecticut.

Future Narrative

This section describes a plausible "worst-case scenario" for midcentury in which a prolonged drought followed by a tropical cyclone occurs in the Eversource service area.

In this scenario, a 5-year drought occurs in the northeastern United States, rivaling the duration and intensity of the 1960s drought. During this time, 75% of the months experienced below average precipitation in both Connecticut and Massachusetts, with under 30 inches of liquid precipitation per year observed across the service territory. The drought is exacerbated by multiple prolonged heat waves. During late August of the fifth year of the prolonged drought, while temperatures are still well above normal, a tropical cyclone develops in early September in the tropical Atlantic Ocean, steered northwestward towards the northeastern United States due to an unusually strong and north-displaced Bermuda high. The fast-moving tropical cyclone first makes landfall over Long Island as a Category 4 hurricane before making landfall as a Category 3 hurricane east of New Haven and continuing north into Hartford, CT. This storm impacts nearly all of Eversource's service territory significantly for 12+ hours as it makes landfall, particularly across Connecticut, western Massachusetts, and southern New Hampshire. The tropical cyclone rapidly moves inland, extending the area impacted by hurricane-force wind speeds well into northern New England, before intersecting a high-pressure system advancing from the Ohio Valley and tracking to the north into Canada. An event of this magnitude could present the following risks to the Eversource service area:

- At its peak, the drought impacts 90% of the land area of Connecticut, Massachusetts and southern New Hampshire. The Quabbin Reservoir drops below 40% capacity for the first time in its history, surpassing the 1967 record.
- During the prolonged drought, the majority of New England experiences multiple periods of 10-15+ consecutive dry days, contributing to severely reduced runoff and rapid water loss from the Quabbin Reservoir over weekly-to-monthly timeframes.
- Towards August of the fifth year of the drought, a heat wave exceeding 20 days across much of southern New England exacerbates drought conditions across the region, leading to severely low soil moisture levels and extremely dry topsoil. During this heat wave, daily maximum temperatures in Hartford, CT, peak at 102°F and remain above 95°F for 7 days.
    - *Severe drought weakens trees and increases the likelihood of mortality, priming tree-on-line events during the subsequent hurricane due to stem breakage or uprooting from high wind loads.*
- Initial maximum sustained winds exceed 125 mph east of the storm center near Mystic and Stonington, CT along with 110+ mph sustained winds in areas slightly to the north and east impacting Hartford and New London, CT. These winds quickly dissipate as the tropical cyclone moves further inland rapidly.
    - *Current design guidelines for combined wind loading alone are set for 95 mph (poles for storm resiliency) and 150 and 130 mph (substations). Storm resiliency design guidelines would be exceeded in this scenario in many locations.*
- The tropical cyclone advances at 40+ mph, rapidly moving into northern New England in under 8 hours. This expands the impact of the hurricane-force wind field, already extending 50 miles from the center of the storm, leading to wind gusts in excess of 90 mph extending as far north as Concord and Manchester, NH, as the storm tracks inland.
- Total rainfall amounts are the highest to the northeast of the eyewall, impacting most of Connecticut and western Massachusetts into southern New Hampshire. Rainfall accumulations exceed 3-5 inches throughout the service territory, with locally higher amounts exceeding 12 inches near Hartford, CT. Rainfall totals exceed 6 inches in portions of New Hampshire due to orographically-forced increases in rainfall totals. This, in combination with increased runoff due to severely dry soils, leads to catastrophic inland flooding throughout Connecticut, western Massachusetts, and southern New Hampshire, making some roads impassable. Widespread power outages occur in the service area due to the high winds and inland flooding.
- Coinciding with high tide, storm surge exceeds 15 feet in both Mystic and New London, CT.

Engineering Risk Assessment

Risk is typically defined as the product of threat, vulnerability and consequence. The recent DOE guidebook for state energy security plans uses the same definition of risk[21].

- Vulnerability is defined as the degree of susceptibility of an asset to loss or degradation from a threat due to weaknesses within the asset or due to the asset's dependency on other critical systems affected by the threat.
- Consequence is defined as the effect of the loss or degradation of an asset on energy supply or service, and the associated indirect impacts of those losses on society. In this report, we focus only on the quantifiable, grid-related consequences.
- The climate projections shown above quantify the threat or hazard, through the projected values of each climate hazard.

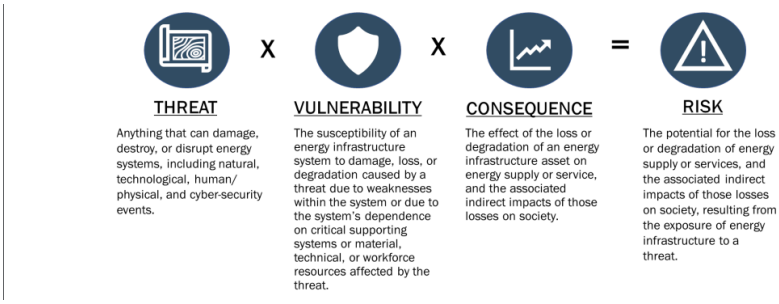


Figure 35. DOE's definitions of risk and its components[22]

The focus of Phase I of the CVA will be on the hazard- asset pairs that were determined to have a high vulnerability, as indicated in red in the table below. Yellow values indicate moderate vulnerability asset-hazard pair and green cells indicate low vulnerability asset-hazard pair. In what follows, after determining the asset type that is vulnerable or highly impacted by a specific climate hazard, we outline the methodology used to identify the subset of each asset type that is exposed to the hazard and the its sensitivity or exposure levels, based on granular spatial analysis.

Table 3 provides a qualitative comparison of the consequences of an outage affecting each asset type. Red indicates large and/ or widespread impacts, yellow indicates moderate impacts and green indicates lower impacts.

[21] https://www.energy.gov/sites/default/files/2024-08/DOE%20Risk%20Mitigation%20Approach%20Guidebook%20for%20States_0.pdf

[22] https://www.energy.gov/sites/default/files/2024-05/DOE%20CESER-Risk%20Assessment%20Essentials%20Guide%20for%20State%20Energy%20Security%20Plans.pdf

Phase II of the climate vulnerability study that is expected to commence in 2026 will include those hazards and assets that have moderate and low vulnerability relationships, as indicated in yellow and green respectively in the Table below.

Table 2. Qualitative relationships of vulnerability of asset types to climate hazards

Climate Hazard/ Asset Type	Bulk Station	Bulk Station Transformer	Overhead Equipment	Underground Equipment
Temperature				
Precipitation				
Drought				
Wind				
Sea Level Rise				
Storm Surge				

Table 3. Qualitative matrix of consequences of failures by asset type

	Consequences
Bulk Station	
Bulk Station Transformer	
Overhead Equipment	
Underground Equipment	

Exposure of Bulk Stations to Sea Level Rise

The analysis of the impacts of sea level rise to bulk stations is performed in our ArcGIS systems. The sea level rise projections from NOAA's sea level rise viewer are ingested in our GIS system. Then, for every station location, the water depth above ground at each station location for each sea level rise scenario can be exported.

Additionally, since these are projections, our modeling logic also flags the stations whose distance to the sea changed significantly, by 10% or more compared to current distance to coastal water by 2050 and by 15% or more compared to current distance by 2080.

A case-by-case visualization reveals a shortcoming of this methodology; while the specific location of the station may be projected to not have flooding due to sea level rise, if the surrounding area is projected to incur sea level rise-caused flooding, access to the station could be lost.

We note that flooding levels at the location of a station because of sea level rise do not necessarily mean that the station and its equipment are inundated. This is because (i) these sea level rise values are future projections and may or may not materialize and (ii) current substation elevation standards may be adequate to protect station assets from sea level rise even without modification.

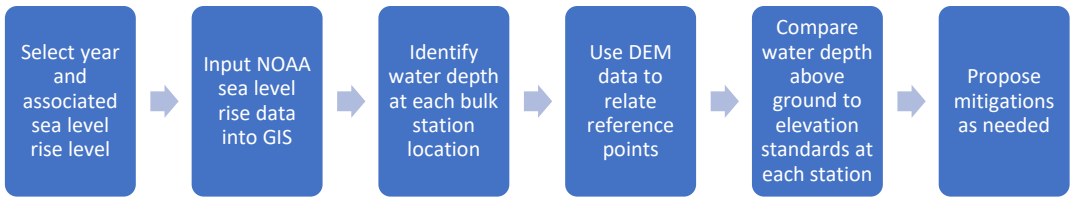


Figure 36. Methodology and inputs to identify bulk stations exposed to sea level rise-caused flooding

Substation elevation standards are currently, in typical utility practice, created based on FEMA's 100-year floodplain maps, that show water depths when a 1-in-100 years hurricane occurs. These may be higher than the sea level rise projections.

However, as mentioned above, NOAA Sea Level Rise viewer and SLOSH viewer report water depth in feet above ground. FEMA 100-year flood plain's Base Flood Elevation (or the flooding levels in a 1-in-a-100-years hurricane) results are in reference to NAVD88 reference point.

New Substations

Substation elevation standards are currently created based on FEMA's 100-year floodplain maps, that show depth of water above ground when a 1-in-100 years hurricane occurs. These may be higher than the NOAA sea level rise projections.

New substation elevation standards should also be based on sea level rise projections. Based on the fundamentals of the NOAA models, it is a very conservative estimate to add projected sea level rise water depths to storm surge-caused flooding, like those projected under the FEMA 100-year flood levels or the NOAA storm surge. Therefore, some middle ground that balances cost efficiency and high levels of flooding mitigation should be targeted.

New Substations

Substation elevation standards are currently created based on FEMA's 100-year floodplain maps, that show depth of water above ground when a 1-in-100 years hurricane occurs. These may be higher than the sea level rise projections.

New substation elevation standards should also be based on sea level rise projections. Based on the fundamentals of the NOAA models, it is a very conservative estimate to add projected sea level rise water depths to storm surge-caused flooding, like those projected under the FEMA 100-year flood levels or the NOAA storm surge. Therefore, some middle

ground that balances cost efficiency and high levels of flooding mitigation should be targeted.

Existing Substations

As can be seen below, no substation locations are projected to incur flooding due to sea level rise by 2050. Two (2) bulk substations are flagged because their distance to coastal water is projected to decrease by more than 10% from current values.

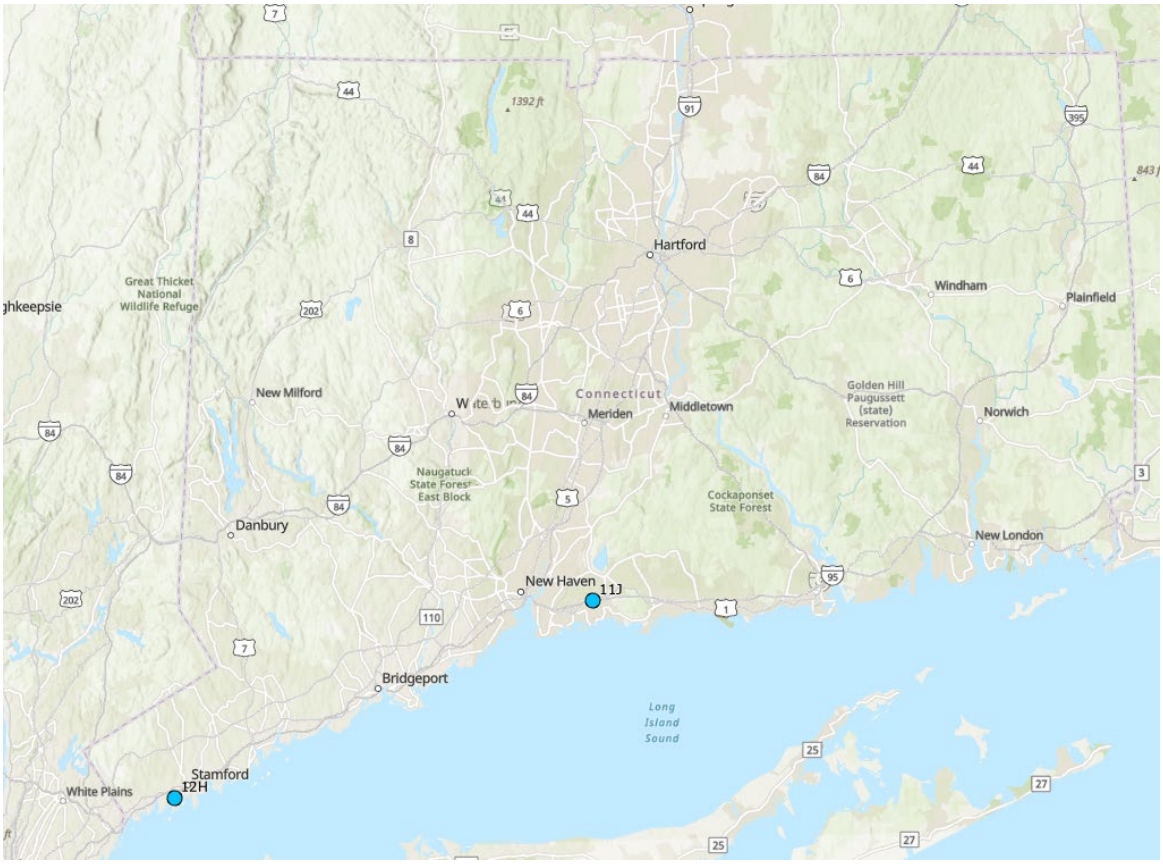


Figure 37. Substations impacted by sea level rise, 2050.

NOAA sea level rise projections for 2080 result in one (1) more bulk station location being flagged for decreased distance to the coastal water. Figure 38 below shows the total of three (3) bulk stations flagged in 2080.

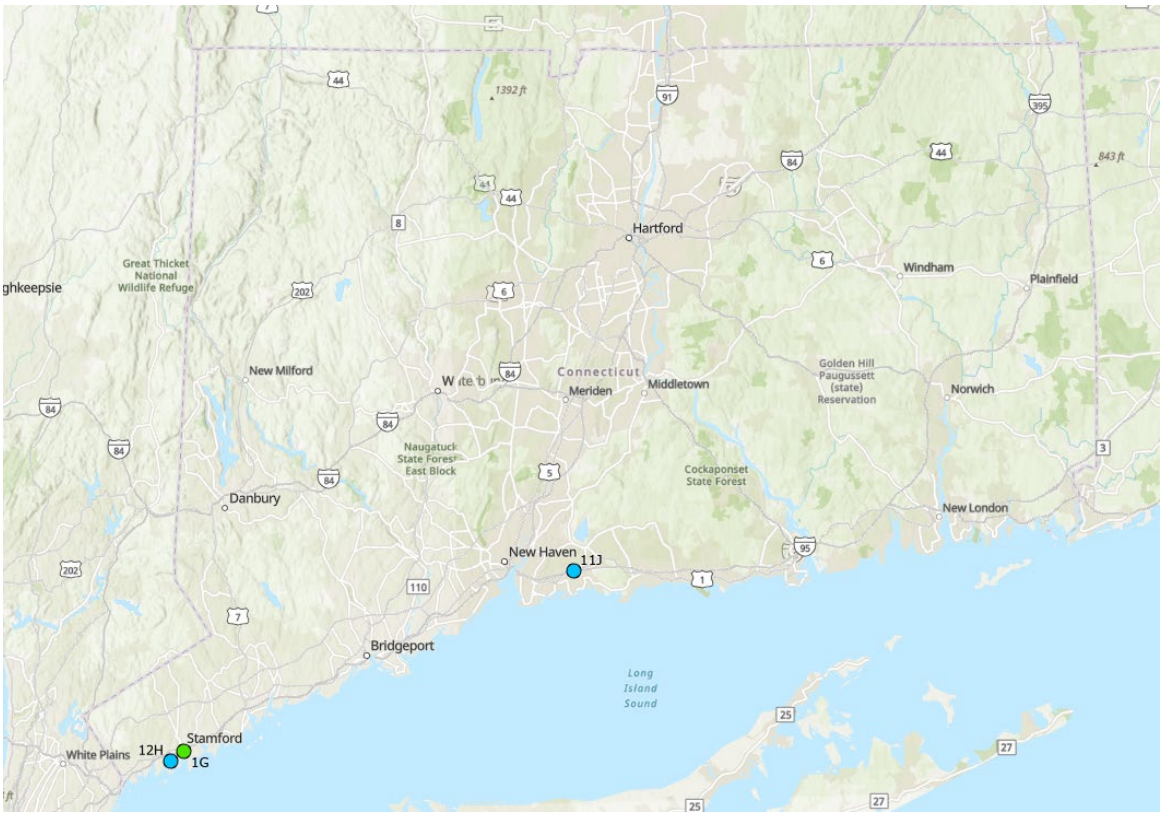


Figure 38. Substations impacted by sea level rise, 2080.

Sensitivity Analysis

To evaluate the robustness of the coastal encroachment flagging methodology and create a list of stations to review across a range of scenarios, a sensitivity analysis was conducted by varying the percent distance change, ϕ, from the station to the water in the 2050 2-feet sea level rise scenario as compared to today.

$$I_{flagged}(S_i) = \begin{cases} 1, \text{ if } d_{SLR}(S_i) = 0 \mid \dfrac{\Delta d(S_i)}{d_0(S_i)} \geq \phi \\ 0, \text{ otherwise} \end{cases}$$

Where $d_0(S_i)$ is present-day shortest distance from each substation S_i, $d_{SLR}(S_i)$ is projected coastline under a 2-ft SLR scenario distance to each substation S_i and $\Delta d(S_i)$ is total change in distance.

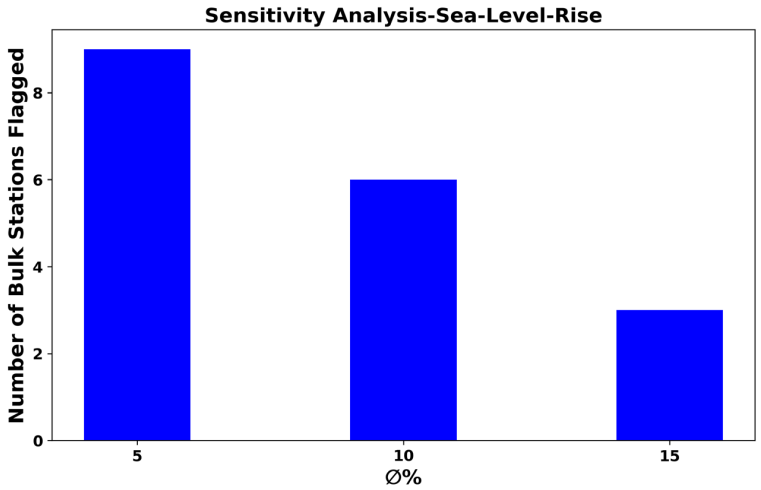


Figure 39. Sensitivity analysis of stations flagged for sea level rise impacts.

The analysis revealed that lower threshold values (e.g., ϕ < 5%) resulted in a higher number of flagged substations. Conversely, higher thresholds (e.g., ϕ > 15%) reduced the number of flagged sites. A threshold of ϕ = 10% was selected as a balanced value Notably, the maximum observed shift in substation exposure due to sea level rise was 89% increase in vulnerability from the current coastline, attributed to a projected 2-foot SLR scenario.

Exposure of Bulk Stations to Storm Surge

The analysis of the impacts of storm surge to stations is performed in our ArcGIS system. The sea level rise results from NOAA's SLOSH model are ingested in our GIS system. Then, for every station location, the water depth for Hurricane 1, Hurricane 2 and Hurricane 3 can be identified and compared with existing station equipment elevation level.

Per NOAA's classification and ranking, Hurricane 3 is of higher intensity than a Hurricane 2 and similarly, Hurricane 2 is of higher intensity than a Hurricane 1[23]. Based on a historical analysis of hurricanes that occurred in our territory, the analysis will focus on Hurricane 1, as a higher probability event. The last occurrence of a Hurricane 1 in the Eversource territory was in 1991, while the last occurrence of a Hurricane 2 was in 1954 and the last occurrence of a Hurricane 3 was in 1938.

23 https://www.weather.gov/mfl/saffirsimpson#:~:text=Hurricanes%20reaching%20Category%203%20and,however%2C%20and%20require%20preventative%20measures

The following workflow showcases the inputs and methodology to identify bulk stations vulnerable to coastal flooding due to Hurricane Cat 1 caused storm surge.

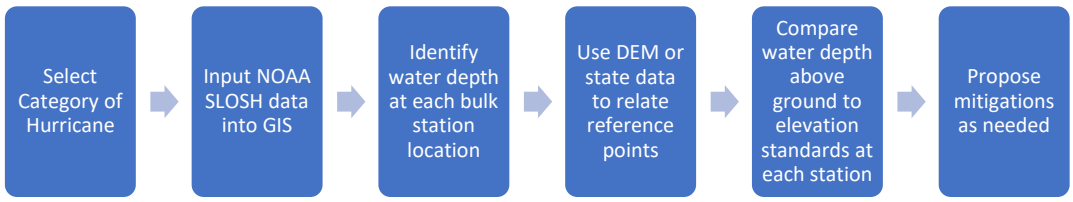


Figure 40. Methodology and inputs to identify bulk stations exposed to storm surge-caused flooding

The maximum projected water levels due to storm surge upon the occurrence of a Category 1 hurricane is 6 feet across all station locations. To validate this number, historically, during Hurricane Bob, which was a Category 2 hurricane that hit Massachusetts in 1991, water depths were as high as 10 feet and over around Buzzards Bay.

Substation elevation standards are currently created based on FEMA's 100-year floodplain maps, that show water levels above ground when a 1-in-100 years hurricane (also referred to as a flood with 1% probability of occurrence) occurs. NOAA SLOSH results are in feet and relative to NAVD88, similar to FEMA 100-year floodplains[24].

Existing Stations

One (1) bulk substation locations that could be subject to flooding due to storm surge of a Hurricane 1. This bulk station is also flagged for decreased distance to water (but not flooding) due to sea level rise.

- When projected water levels exceed the minimum substation equipment elevation by less than 2 feet, a possible mitigation is flood walls or other deployable solutions like pumps and sandbags.
- When the minimum substation equipment elevation covers the projected water levels but with a narrow headroom, a possible mitigation is flood walls or other deployables like sandbags.
- When the projected water levels exceed the minimum substation equipment elevation by more than 2 feet or when a station is also projected to have flooding

[24] https://cteco.maps.arcgis.com/apps/webappviewer/index.html?id=c137b950f1db47c6982f7279e23a2345

due to sea level rise, mitigations like station elevation or relocation should be considered.

- When the minimum substation equipment elevation covers the projected water levels with a sufficient headroom, no mitigations are proposed.

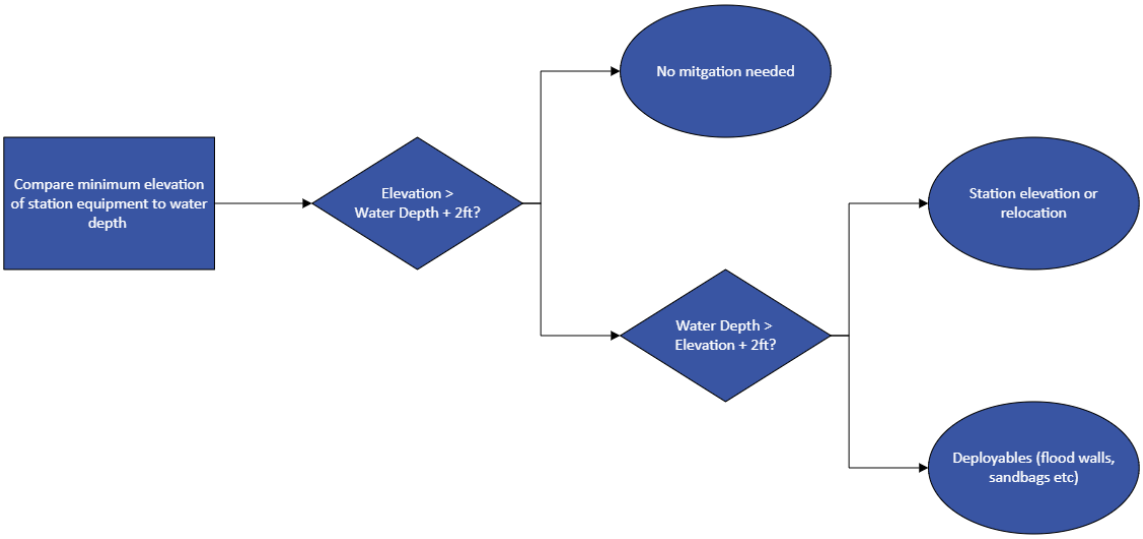


Figure 41. Methodology to identify mitigations for bulk stations exposed to storm surge

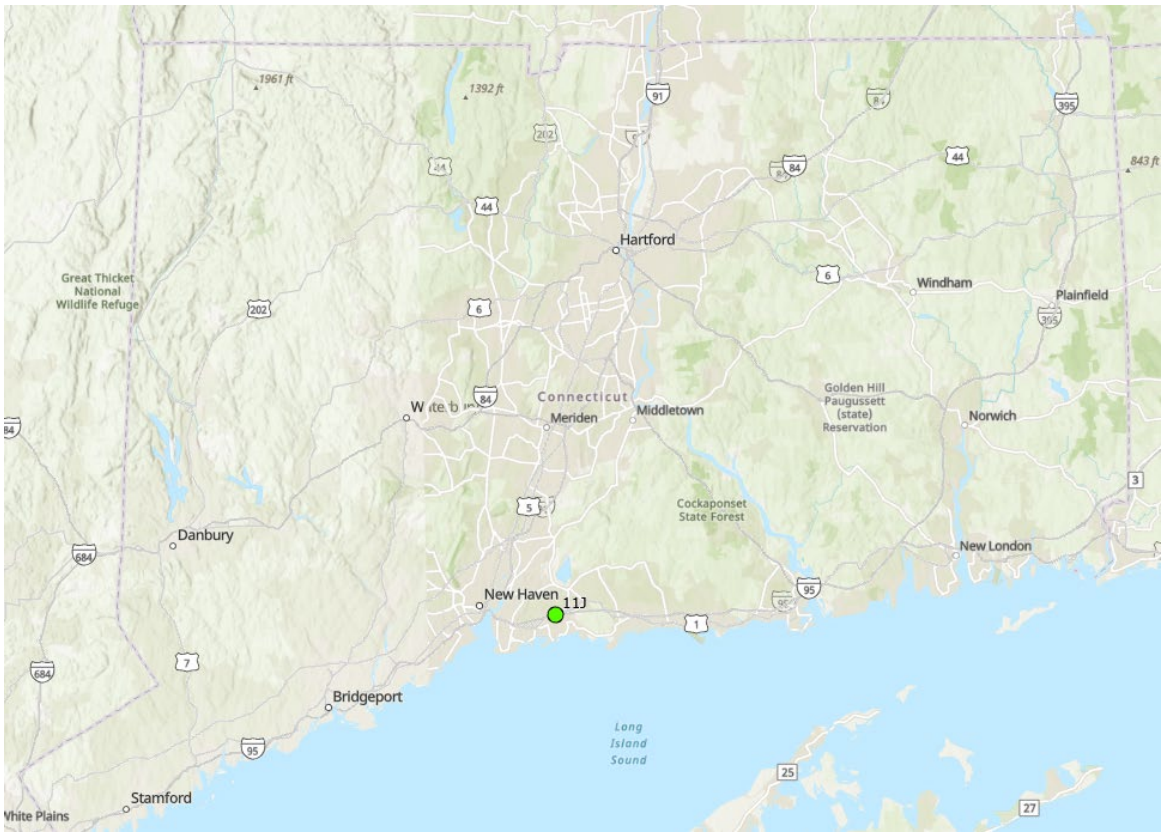


Figure 42. Hurricane 1 impacted stations in Connecticut

Building redundancies by connecting stations or feeders with ties could lessen the consequences of a station flooding event or proactive shutdown of a station due to forecasted flooding.

Other solutions that could lessen the impact of storm surge to stations, but need collaborations with other stakeholders, could be creating pathways for flood water to divert to and be collected.

Exposure of Bulk Stations to Inland Flooding.

While coastal regions and substation locations are potentially subject to sea level rise and storm surge impacts, inland substation locations could be susceptible to flooding due to precipitation.

The climate vulnerability study used 5-day total precipitation forecasts as a measure to quantify potential precipitation. Projected precipitation in 2050 showed the highest 5-day projected precipitation total at 6.5 inches, with the highest single-day total at 3.9 inches.

As part of this report and similar to storm surge, these projections were compared to historical data to ensure applicability. These projected values were significantly lower than what has been observed in historical data. This discrepancy is because global climate models project over longer timescales but the most severe flooding is typically the result of flash floods, which occur over just a few hours. For example, in September 2021, [25] Seymour and Oxford in Connecticut experienced a flash flood with over 9 inches of rainfall in just 1 day. In August 2011, Waterbury [26] saw nearly 6 inches of rain in just 4 hours.

In other words, using a 5-day average metric may not fully capture the impacts of these events, but there are no variables in global climate models that can capture such short-run precipitation and its impact. Understanding the timing and intensity of rainfall is critical for predicting flash flooding, and the CVA precipitation projections, while useful for longer-term trends, did not offer the needed inputs for long-term, targeted investments against precipitation-caused flooding.

Existing Stations

We have mapped all non-coastal substations using ArcGIS. Additionally, the USGS DEM (Digital Elevation Model) is used to obtain the ground elevation for each substation. The USGS DEM provides high-resolution elevation data, which is crucial for accurately analyzing terrain characteristics and identifying substations situated at the lowest elevation points, particularly in areas prone to pluvial (surface water) and fluvial (river) flooding.

[25] https://en.wikipedia.org/wiki/Effects_of_Hurricane_Ida_in_the_Northeastern_United_States#:~:text=During%20the%20storm%2C%20the%20first,down%20three%20large%20oak%20trees.

[26] https://mountwashington.org/disaster-in-the-naugatuck-river-valley/#:~:text=Over%20the%20course%20of%20just,with%20heavy%20rain%20and%20flooding.

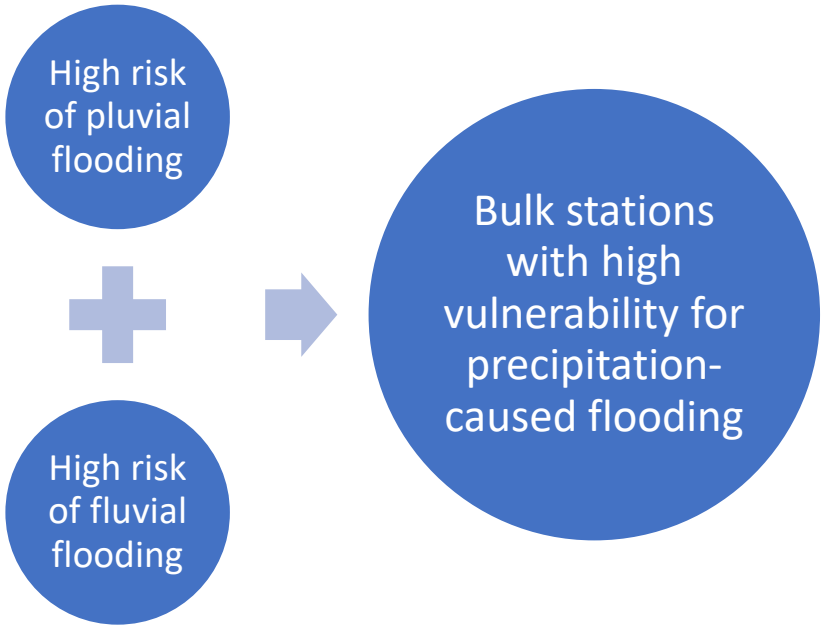


Figure 43. Methodology to identify bulk stations exposed to precipitation-caused flooding

Step 1- Pluvial Flooding Risk: Elevation Analysis within a 0.5-Mile Radius

In the first step, the potential of each station location for pluvial flooding is evaluated. USGS DEM data is utilized to extract elevation values for the exact location of the station and for an additional 10 randomly generated points within a 0.5-mile radius around each substation. These points serve as reference locations to compare the elevation of the surrounding area with the substation's elevation, also obtained from the DEM dataset.

By comparing the elevation of these surrounding points with the substation itself, we can determine whether the substation is located at the lowest elevation relative to its immediate surroundings. This is particularly important for pluvial flooding, where rainwater can accumulate in low-lying areas with poor drainage. Ensuring the analysis reflects accurate topographical data from the DEM helps identify substations vulnerable to surface water accumulation.

Step 2- Fluvial Flooding Risk: Proximity to Water Bodies

For the second step, we analyze the proximity of inland substations to water bodies, such as lakes, ponds, and rivers, as an indicator of the risk of fluvial flooding. Substations situated next to rivers or ponds are particularly vulnerable to fluvial flooding when water levels rise.

Our process identifies stations that are located within certain distance from any water body. This is done using GIS tools in combination with the USGS DEM and hydrography layers. The USGS DEM further helps identify the land contours around these bodies of water, enhancing the precision of determining which substations are at risk due to rising water levels.

Step 3: Intersection of Elevation and Proximity Criteria

Finally, we identify substations that meet both criteria: those located at the lowest elevation within the 0.5-mile radius and those within 200 feet of a water body. Substations that meet both conditions are flagged as being at risk from both pluvial and fluvial flooding.

Flagging substations located near rivers, ponds, or other water bodies, combined with their low elevation, ensures that we prioritize those most vulnerable to surface water accumulation and overflowing water bodies. This process ensures that substations at risk from multiple flooding scenarios are highlighted for further action or mitigation.

Below is the example of flagged station for precipitation-caused flooding. As the GIS snapshot reveals, the station location is adjacent to a river, and its elevation is low, as evaluated by comparing to the elevation of 10 randomly generated points within the surrounding area (5 out of the 10 randomly generated points in the 0.5-mile radius are shown).

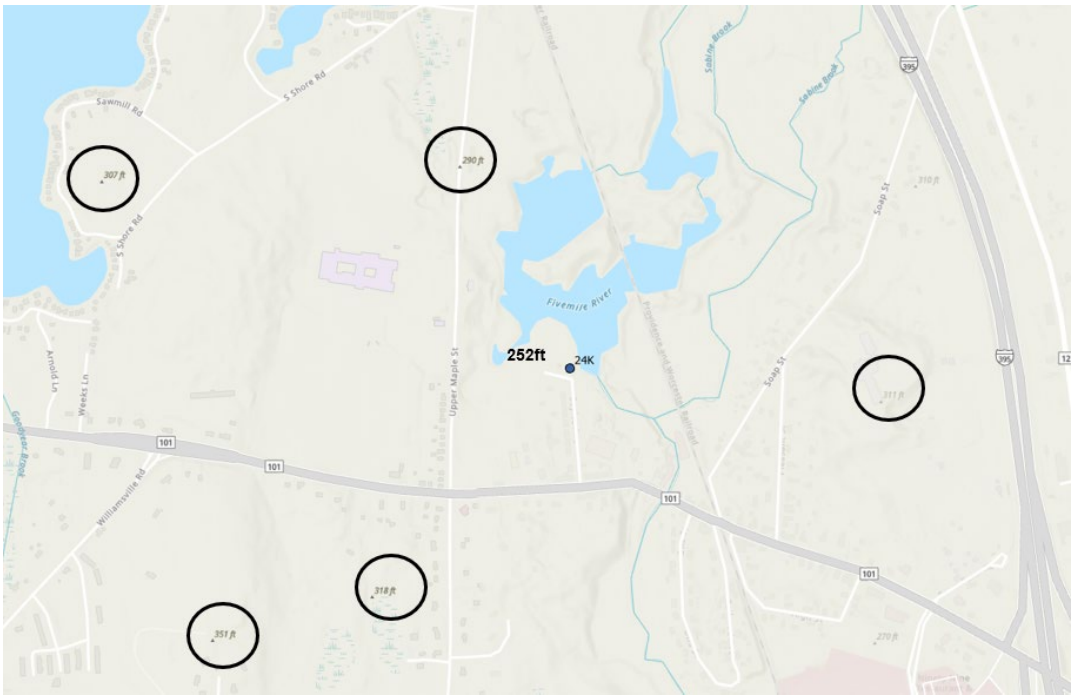


Figure 44. Example of station flagged for inland flooding due to precipitation

There are three (3) substations in Connecticut flagged for inland flooding risk.

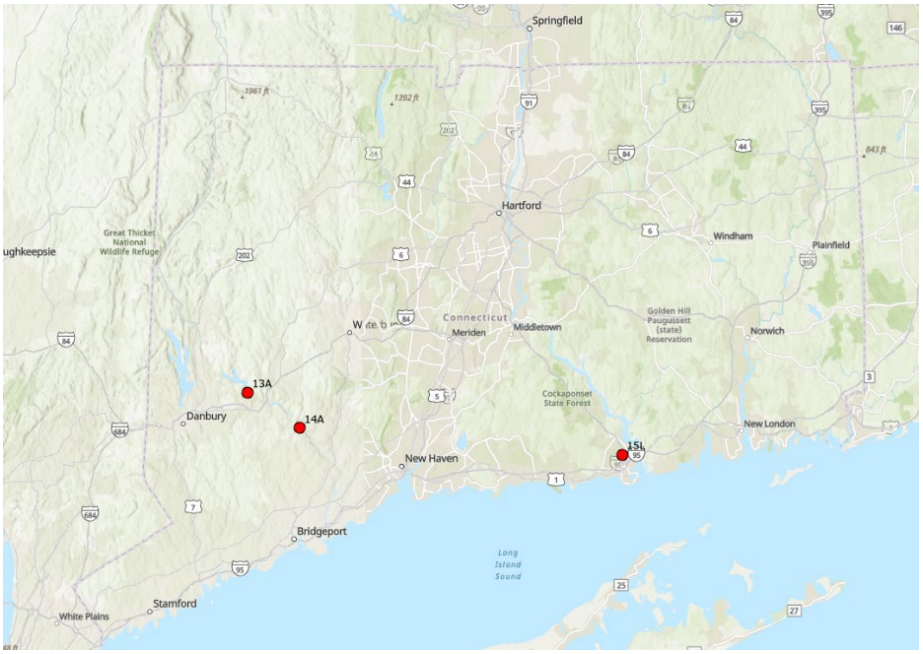


Figure 45. Inland flooding impacted stations in Connecticut

To safeguard against potential flooding, we recommend installing improved drainage systems to manage surface water accumulation, particularly in areas of low elevation. Additionally, deploying flood barriers or berms around substations near rivers, ponds, or lakes can prevent water ingress during extreme weather events. Waterproofing electrical components and elevating critical infrastructure can provide further protection in the absence of predictive flood data. Although the lack of inland flooding history complicates forecasting, proactive measures can significantly reduce the risk of damage and ensure the reliability of power distribution in these flood-prone areas. These steps will help mitigate the effects of potential floods and protect essential infrastructure.

Building redundancies by connecting stations or feeders with ties could lessen the consequences of a station flooding event or proactive shutdown of a station due to forecasted flooding.

Other solutions that could lessen the impact of storm surge to stations, but need collaborations with other stakeholders, could be creating pathways for flood water to divert to and be collected.

Sensitivity Analysis

To evaluate pluvial flooding risk, the variable over which we perform sensitivity analysis is the radius r_{S_i} around the station.

To evaluate fluvial flooding risk, the distance from each substation S_i to the nearest inland water body W_k (e.g., river, lake, or pond) was calculated using GIS spatial analysis. A substation is considered at risk for fluvial flooding if

$$\min_k \|\text{Location}(S_i) - \text{Location}(W_k)\| \leq \delta$$

Where δ represents a distance within which rising water levels may pose a flooding threat. Sensitivity analysis performed in III to evaluate the impact of varying δ.

Final substations that are at risk for pluvial and fluvial risk are flagged for further analysis. A sensitivity analysis was performed by varying the r_{S_i} (pluvial flooding) within a range of 0.25 miles to 2 miles and δ (fluvial flooding) with range of 50 meters to 500 meters. This range aligns with FEMA's Risk MAP, which emphasizes localized flood risk assessments and infrastructure vulnerability and FEMA's Flood Insurance Rate Maps (FIRMs), where flood risk is not binary but varies with distance from water bodies.

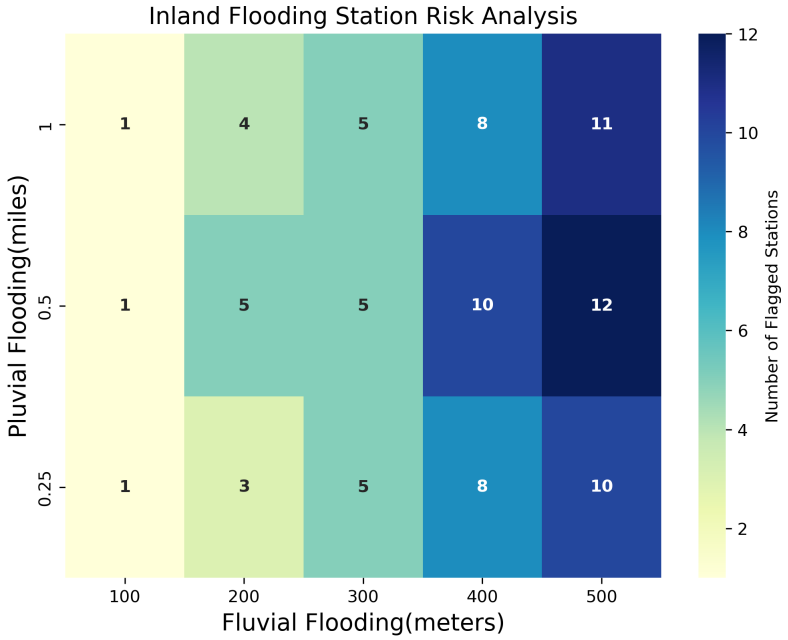


Figure 46. Bulk stations flagged for inland flooding due to precipitation

New Stations

We plan to use the same methodology to assess the risk of potential station locations to inland flooding and select optimal locations in the vicinity of a load pocket from an inland flooding perspective.

Exposure of Overhead Infrastructure to Wind Gust

In 2021-2024, the highest 15-minute wind speed observed in Connecticut was 48 meters per second or 107 miles per hour (observed in 2023).

The highest 15-minute wind gust speed observed in Connecticut in 2023 was 143 meters per second or 320 miles per hour. These are observed in the Berlin weather station.

The highest 15-minute wind gust speed observed in Connecticut in 2024 was 99 meters per second or 221 miles per hour. These are observed in the Berlin weather station.

NESC standards for heavy loading areas, which New England falls under, requires storm loadings of 0.5 inches of radial ice thickness and 40-mph winds. Eversource uses 130 mph wind speeds for guying. For poles, Eversource has further upgraded its Standards to 95 mph winds or 0.75 inches of radial ice thickness with a 40-mph wind. While poles with more equipment (and therefore more weight) mount to them may be more susceptible to winds, the historical wind values have a sufficient headroom compared to the design strengths of poles. Therefore, we conclude that the poles and conductors

should remain unaffected by wind directly and impacts to overhead infrastructure during wind events is due to the interference of trees.

We note that the projected wind speeds in the CVA were also well below the design standards outlined above and therefore are not expected to affect overhead infrastructure directly, but only indirectly due to the interference of trees.

Another shortcoming of the wind projections is that wind-related interruptions are known to correlate with wind gust speeds rather than wind speed. Therefore, the analysis of the risk due to wind events was performed using historical outage information and historical wind gust data.

Analysis of historical tree events was focused on tree-caused events from 2018-2023. The following graphs show that there are more tree-caused interruptions during leaf on periods (Q3) than leaf off periods (Q1).

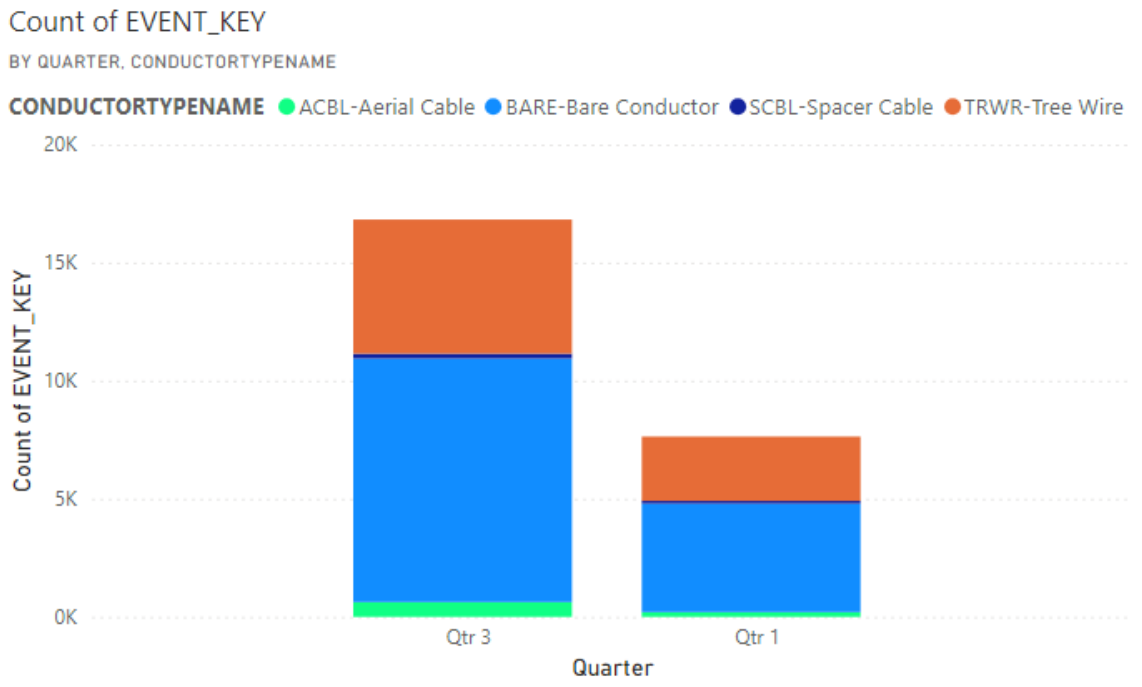


Figure 47. Number of events by conductor type during leaf on and leaf off periods, 2020-2023

Breaking this down into conductor type for each of the two quarters, the decrease in the number of events between leaf off and leaf on periods is more than 45% for all conductor types.

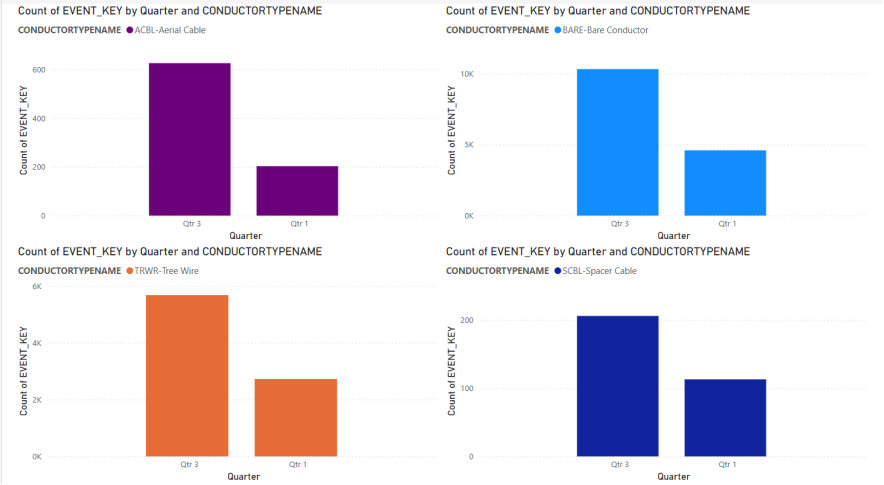
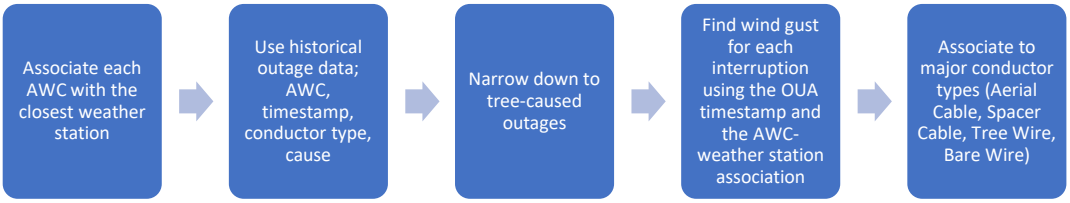


Figure 48. Number of events by conductor type during leaf on and leaf off periods, 2020-2023

A similar conclusion can be reached by cross-referencing wind gust speeds with interruptions. The following workflow shows the process followed to associate events with wind gust speeds.



As expected, bare conductors' breaking point, measured as the minimum wind gust speed resulting in an interruption, was found to be on average lower than that of spacer cable and tree wire. Specifically, spacer cable was found to incur tree-caused interruptions at wind gust speeds 17% higher than bare conductors, while tree wire at wind gust speeds 58% higher than bare conductors.

Further analysis of time under tension (by examining consecutive hours of wind or wind gusts before outage occurs) and concurrency with other conditions like precipitation, could be used to further refine these results.

We therefore prioritize the replacement of bare conductors with undergrounding or reconductoring to tree wire or performing vegetation work for zones that fall under the following criteria:

- Conductor is bare wire, and
- Had on average more than one (1) interruption per year in the examined 4-year period (2020-2023)

This results in evaluating the need for mitigations for approximately 148 bare conductor zones. Zones where the operating device is a fuse are proposed for replacement of the fuse with a TripSaver or lateral recloser (approximately 71 zones). The remaining 77 zones represent approximately 80 miles of bare conductor.

Following the table below for assumed cost and reduction of customer minutes of interruption (CMI) to mitigate zones that fall under the criteria above, the mitigation proposed is the one with the lowest cost efficiency metric of $/CMI (or $/CI).

Table 4. Percent reliability improvement and cost per mile of typically reliability programs.

Measure	SAIDI Improvement	Cost ($M/mile)
Undergrounding	98%	4
Aerial Cable	82%	2.2
Reconductoring (other)	50%	1.1
Vegetation	35%	0.1

Exposure of Bulk Station Transformers to Warming Temperatures

Overhead conductors and station and network transformers are sized and operated based on ambient temperature.

The ratings for station transformers and network transformers depend on ambient temperature, amongst other factors. In the Company's Standards, the transformer daily peak load standards and ANSI loading limits are expressed as percentages of the transformer's nameplate rating for summer normal, summer emergency, winter normal, and winter emergency. These assume a 0°C winter ambient and a 25°C summer ambient. For emergency rating calculations, an ambient temperature of 40°C is used for summer emergency rating and 10°C for winter emergency ratings. In a warming climate due to climate change, Eversource expects that those loading factors could need to be derated.

Considerations for transformer operations and sizing during planning shall depend on the projected loading of the transformer over time. Transformer loss of life is time-coupled, where the hottest spot temperature, which is the critical indicator of the transformer stress and associated loss of life, depends not only on the ambient temperature and the transformer load but also on the pre-existing temperature inside the transformer. In other words, loss of life for a transformer is accelerated when its hottest spot temperature is continuously high, in contrast with high periods followed by low load periods that allow

the transformer to cool down. The hottest spot temperature can be elevated continuously due to continuously high ambient temperatures, such as those in a heat wave. This hottest spot temperature rise is exacerbated by the fact that a heat wave increases demand and thus further increases transformer loadings. This is why the duration of heat waves, and the maximum daily temperatures are both highly influential climate variables for assessing the need to adapt transformer sizing and operating practices in the face of climate change.

Eversource utilizes EPRI's PTX tool to track transformer health and prioritize asset-health based transformer replacements based on a comprehensive risk assessment. Transformers whose hottest-spot temperature increases due to increased ambient temperatures and increased loads to cover rising cooling loads are expected to rank high in the PTX tool results and therefore be priorities for replacement with existing processes.

The first focus is on bulk station transformers that are located in areas where the average annual maximum temperature is high and there are multiple 2-day heat waves (heat waves here are defined as days where the maximum temperature exceeds 90th percentile of observed).

Sensitivity Analysis

A sensitivity analysis was conducted by varying:

- Temperature threshold (θ) from 95°F to 103°F
- Heat wave frequency (λ) from 8 to 12 two-day events per year

Analysis for SSP2-4.5 90th 2050 percentile scenario was done and results can be shown in Figure below.

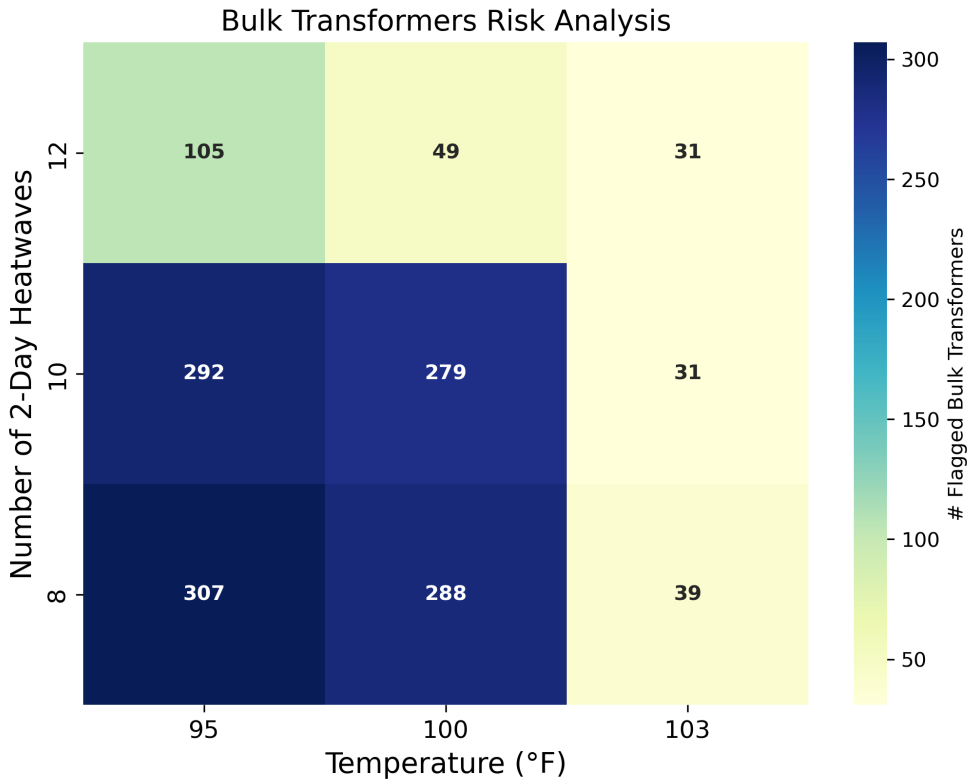


Figure 49. Sensitivity analysis of impact of rising temperature to station transformers

From above heat map based on number of stations flagged with θ as 100°F and 12 two-day heatwave events yields a focused list of substations where adaptation strategies such as derating, enhanced cooling, or accelerated replacement can be prioritized effectively. The following bar chart shows the number of bulk station transformers, where the projected maximum daily temperature exceeds 100°F and there are more than 12 two-day projected heatwave events, across all other scenarios considered.

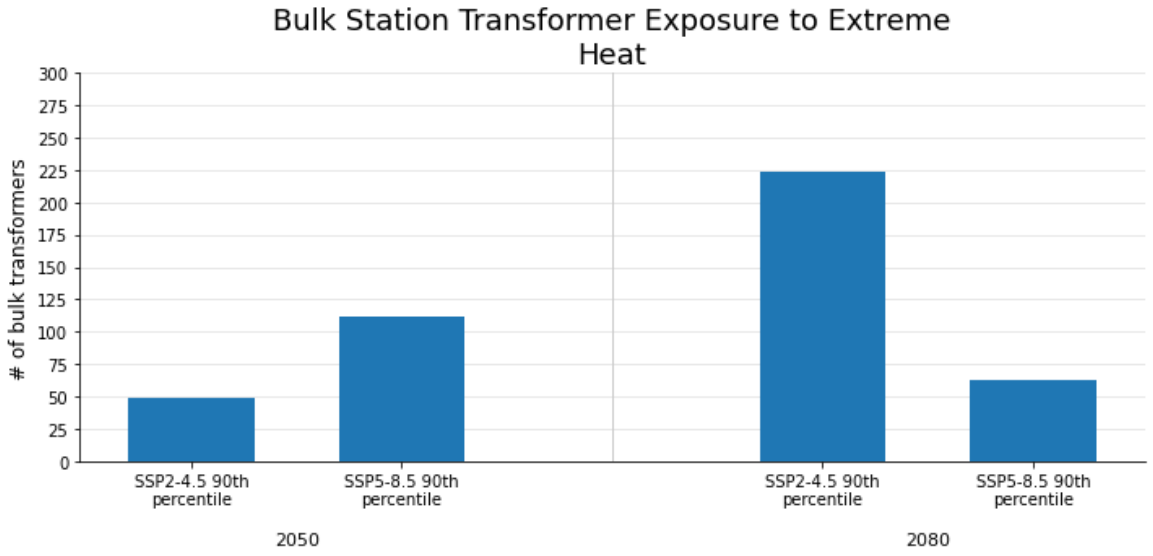


Figure 50. Summary of bulk transformers' exposure to extreme heat across multiple scenarios, 2050 and 2080 projections.

The map below shows the grids with average annual maximum temperature above 100F in blue, the grids with more than 12 projected 2-day heat waves in orange, and the grids with both average annual maximum temperature above 100F and more than 12 projected 2-day heat waves in red. The black dots represent the potentially exposed bulk stations. 49 bulk transformers in approximately 13 bulk stations are projected to be exposed to these two heat conditions under SSP2-4.5 90th percentile by 2050.

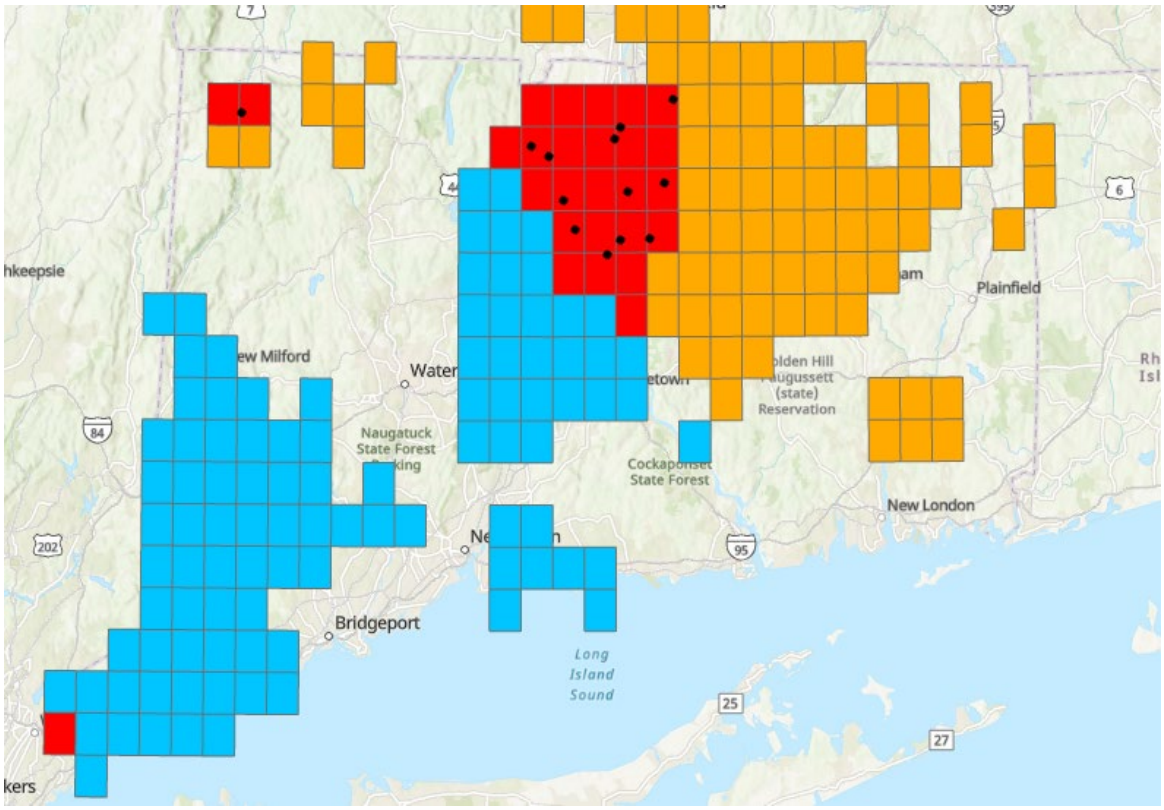


Figure 51. Locations with high maximum temperature and heat wave frequencies and bulk and distribution station locations under SSP2-4.5 90th percentile in 2050

In 2050, when using the SSP5-85 90th percentile, a much larger area, expanding more around Hartford, incurs average annual maximum temperatures above 100F and more than 12 2-day heat waves. 112 transformers in approximately 39 bulk stations are projected to be exposed to these two heat conditions under SSP5-8.5 90th percentile by 2050.

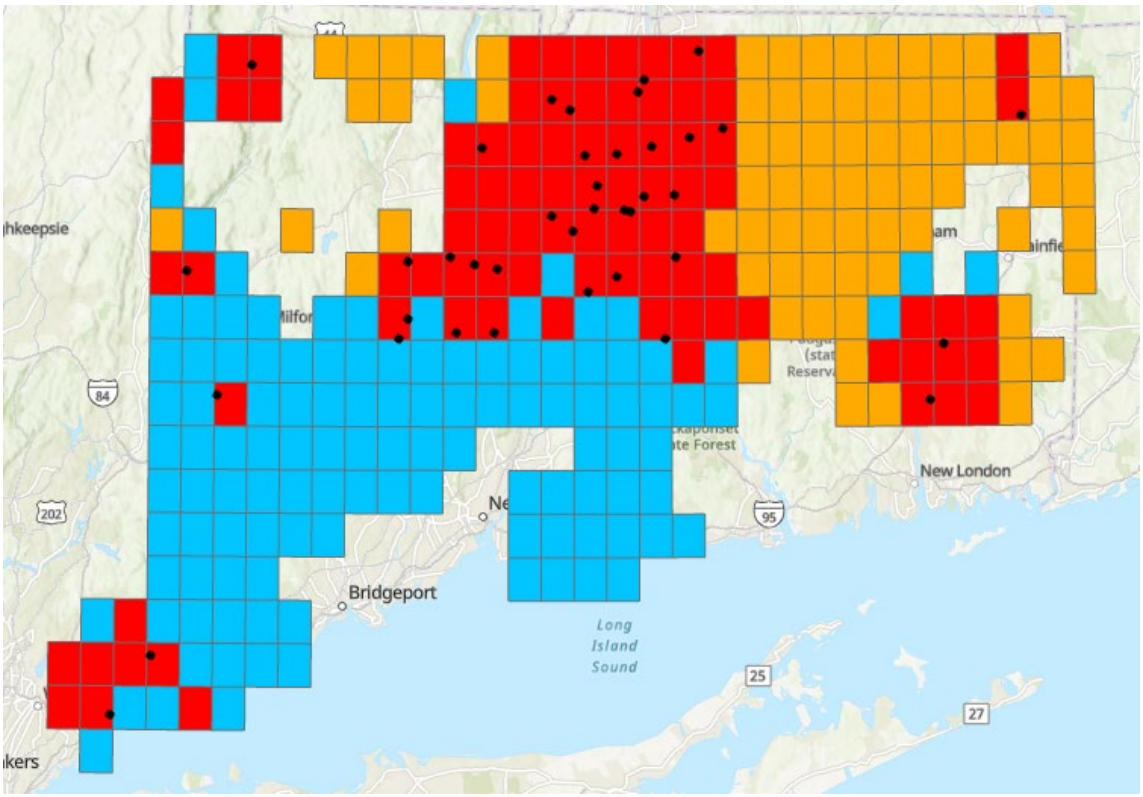


Figure 52. Locations with high maximum temperature and heat wave frequencies and distribution station locations under SSP5-8.5 90th percentile in 2050

In 2080, the SSP2-4.5 90th percentile projections show that an even larger geographical area, where most AWCs, with the exception of Newtown, Waterbury, Torrington, Madison and New London, incur average annual maximum temperatures above 100F and more than 12 2-day heat waves. 223 transformers in approximately 64 bulk stations are projected to be exposed to these two heat conditions under SSP2-4.5 90th percentile by 2080.

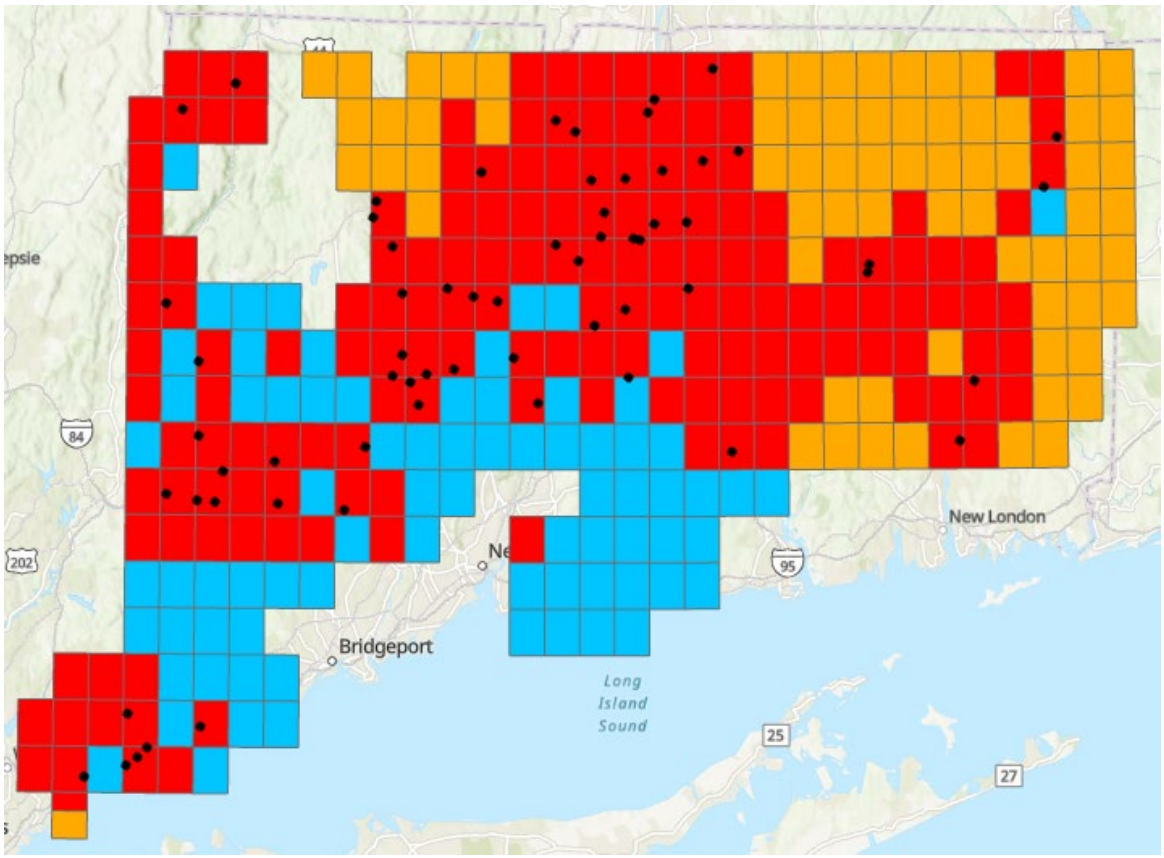


Figure 53. Locations with high maximum temperature and heat wave frequencies and distribution station locations under SSP2-4.5 90th percentile in 2080

In 2080, under the SSP5-85 90th percentile-based projections, the Northeast part of the state is projected to incur average annual maximum temperatures above 100F and more than 12 2-day heat waves. We note that, in this scenario, the affected territory where the two heat conditions concur, is reduced in the southwest and east of the state, compared to SSP2-4.5 90th percentile (also for 2080, see Figure 50). 63 transformers in approximately 30 bulk stations are projected to be exposed to these two heat conditions under SSP5-8.5 90th percentile by 2080.

While peak values of climate hazards typically increase and cover larger geographical areas in SSP5-8.5 compared to SSP2-4.5 and in 2080 compared to 2050, the ensemble of the coincidence of these two heat-related conditions resulted in a smaller geographical area (and hence a lower count of exposed bulk stations) with higher values at each grid under SSP5-8.5 90th percentile in 2080 compared to SSP2-4.5 90th percentile in 2080 and to SSP5-8.5 90th percentile in 2050.

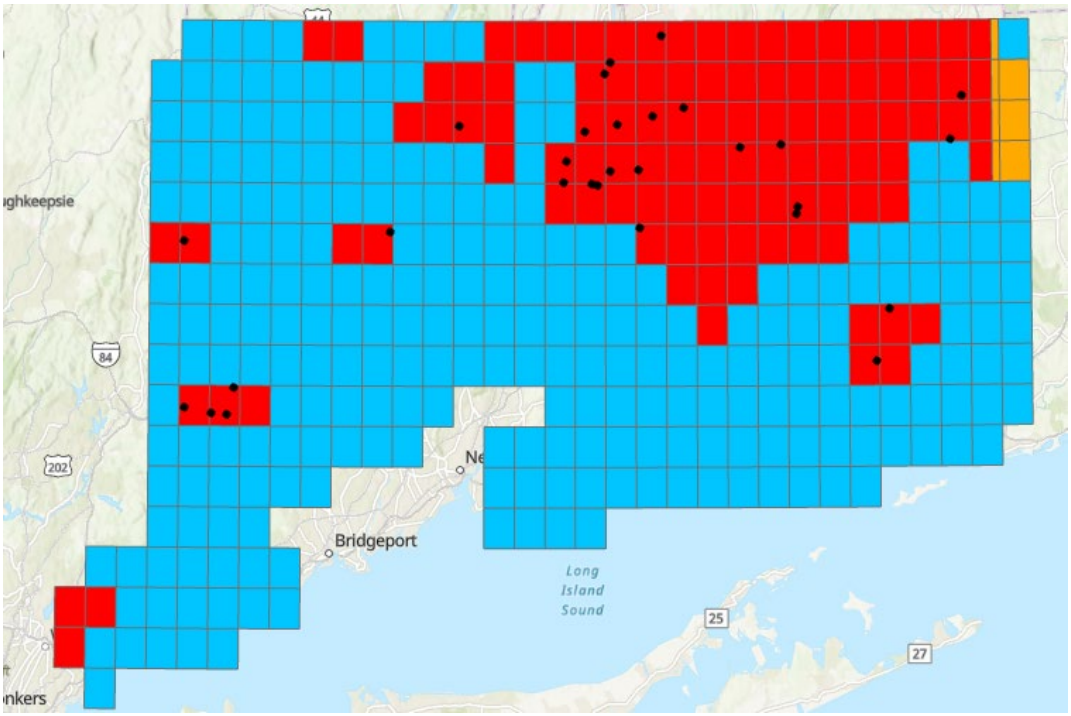


Figure 54. Locations with high maximum temperature and heat wave frequencies and distribution station locations under SSP5-8.5 90th percentile in 2080

Exposure of Overhead Conductors to Warming Temperatures

Overhead conductor rating is dependent on ambient temperature. The Company's Standards dictate a summer normal, summer emergency, winter normal, and winter emergency ampacity per conductor type and size based on assumptions on the average daily temperature. Specifically, the ambient temperature used for summer normal and emergency ampacity is 30C, while the ambient temperature used for the winter normal and emergency rating is 0C.

Using the number of days with average temperature more than 30C (or 86F), the following table summarizes the potential exposure of overhead conductors for each scenario and year. The 528 miles of overhead conductors that are exposed to high temperatures under SSP2-4.5 90th percentile in 2050 are also exposed to high temperatures also in all years and all scenarios and therefore are prioritized as higher risk.

We expect that a much smaller subset of the mileage reported here would need to be mitigated, primarily sections with increasing loads. Mitigation could be the derating of the conductor ampacity due to the warming climate expectation and/ or eventually the need to replace the conductor with higher ampacity conductor.

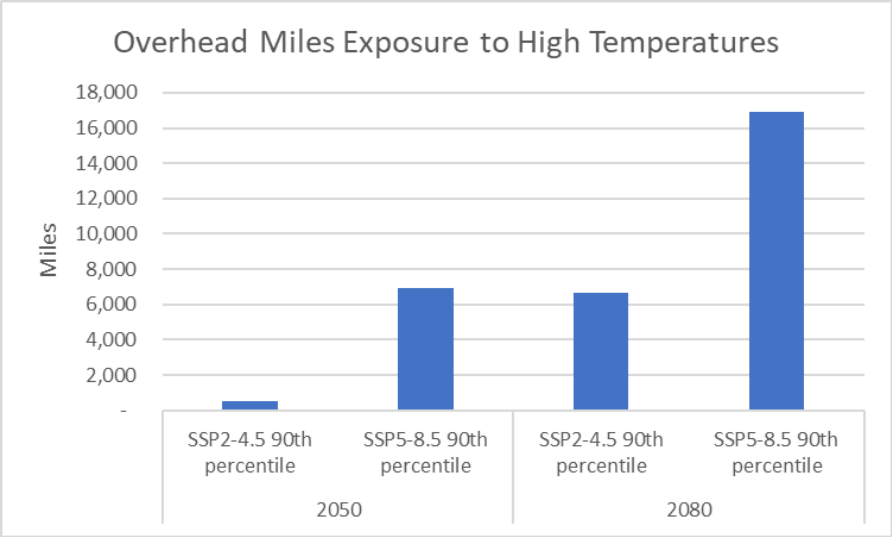


Figure 55. Summary of miles of overhead primary exposure to warming temperatures across multiple scenarios, 2050 and 2080 projections.

Eversource does not expect the ampacities of the underground cables to require derating due to climate-change related ambient temperature change.

Qualitative Assessment of Exposure of EJ Communities to Climate Hazards

This section showcases the latest efforts of the Company to align the projections for climate hazards with the location of Environmental Justice (EJ) communities. Below, the figures show the location of EJ communities relative to the grids where two conditions of extreme heat concur; average annual maximum temperature exceeds 100F and there are more than 12 2-day heat waves projected, in 2050 under two scenarios, SSP2-4.5 90th percentile and SSP4-5.8 90th percentile and in 2080 under the same two scenarios.

Most of the EJ communities around the coast close to Hartford are exposed to the two high heat conditions under all scenarios for 2050 and 2080. We note that the maps below show EJ communities in the entire state, including areas outside Eversource's electric territory, while the climate projection are only on Eversource's footprint.

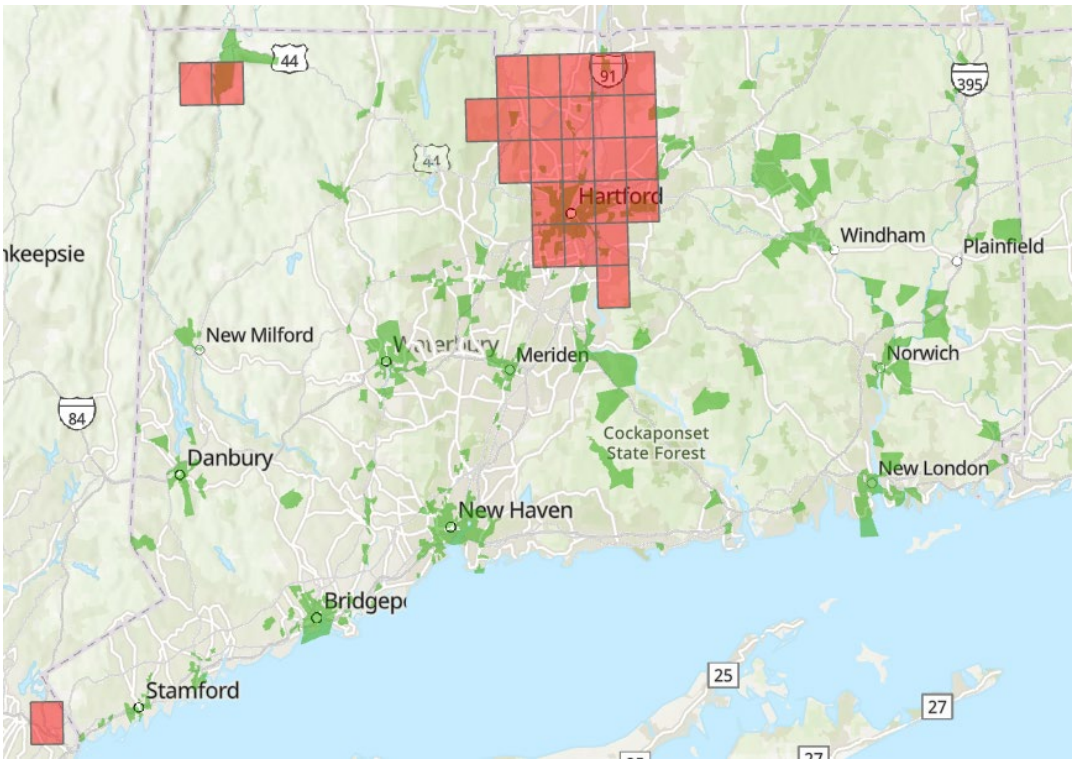


Figure 56. Environmental Justice Communities and high heat grids, 2050, SSP2-4.5 90th percentile.

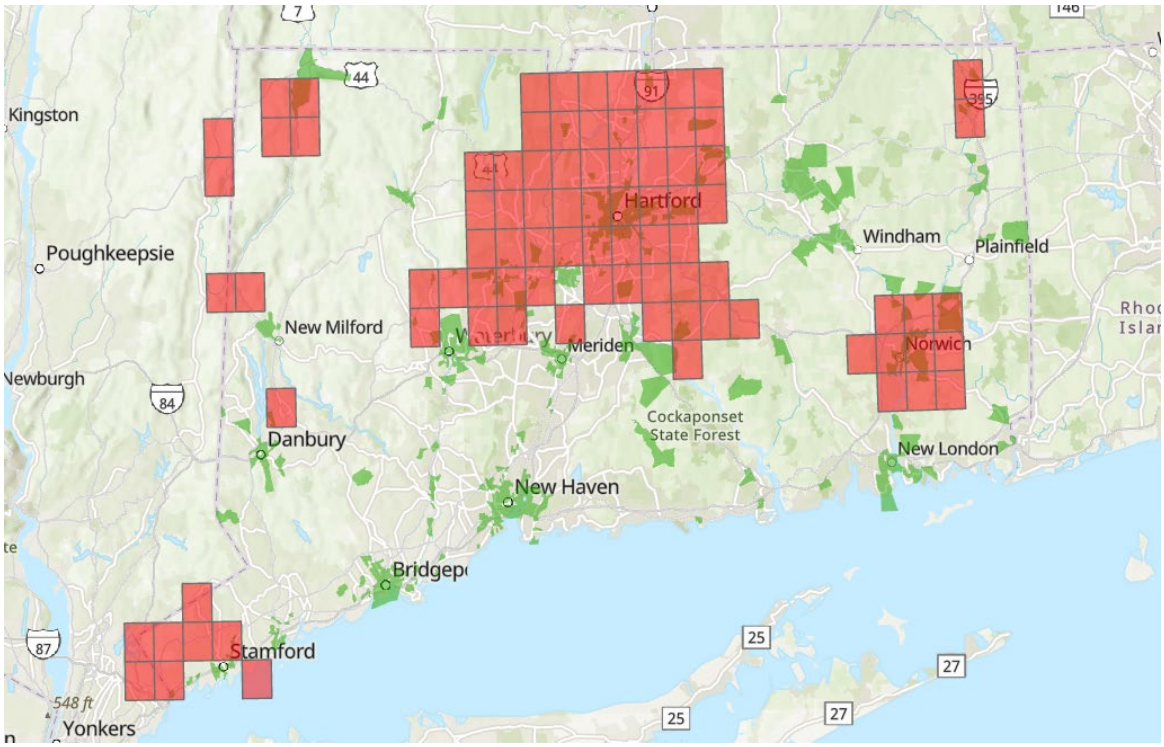


Figure 57. Environmental Justice Communities and high heat grids, 2050, SSP5-8.5 90th percentile.

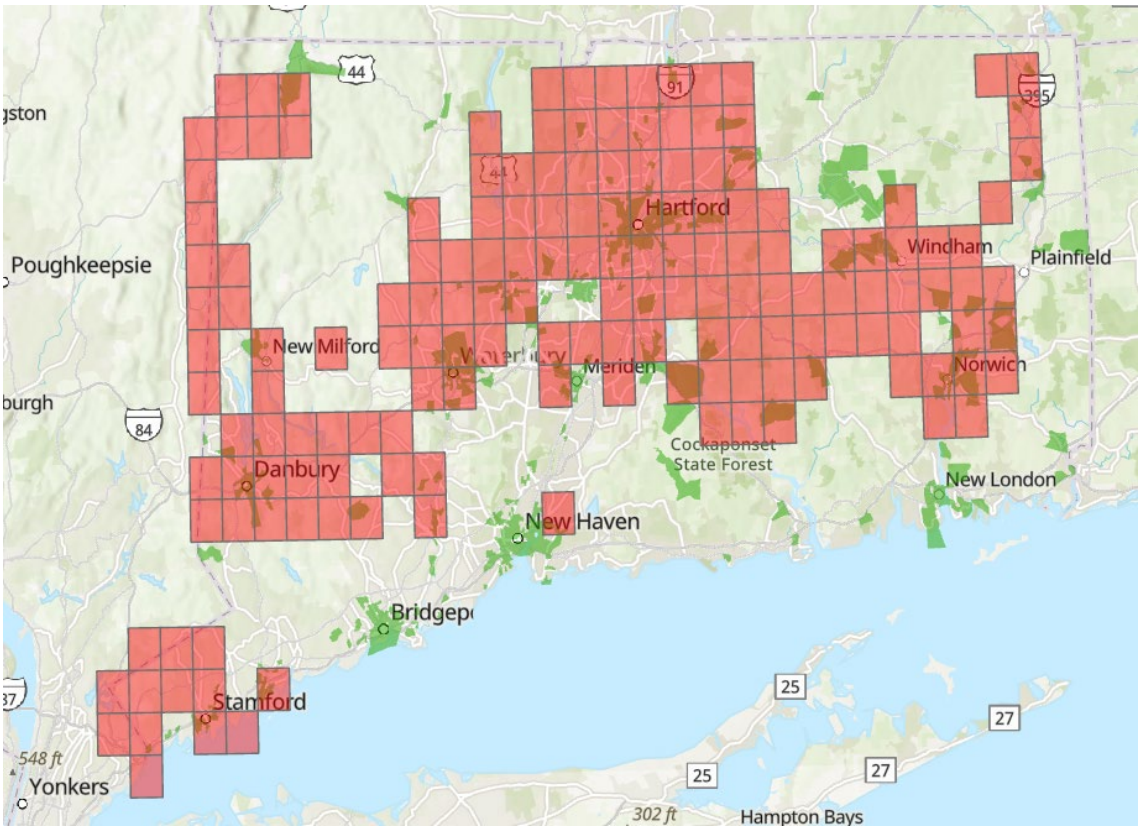


Figure 58. Environmental Justice Communities and high heat grids, 2080, SSP2-4.5 90th percentile.

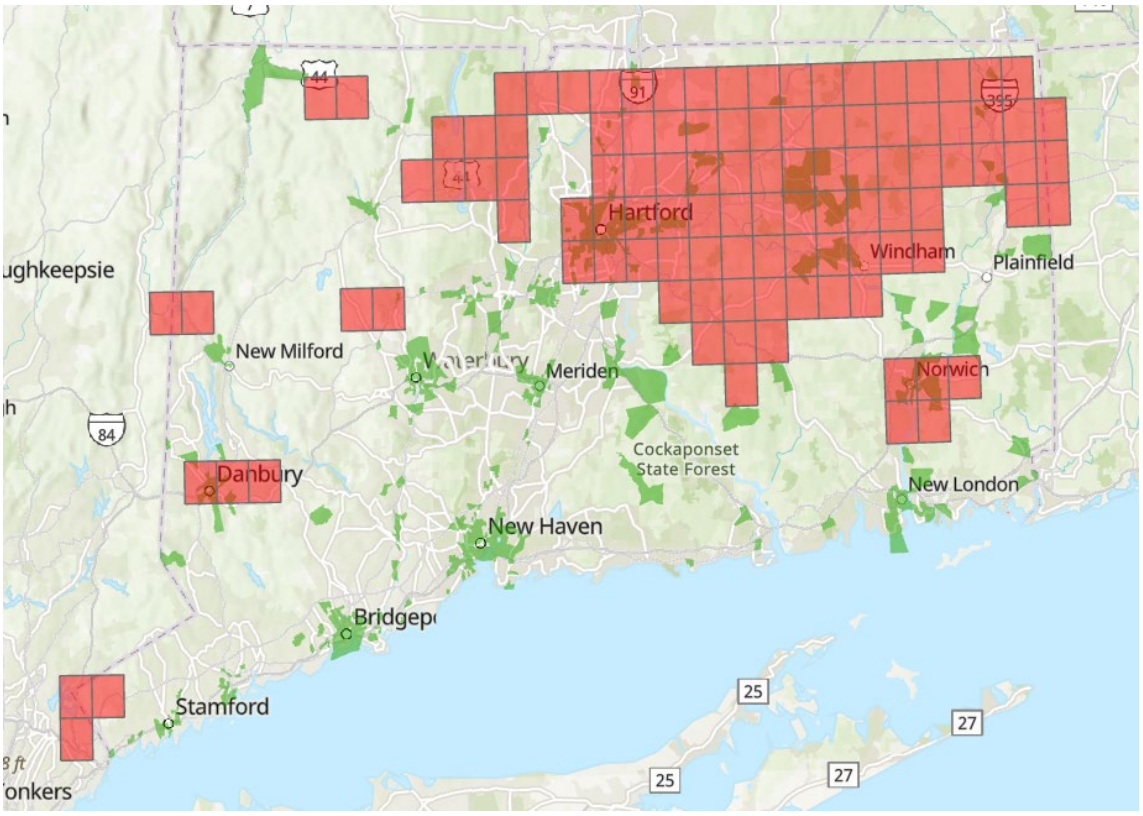


Figure 59. Environmental Justice Communities and high heat grids, 2080, SSP5-8.5 90th percentile.

The following figures show the EJ communities location in relation to the Cat 1 storm surge projections and the 2080 sea level rise of 3 feet.

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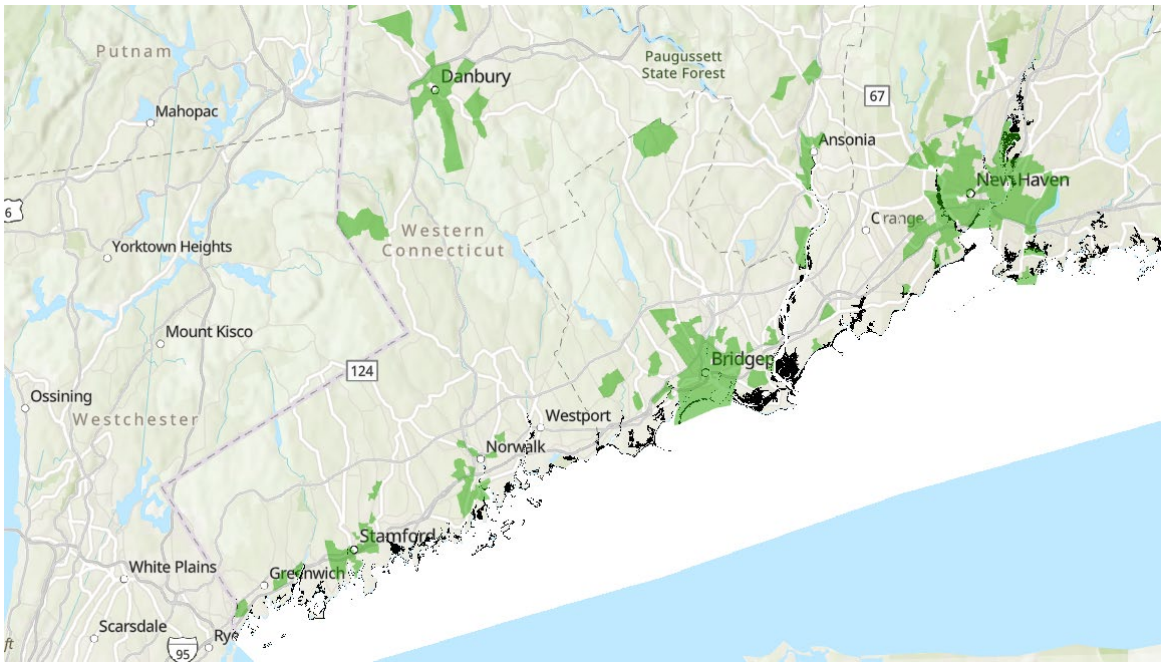

Figure 60. Environmental Justice Communities and 3-feet sea level rise, Stamford-Norwalk, 2080.

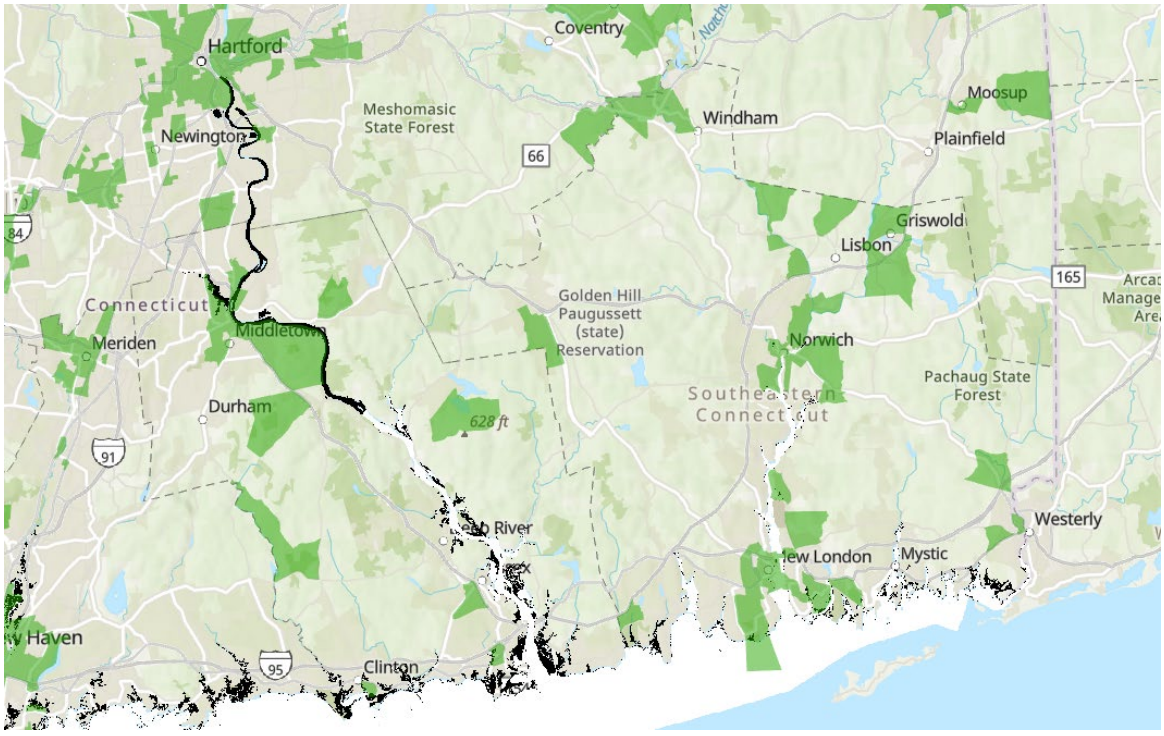

Figure 61. Environmental Justice Communities and 3-feet sea level rise, Eastern Connecticut Area, 2080.

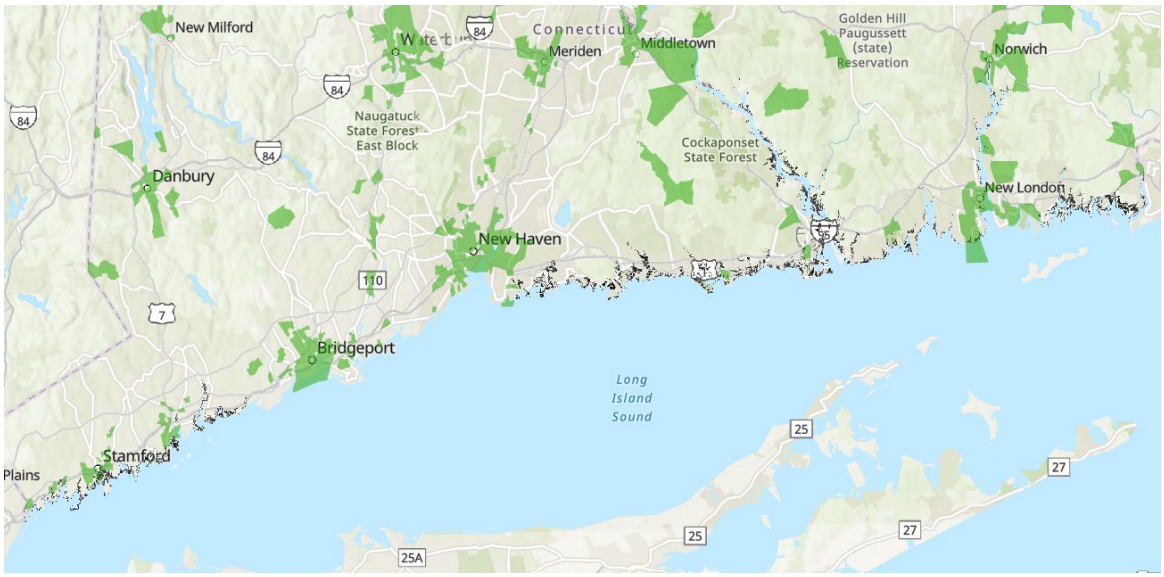

Figure 62. Environmental Justice Communities and Cat.1 storm surge, Connecticut.