Central Maine Power
An Avangrid company

Climate Change Vulnerability Study

Central Maine Power

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1. Executive Summary

Climate change poses a significant threat to utilities across North America. The wide range of impacts including rising temperatures, more severe storm events, and increased flooding, among others, threaten to damage infrastructure, disrupt operations, and result in equipment damage, outages, and threats to health and safety. Central Maine Power (CMP) is deeply aware of these threats and is committed to confronting these challenges by building a more resilient system that can continue to deliver reliable power to the communities it serves.

While this study, and the Climate Change Protection Plan that it informs, was initiated as a response to Title 35-A § 3146 of Maine Public Law Chapter 702, "An Act Regarding Utility Accountability and Grid Planning for Maine's Clean Energy Future," it directly aligns with CMP's overall goals of continuously working to evaluate and address the impacts of climate change on the Company and its customers.

The Climate Change Vulnerability Study (CCVS) provides an assessment of climate change's future impacts to CMP's assets and operations. The study builds upon years of effort that CMP has taken to build an electric system that is resilient to climate risk. To ensure a reliable, actionable outcome, the study team worked closely with Subject Matter Experts (SMEs) across the Company, engaged with local stakeholders, and consulted many of Maine's key climate resources, including the Maine Climate Council and Maine Won't Wait (Maine's Climate Action Plan). The assessment of climate change's effects on the electric system was performed through a multistep process rooted in Intergovernmental Panel on Climate Change (IPCC) best practices. This process utilized the best available climate science data to identify the vulnerability of utility assets and operations to climate hazard projections. The figure below illustrates the process associated with this broader effort.

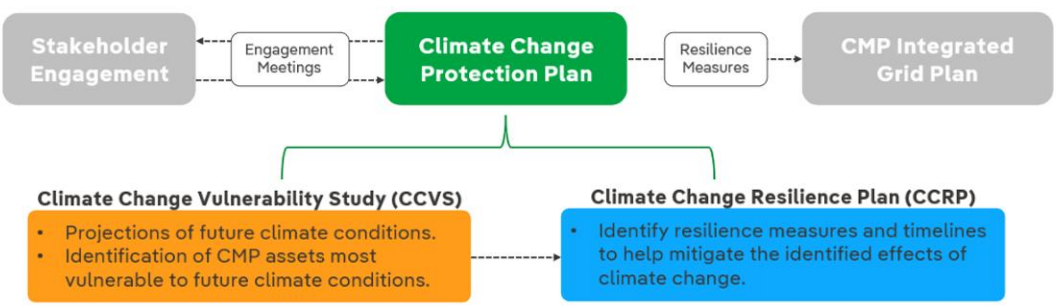


Figure 1. CMP CCVS and CCRP Study Process

Following the CCVS will be the Climate Change Resilience Plan (CCRP). Together, these reports comprise the result of CMP's Climate Change Protection Plan and will be completed alongside CMP's Integrated Grid Plan, informing future investment, operational priorities, and corporate policies. An overview of the CCVS is provided in the subsequent sections.

1.1 Climate Exposures

Across the multiple emissions scenarios that the study team evaluated (SSP2-4.5 50th, SSP5- 8.5 50th, and SSP5-8.5 90th), climate projections in CMP's service territory align with much of the rest of the Northeast United States. Storm events and wind, extreme precipitation events are projected to intensify. Accompanying these hazards, inland and coastal flooding driven by storms and sea level rise are expected to increase. In addition, the potential for drought and wildfire may increase due to changes to seasonal extremes and interannual variability. Presently, each of these events can result in significant disruption throughout CMP's the service territory; with impacts expected to worsen by mid-century and beyond.

The formation and intensity of major storm events and the extreme winds they can bring are difficult to quantify based on the current availability of reliable data. Instead, these hazards were assessed using a qualitative approach that relied on literature reviews and informed inferences based on historical trends, natural phenomenon, and the latest scientific research. This analysis found that exposure to major storm events and the accompanying severe winds are expected to remain a high exposure for CMP and its assets.

While temperatures are expected to rise, most of the service territory is relatively insulated from the worst of these impacts for the first part of the 21st century. Only the Alfred area of the service territory is expected to experience significant enough warming by mid-century that CMP service could be disrupted. However, by late century, the entire service territory is expected to experience more significant extreme heat events. Conversely, chronic extreme cold and frozen precipitation is expected to decrease across the service territory by mid-century, though polar vortex events are expected to continue. Drought and wildfire exposure are projected to remain relatively consistent with current conditions through late century. However, it is noted that year-to-year variability of drought and wildfire could still occur cause periods of drought, increasing the risk of wildfire.

The study team also evaluated climate change's impact on wood decay, a key indicator that can have implications for the health of wooden poles as well as vegetation management. Wood decay is expected to increase by mid-century. Woodpeckers have been a known hazard and threat to CMP's wooden structures, and are anticipated to increase as CMP service area becomes more habitable under the future climate.

1.2 Vulnerabilities

The study team utilized a vulnerability methodology that was rooted in IPCC definitions and best practices. This approach combined the exposure results with sensitivity (the degree to which assets could be affected by exposure to climate hazards), and criticality (the magnitude of negative outcomes for the CMP systems, customers, or staff when an asset is damaged) to produce vulnerability scores, which were characterized as high, medium, or low. The figure below illustrates this process and how SME input was incorporated throughout.

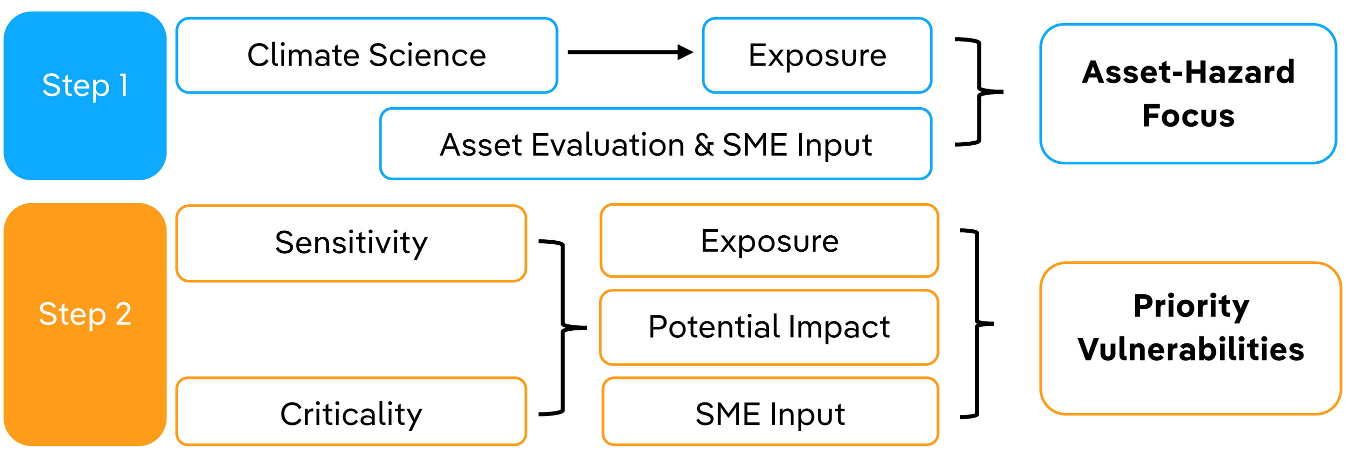


Figure 2. Vulnerability Study Process

In addition to assets, the study team assessed operational vulnerabilities qualitatively through extensive interviews with SMEs from each of the operational groups included in the study. This included vegetation management, load forecasting, workforce safety, reliability planning, asset management, emergency management, and facility ratings. Similar to the asset analysis, vulnerability was determined by evaluating factors that could contribute to the operation's sensitivity, criticality, and change in exposure to a specific hazard.

The vulnerability analysis revealed vulnerabilities across multiple hazards and asset types, and operational groups. Any assets that received a high vulnerability score for a given hazard were categorized as a priority vulnerability. Due to the qualitative nature of the operational vulnerability, any operational group that was considered vulnerable to a given hazard was characterized as a priority vulnerability as well. The table below presents CMP's priority vulnerabilities by hazards and asset type, or operational group.

Table 1. CMP Priority Asset Vulnerabilities and Operational Vulnerabilities

Climate Hazard[1]	Priority Vulnerability Asset	Vulnerable Operation Group
Extreme Precipitation, Inland Flooding, and Coastal Flooding	▪ Distribution pad mount / underground transformers ▪ Substation Transformers ▪ Substation Circuit Breakers ▪ Substation Dynamic Reactive Devices ▪ Substation Control House ▪ Substation Regulators	▪ Asset Management ▪ Workforce Safety ▪ Vegetation Management ▪ Reliability Planning ▪ Emergency Management
Extreme Heat	▪ Substation Transformers ▪ Substation Circuit Breakers ▪ Substation Regulators	▪ Asset Management ▪ Workforce Safety ▪ Vegetation Management ▪ Reliability Planning ▪ Emergency Management ▪ Facility Ratings ▪ Load Forecasting
Storm Events & Wind	▪ Substation Regulators ▪ Distribution Line Structures ▪ Transmission Line Structures	▪ Asset Management ▪ Vegetation Management ▪ Reliability Planning ▪ Emergency Management
Frozen Precipitation		▪ Asset Management ▪ Vegetation Management ▪ Reliability Planning ▪ Emergency Management
Wildfire and Drought		▪ Asset Management ▪ Workforce Safety ▪ Vegetation Management ▪ Reliability Planning ▪ Emergency Management

These priority vulnerabilities directly informed an exploratory risk analyses that provided additional insights into the qualitative and quantitative consequences and likelihoods of climate change's impacts on the CMP system. This included a visual assessment of flooding on substations, an analysis of the relationship between outages and climate hazards, the impacts of woodpeckers (and climate-related migratory changes) on wooden poles, the impacts of extreme heat on CMP staff, and the impacts of climate change on tree health.

[1] Increase exposure to cold events was not identified as an increasing climate hazard and is not listed in this table.

1.3 Key Results

The findings of this study indicate that CMP is expected to be impacted by multiple climate hazards. The vulnerabilities associated with these impacts range in both magnitude and severity and affect assets and operations. Although this report generally considers how climate change will mitigate or exacerbate climate vulnerabilities to CMP's electric system and operations, it cannot be overemphasized that while climate shifts may indicate long-term trends, weather can vary significantly – and may be increasingly volatile due to climate change – and the importance of preparing for weather events, including wildfire, should not be minimized. The following presents some of the key takeaways of this report:

1) Both coastal and inland flooding pose a significant risk to CMP assets as well as operations. While the substation coastal and inland flood risk analysis found that substation risk is projected to be limited, this analysis relies solely on current FEMA floodplains and NOAA SLR data (which does not consider storm surge). Projected increases in extreme precipitation and as well as storm events may increase this risk in the future. The impacts of flood events to CMP may be extreme as there are multiple asset types with high potential impacts associated with both coastal and inland flooding, as well as many operational divisions that could be severely affected. Further, repairing flood and storm damage to assets may be impeded by flooded access roads.

2) Storm events have been increasing in the service territory and are likely to intensify in the future due to climate change, potentially causing major challenges for CMP. The risks and impacts associated with high winds are expected to intensify with climate change, although there is a high degree of uncertainty as to the extent and timing of these changes to storm events. Given that severe wind can cause significant problems for critical overhead assets and severely impact multiple operational groups, it should continue to be treated as a priority.

3) For many utilities in the United States, heat risk is one of the biggest challenges posed by climate change as many utility assets are highly sensitive to the impacts of heat. This study found that by 2050 CMP's heat risk is somewhat limited compared to peer utilities except for the southernmost regions of the CMP service territory. Heat risk is expected to increase by late century and the confluence of even moderate increases in temperatures alongside load growth caused by electrification and energy intensive customers may cause future issues for assets and operations as soon as mid-century.

4) Drought has limited direct impacts on most transmission and distribution grid assets but can create conditions that increase the likelihood or severity of other hazards. This includes potentially increasing risk of conditions conducive to wildfire, and when paired with sudden extreme precipitation after drought conditions, there can be increased risk of flooding, landslides, or mudslides. Utility equipment is generally not designed to be exposed to fire, accordingly wildfire poses a threat to many assets as it has the potential to cause significant damage or destruction. Future projections suggest a wetter and warmer Maine service area which will likely increase vegetation growth overall. The drought indicator used as a proxy for wildfire risk suggests that current conditions will continue. Year-to-year variability of droughts could continue to be an issue, amplified by vegetation growth, suggesting continued exploration of wildfire risk and future trends is necessary.

5) Operational impacts to climate change are widespread and cross cutting. However, CMP has already taken significant steps to mitigate climate risk and many resilience measures that can be taken to adapt to climate change apply to multiple hazards and/or multiple operational divisions.

6) Frozen precipitation is expected to decrease over the next few decades in response to climate change; though the potential severity of the most intense events may increase. As other risks increase, the leading causes of outages is likely to shift as well.

1.4 Next Steps

CMP is committed to building resilience to climate change throughout its electric system. The results of the CCVS are based on evaluation of current standards and practices compared with the expected future climate of Maine. The CCVS will be followed by development of a Climate Change Resilience Plan that will outline a range of appropriate, effective, and realistic actions to address the vulnerabilities identified in this report. These actions, or resilience measures, will be categorized in two broad ways Strategic and Site-Specific Resilience Measures:

> **Strategic Resilience Measures:** Activities like updating equipment specifications and/or internal processes to gradually incorporating climate resilience into the electric system through business-as-usual activities.
>
> **Site-Specific Resilience Measures:** Activities to address acute climate hazard vulnerabilities for a specific site or group of assets.

The CCVS, and the CCRP with its exploration of potential resilience measures to build resilience to climate hazards, will guide and inform CMP's strategies for implementing climate-informed planning and decision-making, and will continue to be an area of focus in future rate proceedings. CMP remains committed to continuously understanding and reducing its climate risk. This report will be revisited, revised, and expanded upon as required to include updates science and climate data.

Introduction

2. Introduction

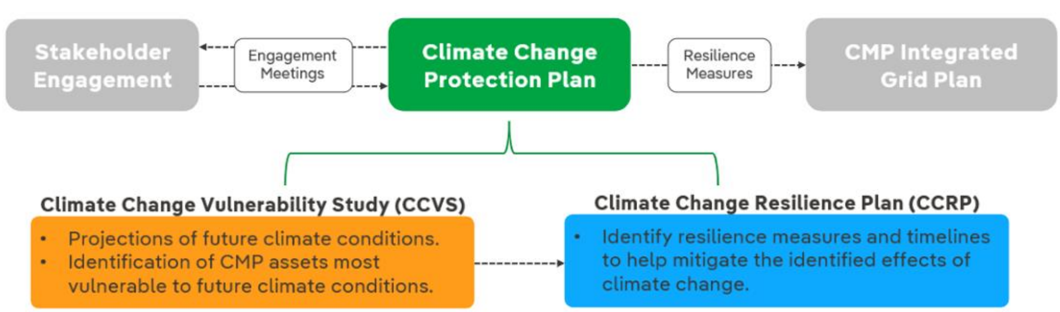
Climate change is posing an increased risk to infrastructure and human health and safety across the country with the changes becoming more pertinent as greenhouse gas (GHG) emissions continue to rise. Maine has not been immune to these effects as significant precipitation in recent years has led to powerful floods along the Kennebec and Androscoggin Rivers, and coastal storms have left shoreline communities inundated. These types of events, as well as heat and sea level rise, among others, are only expected to increase throughout Maine in the coming decades.[2]

Across the country, the utility industry is already experiencing the impacts of climate change. According to the Fifth National Climate Assessment (NCA5), major power outages increased by 64% between 2011 and 2021 primarily due to extreme weather events. These outages also bring increasingly large costs, with a projected 25% increase in infrastructure costs for utilities nationwide under a high emissions scenario.[3] Electricity outages can have significant impact on communities, particularly as they become more reliant on electricity to meet energy needs that were historically served by fossil fuels. In Maine this shift of future reliance is especially noteworthy in the continued electrification of the heating and transportation sectors, and evidenced by forecasts used by the Governor's Energy Office in its *Pathways to 2040 Report* and Maine Energy Plan, by the Efficiency Maine Trust in the development of its triennial plan, and by CMP at the direction of the Maine Public Utilities Commission in the development of CMP's integrated grid plan, due in January 2025.

In recognition of these risks and the need for utilities to continue to provide safe and reliable power under a changing climate, in 2021 Governor Janet Mills signed into law "An Act Regarding Utility Accountability and Grid Planning for Maine's Clean Energy Future" (Public Law Chapter 702). Title 35-A § 3146 of the law requires electric transmission and distribution utilities in the state to submit a Climate Change Protection Plan (CCPP). The plan must outline actions over the next ten years for addressing the expected impacts of climate change on the utility's assets needed to provide reliable power to its customers. Utilities must submit an updated plan every three years.

In 2023, CMP developed and filed their CCPP. This document outlined the specific actions that the utility would take to assess climate hazards and identify resilience measures. In 2024, CMP contracted a climate risk and resilience consulting team from TRC to assist with further development of its CCPP.

The CCPP includes two main parts— development of a Climate Change Vulnerability Study (CCVS) that uses downscaled climate projections and review of scientific materials to interpret the potential impacts of multiple climate hazards on the CMP system through late century, and a Climate Change Resilience Plan (CCRP), that will identify a framework for advancing CMP's resilience maturity, and propose specific resilience measures to address the vulnerabilities and risks identified in the CCVS. Upon completion, the findings and recommendations of the CCPP will inform CMP's Integrated Grid Plan filings. Figure 3 outlines an overview of the study process.



[2] Maine Climate Council. "Home | Maine Climate Plan," 2020. Accessed February 5, 2025. https://www.maine.gov/climateplan/.
[3] Allison R. Crimmins, "Fifth National Climate Assessment," Fifth National Climate Assessment, November 14, 2023, https://nca2023.globalchange.gov/.

Figure 3. CMP CCVS and CCRP Study Process

2.1 Central Maine Power

Central Maine Power (CMP) is a subsidiary of Avangrid, Inc., and is the primary electric utility for central and southern Maine. CMP serves over 650,000 electricity customers over an 11,000 square mile service area with its electric transmission and distribution system. The Company was founded in 1899 by Harvey Eaton and Walter Wyman, originally powering just 100 customers. Over the past century the Company experienced substantial growth and is now the largest utility company in the state. Through many changes in technology, the environment, and the communities it serves, CMP remains committed to providing safe, clean, and reliable power to its customer across the State of Maine.

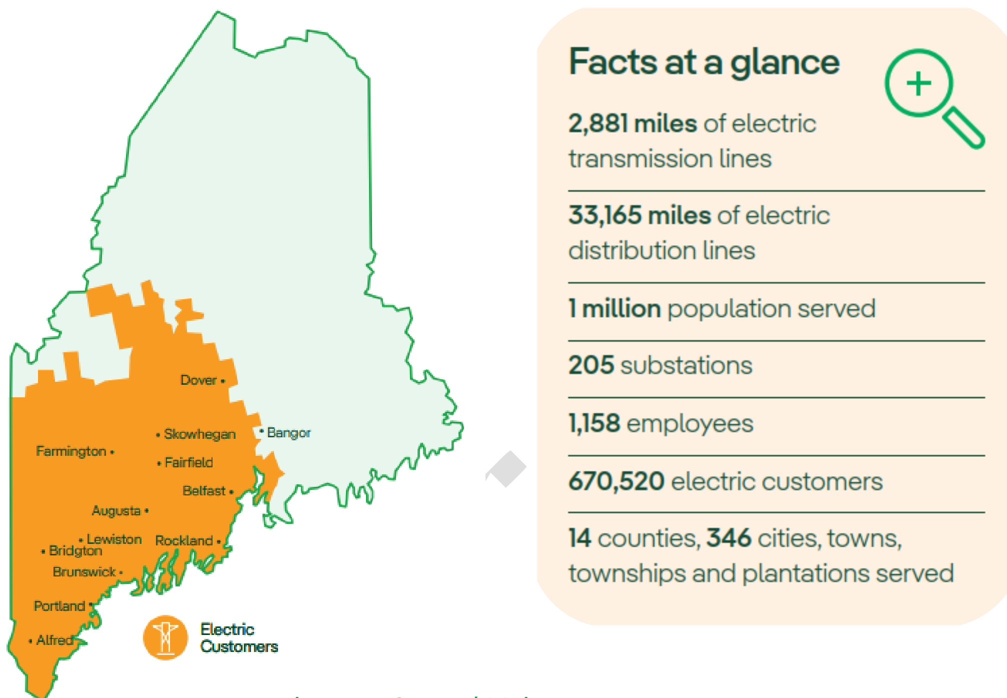


Figure 4. Central Maine Power.

2.2 Stakeholder Engagement

Throughout the development of the CCVS, interested parties were able to not only hear updates directly from the Company, but also provide input to the CMP on its plan to address the effects of climate change. This stakeholder engagement process sought to provide input and awareness to a diverse group of stakeholders that included both internal CMP employees as well as a wide range of external parties throughout the service territory.

The stakeholder engagement process was integrated through all project phases of the CCVS and will be included during the development of the CCRP. Engagement techniques varied depending on the phase of the project and target audience, and included interviews/focus groups, townhall style meetings that were hosted virtually and in-person.

Four different categories of stakeholders were engaged. For each group, CMP tailored the engagement strategy to best suit their needs. The four stakeholder groups included:

1) CMP core team: A group of CMP subject matter experts representing maintenance and operations, engineering and design, emergency management, risk management, and asset management.

2) Integrated Grid Planning/CCPP Stakeholders: Community and non-government organizations throughout the service territory.

3) CMP Customers: CMP launched an externally facing Grid and Climate Planning website where customers were able to view sign-up for alerts, view past meeting recordings, and use links to CMP's final reports.

4) State Agency and Universities: Representatives from municipalities, energy and environmental agencies, higher education institutions, the independent system operator, the energy research and development authority, and other utility or telecommunication service providers.

2.3 Emphasis on Equity

Climate change and its associated potential impacts to the energy grid can adversely affect certain communities disproportionately more than others. Power outages can further exacerbate the issues faced by vulnerable communities. For example, replenishing groceries that have spoiled during a power outage is often more difficult for households on nutritional assistance programs; customers who use at-home medical or accessibility equipment may face dangers or difficulties without a power supply; and wage workers may lose wages if businesses close during an outage event. These immediate outage-related impacts on vulnerable communities may coincide with other direct impacts of climate change, such as people with disabilities or lower income households being potentially unable to access alternative lodging, a limited financial ability to rebuild after a flood or having a medical condition that makes heat exposure more dangerous.

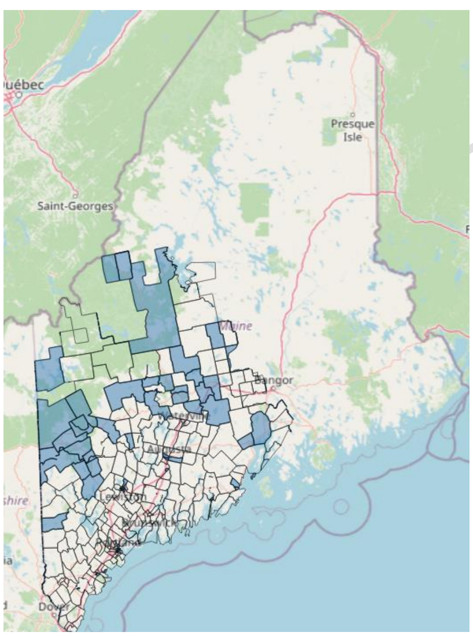


Figure 6. Disadvantaged Community

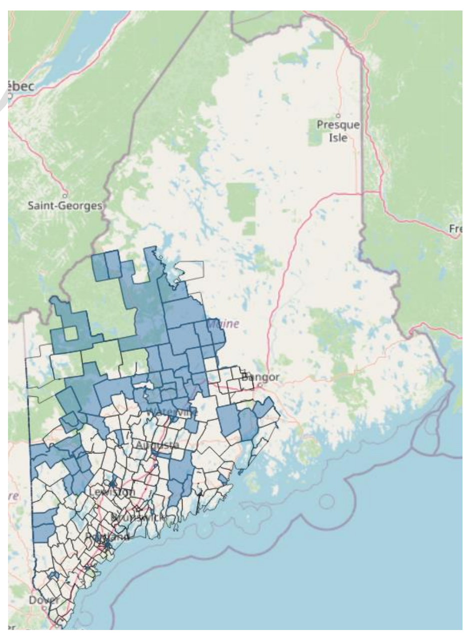


Figure 6. Disadvantaged Communities (CEJST)

The Energy Information Association (EIA) classifies Maine as the most rural U.S. state, with more than three-fifths of the population residing in rural areas. American Community Survey and Bureau of Labor Statistics data show Maine as having an overall population density of just below 38.6 people per square mile. About a third of the state is considered a disadvantaged community (DAC) by the White House Council on Environmental Quality (CEQ) Climate and Economic Justice Screening Tool (CEJST). Maine also has one of highest energy burdens in the country according to the US DOE's LEAD Tool, and CMP's service territory is, on average, in the 81st percentile for energy burdens across the country according to CEJST.

The study team identified disadvantaged communities in the service territory using the Climate and Economic Justice Screening Tool (CEJST).[4,5] As noted by the Union of Concerned Scientists, nationwide, communities identified as disadvantaged by CEJST contain roughly twice as many at-risk infrastructure assets per capita as non-disadvantaged communities, making them more vulnerable to climate impacts on infrastructure, including the power grid.

2.4 Evaluation of Future Vulnerabilities

This report summarizes future amplified and emerging climate vulnerabilities of the CMP system, including impacts on assets and operations, with a focus on 2050 conditions. These new projected vulnerabilities are outside of CMP's current state of practice and design. While natural hazards currently pose a threat to the CMP system, CMP already takes steps to mitigate many of these current vulnerabilities. Although some of these hazards have already been influenced by climate change, the purpose of this analysis is to project and prepare for future conditions. At times, this may result in hazards that currently present risks to CMP being characterized as not posing a risk in the future (as this is a future-facing report). The Resilience Plan identifies opportunities to further mitigate current climate-related risks as well as address longer-term projected risks.

As this document is intended to directly inform CMP's Resilience Plan, the study team carefully chose a reasonable future scenario that represents a future with minimal mitigation or reduction of climate change drivers. This then informs CMP in preparing for the possibility of more heightened risks (even if it's less likely than other scenarios). The future conditions are based on averaging across climate models, instead of basing future conditions on a few climate models projecting the worst conditions. This climate model ensemble average lends to greater overall confidence in using these results for planning purposes. Finally, given both CMP's long-term planning horizon and the significant uncertainties when projecting out towards the end of the century, future conditions in the 2050 time period were selected for evaluation of CMP system vulnerabilities. In sum, the future 2050 conditions used to evaluate CMP vulnerabilities are developed from a higher emissions scenario and based on the climate model ensemble.

2.5 Building On Past Work

The CCPP marks the first comprehensive assessment of climate vulnerabilities for CMP. However, this assessment builds on previous assessments and studies conducted by Avangrid, including a January 2016 *Assessment of Vulnerabilities Due to Climate Change and Extreme Weather*, which identified vulnerabilities and resilience strategies and the November 2016 *Resilience Planning for Climate Change and Extreme Weather*, which further expanded on the previous report to prioritize resilience investments. The CCVS draws on previous efforts

[4] U.S. Department of Energy working definition of disadvantaged communities pertains to EO 14008, or the Justice40 Initiative. The dataset provides 36 inputs to the index at the census tract level as well as the classification of each census tract as disadvantaged or not disadvantaged. The top 20% of census tracts in each state are then selected to ensure every state is represented. All census tracts are then screened to ensure at least 30% of households are at/below 200% of the Federal Poverty Level and are considered low-income households by the Department of Housing and Urban Development (HUD), defined as making 80% of the area median incomes.

[5] Climate & Economic Justice Screening Tool (CEJST) identified disadvantaged communities that are underserved and overburdened by pollution for prioritized federal funding and informing Justice 40, as pertaining to Executive Order 14008. Metrics for climate change include agricultural loss, building loss, population loss, flood risk, and wildfire risk, while metrics that contribute to disadvantage status includes energy cost, particulate matter in the air, health issues including asthma, diabetes, heart disease, low life expectancy, housing issues including historic underinvestment, housing cost, lack of green space, lack of indoor plumbing, lead paint, and workforce development including linguistic isolation, low median income, poverty, and unemployment. At the time of the production of this report, the CEJST tool was no longer available through White House Council on Environmental Quality. The data used in this study is sourced from an archival source hosted by the Public Environmental Data Project. See Climate + Economic Justice Screening Tool — Data + Screening Tools.

that do not explicitly reference climate change, but play a role in mitigating its impacts, such as reliability planning, storm hardening, and vegetation management plans, reports, and programs.

Climate Hazards and Exposure

3. Climate Hazards and Exposure

This section describes the findings of the study team's in-depth analysis of climate change across the CMP service area focusing the evaluation of climate hazards commonly faced by electric utilities and confirmed by the study team. The evaluated hazards include storm events and wind, extreme precipitation and inland flooding, frozen precipitation, sea level rise and coastal flooding, extreme temperature (heat and cold), drought, and wildfire. In the following sections each climate hazard is identified along with a brief description of its current and future potential to affect the CMP system; this consisted of establishing a baseline of current and historical climate conditions as well as examining future-looking conditions of climate hazards through mid and late century. The assessed change from a baseline condition to future intensity or frequency of a climate hazard is presented as the "exposure score."

3.1 Climate Change Projection Methodologies

The development of climate change projections relies on global climate models (GCM). GCMs are computer-based simulations of Earth's climate and physical processes. These GCMs are used to help understand how different levels of GHGs, solar radiation, and other factors may affect future climate. The data used throughout this CCVS were generated from multiple different models that are part of CMIP6, an ongoing international scientific effort with the goal of creating and maintaining GCMs. The projection results from different models can vary based on how they are parameterized. To capture a range of possible outcomes, results from different models can be combined to create an ensemble of future climate data that can be used to develop a probabilistic range of potential future climates.

In addition, GCMs are initialized with differing parameters based on assumptions defined by shared socioeconomic pathways (SSP). Each SSP captures unique global socioeconomic realities, development strategies, climate policies, and GHG emissions trajectories generated to represent possible climate futures and were developed by the Intergovernmental Panel on Climate Change (IPCC) for its Sixth Assessment Report (IPCC 2022). This CCVS utilized two SSPs to represent the range of possible climate futures:

- **SSP2-4.5:** Pathway that assumes carbon dioxide emissions remain around current levels until 2050 then reduce. This scenario limits warming to under 3˚C (5.4˚F). It takes moderate emissions reduction challenges into account, as well as future impact adaption, with slow progress towards sustainability goals.
- **SSP5-8.5:** Pathway where carbon dioxide emissions continue to increase until late into the 21st century with warming exceeding 4˚C (7.2˚F) by 2100. It incorporates optimistic trends for human development coupled with an energy-intensive fossil fuel-based economy.

Though it is uncertain at which rate the global economy will decarbonize the SSP5-8.5 50th percentile of results was selected as the CCVS' planning scenario as the planning scenario as it represents a possible climate future for comparison with baseline conditions.

3.2 Quantitative Data Sources

Downscaled climate projections derived from GCM simulations results were used to assess changes in extreme temperature, heavy precipitation, and drought/wildfire conditions. For other hazards, a combination of other data sources (such as FEMA floodplains) and reviews of the latest scientific literature were used to draw conclusions on forward looking trends. In addition, findings from peer-reviewed and trusted sources were referenced where appropriate:

World Climate Research Programme's (WCRP) Coupled Model Intercomparison Project Phase 6 (CMIP6): For temperature, precipitation, and drought, the report uses statistically downscaled global climate model data of daily minimum temperature, daily maximum temperature, and daily precipitation from the World Climate Research Programme's (WCRP) Coupled Model Intercomparison Project Phase 6 (CMIP6) Localized Constructed Analogues version 2 (LOCA v2) data (Pierce 2021). LOCA v2 has a 6km by 6km (~3.7 mile by 3.7 mile) spatial resolution. Twenty-two climate models were evaluated across two Shared Socioeconomic Pathways (SSPs) futures, including SSP2-4.5 and SSP5-8.5. These models were selected as ones that were available for both SSPs to ensure consistent comparison across values. All available models were used.

Federal Emergency Management Agency (FEMA) flood zone data: For inland flooding, the report uses Federal Emergency Management Agency (FEMA) flood zone data for identifying assets exposed to current flood hazards, the was used and overlaid with CMP geoprocessed asset data to identify intersections with the 100-year and 500-year flood plains. Importantly, FEMA flood maps do not include aspects of climate change that could affect the extent or depth of flooding. To help gauge potential impacts and identify future at-risk substations a buffer was applied around each substation to identify locations for future substation flooding, including potential impacts that local flooding would have on access to substations that could hamper repair and restoration work.

FEMA flood zone data and CMP geoprocessed asset data: For coastal flooding, the report uses these two data sources. For historic conditions, the FEMA flood zone data was used to identify CMP geoprocessed asset data that intersect with the 100-year and 500-year flood plains using a buffer. In addition, for future conditions, NOAA sea level rise depth data was used to identify which CMP assets may be exposed to coastal inundation under the 2 foot and 10-foot sea level rise scenarios. This is a proxy for changes in the extent and depth of coastal flooding as the NOAA sea level rise data is based on sea levels rising above mean higher high water (i.e., higher high tides).

Other Resources

In addition, a number of resources provided by the Maine government and academic institutes were reviewed with the appropriate portions of each and integrated into this analysis:

- Scientific Assessment of Climate Change and Its Effect in Maine – 2024 Update Report
- Maine Climate Plan Climate Science Dashboard
- State of Maine Sea Level Rise Guidance
- Maine Climate Office Statewide Monthly/Seasonal Temperature and Precipitation Data
- Maine Geological Survey Sea Level Rise and Storm Surge GIS Mapping Tool
- University of Maine Climate Future Report
- NOAA National Centers for Environmental Information Maine State Climate Summary
- Maine Cooperative Snow Survey
- Maine State Department of Agriculture, Conservation, and Forestry Floodplain Management Program – State Flood Hazard Map
- Effects of climate, regulation, and urbanization on historical flood trends in the United States. Hodgkins et al., 2019

Future Effects of Hazard Exposure

As this study focuses on future changes that may require CMP to consider strategies beyond what is currently utilized, the exposure to additional or more intense climate hazards was categorized. Exposure is defined as the degree to which assets could face climate hazards, was evaluated using the following definitions:

- Low Exposure Score: Similar or reduced hazard exposure compared to current conditions.
- Medium Exposure Score: Moderate increase in hazard exposure compared to current conditions.

- High Exposure Score: High increase in hazard exposure compared to current conditions.

For select climate hazards discussion may include separate evaluations of chronic and acute effects of climate change:

- Chronic Effects: effects that are due to gradual changes to the climate over time, for example temperature or precipitation.[6]
- Acute Effects: changes to short duration but impactful events like intense storms, or heatwaves.[7]

Uncertainties

As with all projections of future conditions there are uncertainties inherent in the results. These include:

- Scientific Uncertainty: Individual climate models differ in various ways to simulate the climate system. In addition, not all phenomena are completely understood and can be challenging to model across a wide range of future conditions. To address this uncertainty, ensembles (a number of climate models) are used. This is a constant area of scientific research and understanding.
- Evolution of Global Society: It is unknown how global society will evolve over the coming century. Scenarios have been developed by the climate community to capture reasonable and plausible futures. These futures are representative of changes in population growth, fossil-fuel use, land-use, regulations of emissions, technological advancements, and so on.
- Natural Internal Climate Variability: The climate system experiences unpredictable natural fluctuations, some of which are included in climate models.
- Qualitative and Quantitative Projections: GCMs are limited in their ability to resolve highly dynamic or extreme weather events. These GCM projection limitations, particularly pertaining to acute events, exist due to a combination of how extreme events occur over small spatial and time scales, the shortness of the historical record relative to the rarity of the events, and the complex and rare environmental and meteorological conditions that promote their occurrence. Due to these known and anticipated limitations, some climate projections utilized in the CCVS do not fully resolve all features of these extreme events in a quantitative fashion but rather rely on a qualitative review of relevant scientific literature where necessary to identify the impacts from climate change.

Nearly all of the climate hazards identified as disruptive and/or damaging to CMP assets and operations are expected to intensify due to climate change. The following sections include details of how these climate hazards may be affected by climate change. Climate change projections and studies suggest that the exposure to impactful climate hazards like storm events and wind, flooding, and heat, are each projected to increase.

[6] Chronic exposure refers to the long-term averaging of 30-years of climate data across climate model ensemble.

[7] Acute exposure refers to year-to-year variability where a significant climate event could occur even in cases where the overall trend suggests a reduction or no-change from today.

3.3 Hazard Projections and Exposures: Storm Events & Wind

Key Findings

- Strong winds are considered a high significant risk today and over the coming decades.
- Severe thunderstorms are projected to intensify and become more frequent, which can lead to stronger winds, hail, and heavier precipitation events.
- Severe windstorms, like Nor'easters, are a significant hazard in Maine and could intensify over the coming decades, though changes in the frequency of events is less certain.

Storms events are a primary cause of outages for many utilities across North America. These events often bring high winds, frequently causing vegetation and other debris to come into contact with utility assets, potentially leading to damage or failure. In addition, depending on the severity these events can delay response and outage restoration and recovery efforts.

This section identifies projections for four unique hazards whose projections are collectively discussed in the CCVS as storm events and wind:

- Winter Storms
- Coastal Tropical Storms
- Severe thunderstorms
- Mid Latitude Cyclones

The CMP service area experiences a range of severe storms including thunderstorms, hail, and tornadoes during the summer and fall months, and ice storms, Nor'easters, and blizzards from fall through early spring. Nearly all of the counties' Hazard Mitigation Plans within the CMP service area identified both summer and winter severe storms as a high risk.

Due to the complex and dynamic nature of storm formation and evolution, it is difficult to definitively model how precisely these events will change over the 21st century. This is particularly true for mesoscale events such as thunderstorms and severe wind events which occur at very small geographic and temporal scales. Understanding the mechanics and relationships necessary for simulating how severe thunderstorms, winter storms, coastal tropical cyclones and mid-latitude cyclones may change over the coming century is an area of active research throughout the climate science community.

Nor'easters, are a common occurrence during winter months and can bring heavy snow, high winds, and coastal flooding. However, evolving research indicates that southwesterly winds are increasing in intensity and stressing vegetation in uncommon ways, leading to new challenges for Maine forests and increased exposure for utility assets.[8]

Winter storms

Are projected to intensify leading to heavier precipitation and stronger winds. However, it is not understood if there will be a change in the number of winter storms per year.[9]

These events are all exceptionally impactful to CMP and its customers. Based on how these climate events are formed and develop, quantitative projections for changes to storm intensity and frequency are not possible; however, there is general consensus that these events will increase in severity, while changes in frequency of occurrence as well as changes to storm track are less certain.

[8] Burkholder, K. C., Lee, J. H., Kime, M., Calabro, C., & Manning, J. P. (2024). Decadal-scale variability in the surface flow of the Gulf of Maine Coastal Current: The impact of changing climate conditions on coastal circulation. NOAA.gov.
[9] "Maine Governor's Office of Policy and the Future," 2024, accessed February 6, 2025, https://www.maine.gov/future/.

Coastal Tropical Storms

Commonly referred to as hurricanes, or hurricane remnants, have intensified for the North Atlantic and are projected to continue to intensify over the next century. However, coastal storm surge from these storms is considered an unlikely threat for Maine though rising seas will amplify impacts.[10]

Severe Thunderstorms

Severe thunderstorms can cause significant damage due to hail, lightning, strong winds (tornados in some locations), and heavy precipitation. There are a few variables that are evaluated in assessing how these storms may change, including two primary variables: Convective Available Potential Energy (CAPE) and wind shear. CAPE is fuel for the storm and signifies the amount of warm, moist buoyant air to help the storm grow. Wind shear describes how the wind speed and direction change with altitude where significant wind shear helps thunderstorms become severe, hail-making events. If both CAPE and wind shear are projected to increase, then severe thunderstorms would intensify.

There are a few studies that have developed relationships between thunderstorm intensification with rising temperatures. Recently, Lepore et al. (2021) assessed future changes in convective variables as a function of rising global average temperatures (using seven CMIP6 GCMs run under the SSP5-8.5 pathway). This study suggests an increase of 5% to 20% per ˚C of global temperature rise, though noted variability particularly in the Northern Hemisphere. This increase signifies better conditions for severe thunderstorm growth; however, it is likely that the increase in actual events will be smaller as not all conditions will create a severe thunderstorm. For the United States, for each increase in global temperatures, severe thunderstorm environments are projected to increase by 9% (summer) to 25% (winter). Notably, Maine falls within U.S. regions projected to experience higher increases than other parts of the country. This may be because Maine experiences more limited severe thunderstorms and therefore a small increase translates to a larger percent. Based on current available science, severe thunderstorms are projected to increase in frequency and severity for Maine over the coming decades, as well as a potential expansion from occurring mainly in the summer to additional seasons throughout the year.

Table 2. Percent Change In Severe Storm Frequency For The United States Per Unit of Global Temperature Rise (Lepore Et Al. 2021)

WINTER (DJF)	SPRING (MAM)	SUMMER (JJA)	FALL (SON)
25% (+/-4)	14% (+/-2)	9% (+/-0)	16% (+/-2)

Maine experiences major storms and wind events discussed in preceding sections that can cause significant damage directly to utility equipment but can also cause damage to nearby trees or branches impacting CMP's assets frequently causing customer outages. As anticipated, a review of historical weather and outage information suggest a close relationship between strong winds and customer outages.

Mid Latitude Cyclones

As the climate warms, models suggest an overall intensification of mid-latitude cyclones, but a potential reduction in the number of events per year (i.e., fewer but stronger storms).[11] It is unclear how the storm track across the mid-latitudes may change over the coming century (i.e., will these developed storms hit Maine). Recent major storm events have been caused by the mid-latitude cyclones (associated with cold fronts) passing through Maine such as during the 2017 and 2019, as well as a southeasterly wind event in mid-December 2023.[12] The 2023

[10] "Maine Governor's Office of Policy and the Future."

[11] Arnold et al., "Scientific Assessment of Climate Change and Its Effects in Maine - 2024 Update."

[12] Susie Arnold et al., "Scientific Assessment of Climate Change and Its Effects in Maine - 2024 Update," report, by Maine Climate Council and Scientific and Technical Subcommittee, *Maine Climate Council* (Maine Climate Council, 2024).

southeasterly wind event produced gusts of 50-70 mph (and more in some locations), as well as producing significant rainfall across the state. These effects led to widespread power outages and flooding lasting multiple days.

Wind gusts brought by powerful storm events pose some of the most the significant harm to CMP assets. These wind gusts occur on the order of seconds to minutes. This small temporal scale precludes GCMs from being able to develop robust and actionable projections of future impacts of climate change to maximum windspeeds. In order to determine the potential for future storm events and the associated wind gusts, the projects are developed qualitatively based on specific research performed on these events. This is an ongoing area of research and identified as a top priority by the MCC's Scientific Assessment of Climate Change and its Effects in Maine (2024).

As these storm events are projected to intensify over the coming century, storm events & wind exposure was identified as a "high" exposure.

Asset Exposure to Storm Events & Wind					
Impact: Storms that bring high winds can damage elevated utility equipment directly or through causing impact to nearby vegetation					
Hazard	Baseline	Mid-Century Exposure	Late-Century Exposure	Impacted Service Areas	Exposure Score
Severe Thunderstorms	High	High	High	All	High
Winter Storms	High	High	High	All	High
Coastal Tropical Storms	High	High	High	All	High
Mid-Latitude Cyclone	High	High	High	All	High
Chronic Exposure:	Storm events and the accompanying strong winds are acute events that do not have a chronic component. Projections for chronic changes to wind, e.g., daily max windspeed, cannot be readily simulated as part of climate change projections.				
Acute Exposure:	The High exposure score for these hazards is based on the findings that storm events and associated wind gusts are generally expected to intensify in the future due to climate change.				

3.4 Hazard Projections and Exposures: Frozen Precipitation

Key Findings

- Annual frozen precipitation is projected to decrease over the coming decades as temperatures warm.
- Acute events with significant amounts of frozen precipitation are expected to remain a hazard in Maine.

Frozen precipitation and the additional weight placed on transmission and distribution assets from ice accumulation can cause damage or even failure. Furthermore, the weight placed on vegetation, particularly on coniferous trees, or deciduous trees if the event occurs before the leaves have fallen, can cause branches to sag or break casing significant impacts on nearby utility assets.

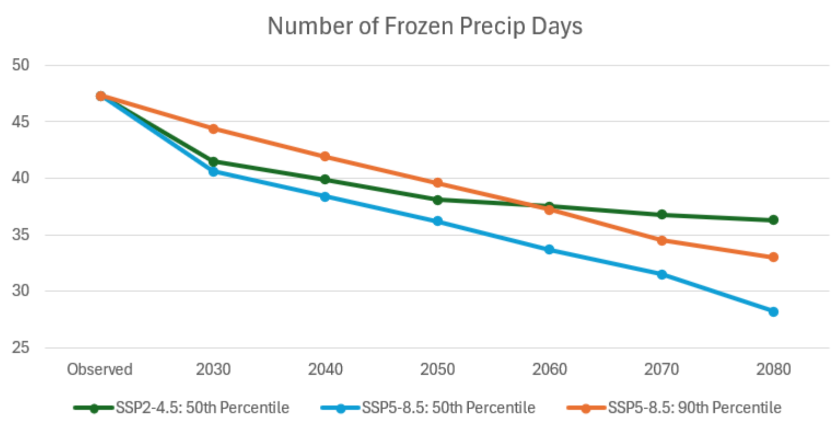


Figure 7. Number of Days with Frozen Precipitation

Two frozen precipitation variables were used for this analysis: the number of days where frozen precipitation could occur and the maximum daily frozen precipitation intensity. These variables suggest that changes in frozen precipitation are expected to make these events less frequent. Data underlying the Frozen Precipitation Intensity shows that the quantity of precipitation during the winter season is projected to increase, however the expected increase in winter temperatures will cause fewer precipitation events to occur at or below 32°F causing an overall decrease in projections for Max Daily Frozen Precipitation Intensity.

The projections suggest there will be a reduction in frozen precipitation over time under all three scenarios evaluated. The rate at which this reduction is projected to occur varies across scenarios, with the SSP5-8.5 50th percentile scenario displaying the highest intensity reduction rate and decrease in frozen precipitation days. Conversely, the SSP2-4.5 50th percentile scenario projects the lowest reduction rate and frozen precipitation day decrease of the scenarios evaluated. Although annual frozen precipitation is projected to decrease, research indicates that a warming atmosphere may increase the intensity of the most significant frozen precipitation events.

Asset Exposure of Frozen Precipitation

Impact: Can cause damage directly to transmission and distribution overhead assets, as well as impacting nearby vegetation. In addition, this hazard has the potential to hinder restoration efforts.

Variables	Observed	Mid-Century Exposure	Late-Century Exposure	Impacted Service Areas	Exposure
Maximum daily frozen precipitation intensity	9.6	Low	Low	None (all Low)	Low
Potential number of days of frozen precipitation	47.3 days	Low	Low	None (all Low)	

Chronic Exposure:	The general warming trend due to climate change is projected to decrease the annual frozen precipitation intensity, and number of days where frozen precipitation occurs.
Acute Exposure:	Although the climate is warming acute events with significant frozen precipitation events can still occur. Although annual frozen precipitation is projected to decrease, research indicates that a warming atmosphere may increase the intensity of the most significant frozen precipitation events.[13]

Key Findings

- Precipitation is projected to increase by up to 20% in 2050 under the planning scenario, suggesting a moderate exposure score.
- Heavy precipitation events are projected to continue to increase potentially leading to increased flooding, particularly to flood prone areas (e.g., 100-year floodplain).
- Under projected precipitation and temperature changes in the near-term, there is a potential for more rain-on-snow events and snowmelt driven flood frequency across the state.
- Flood depths associated with coastal flooding are projected to increase with sea level rise and storm intensification.

3.5 Hazard Projections and Exposures: Flooding

Flooding can severely impact electric utility equipment, leading to power outages and significant repair costs. When floodwaters inundate electrical systems, they can cause short circuits, corrosion, and damage to critical components such as transformers, switchgear, and substations. The evaluation of flooding included in the CCVS was separated into inland and coastal flooding as the initiating causes and factors that can exacerbate each can be unique.

For inland flooding the effect and projections for snowmelt flooding and heavy precipitation impacts on inland flooding are discussed. For coastal flooding the discussion focused on sea-level rise and how it can affect tidal flooding, and flooding caused by coastal storms discussed in previous sections.

[13] C.M. Zarzycki "Projecting Changes in Societally Impactful Northeastern US Snowstorms" (2018)

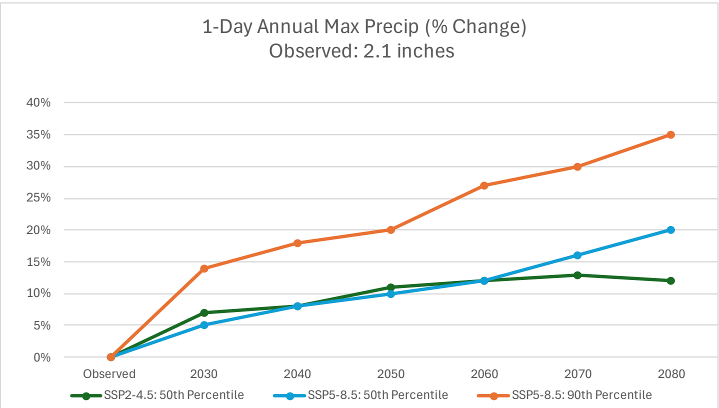
3.5.1 Heavy Precipitation Events and Inland Flooding

Heavy precipitation events and inland flooding[14] can lead to substantial damage to multiple types of assets. Inland flooding, caused by heavy precipitation events, can also lead to asset damage or failure if floodwaters come into contact with equipment that is not designed to be submerged, in particular equipment located inside of electrical substations. Flooding can also lead to increased rotting or scouring of the soil around the base of a structure, such as poles, which can compromise their structural integrity and stability. Flooding also has the ability to inhibit repair and restoration work as it creates potentially unsafe conditions for crews through heightened electrocution risk and restricting access to roadways and facilities.

Heavy Precipitation

This study looked at changes in both 1-day and 5-day annual maximum precipitation to project future changes in heavy precipitation events. Projections suggest there will be increases in the intensity of heavy precipitation events across CMP's service area over time.

Heavy precipitation events are projected to increase across all scenarios ranging from 5% to 15% in the near-term to 13% to about 35% by 2080, relative to 1985-2014 baseline. Not only is seasonal precipitation projected to increase, but also heavy precipitation events. The SSP2-4.5 scenario and the SSP85-8.5 50th percentile scenario track closely until about 2070 when the SSP5-8.5 50th percentile suggests heavier precipitation events. The SSP5-8.5 90th percentile suggests a significant increase in precipitation totals for these events (by definition of the 90th percentile, this scenario represents more extreme totals and illustrates the range across the climate models for these variables). The study scenario (SSP2-8.5 50th percentile) is within or below this threshold, hence the exposure scoring is "medium."



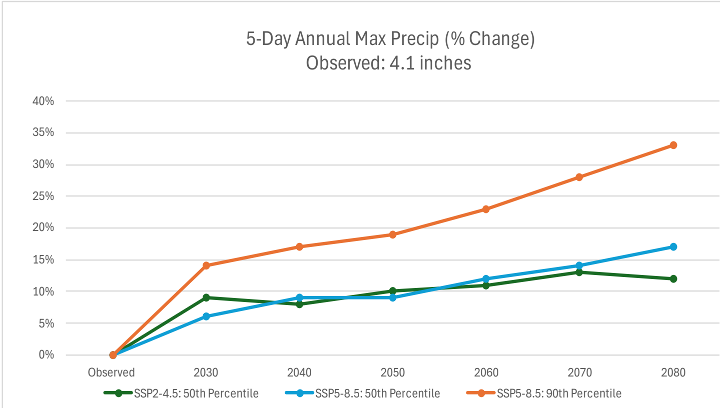


Figure 8 - Projected change in 1-day and 5-day maximum precipitation events.

Inland Flooding

A relatively small percentage of CMP assets are located in the existing Federal Emergency Management Agency (FEMA) 100-year and 500-year floodplains; however, due to the sheer number of assets owned by CMP this equates to a significant number of assets. Interestingly, the quantity of assets exposed to inland flooding is far greater than the quantity exposed to coastal flooding. These inland floodplains do not explicitly include aspects of climate projections, but rather they represent the current-day probabilities of exposure to flooding based on historical data and topographic analysis. For substations the number of exposed facilities include all within a buffer of the denoted floodplain; see section 7.2 for further risk analysis.

[14] Inland flooding includes ponding, pluvial flooding, and riverine flooding.

Table 3. Number of Assets Exposed to 1-in-100 Year Inland Floodplains

Asset Type	Number of Assets Located in or near FEMA Inland Floodplain	Total Number of Assets	Percentage of Assets Located in or near FEMA Inland Floodplain
Substations	52	228	22.8%
Pad Mount Transformers	280	19,635	1.4%
Poles	13,571	674,908	2.0%
Underground Structures	18	1,942	0.9%

Snowmelt Flooding

Inland flooding can occur when there is more water than the ground can absorb or can be contained in storage capacities of the soil, rivers, lakes and reservoirs. Snowmelt flooding occurs when a major water source involved in a flood is caused by melting snow. Northern states and mountainous areas of the U.S. like Maine are particularly susceptible to snowmelt flooding.

Unlike typical rainfall, which can be absorbed by soil almost immediately, a layer of snowpack on top of the ground stores water until its temperature rises above freezing. Snow water equivalent (SWEs) – i.e. the theoretical depth of water that would result from instantaneous snowpack melt, or the amount of water contained in snowpack – varies based on snow depth and density[15]. Rain-on-snow events contribute to intensified snowmelt and potential flood events - the rain and melting snowpack contribute additional water, increasing the potential for flooding.

Maine's mountainous areas, and corresponding river basins, are particularly susceptible to snowmelt flooding. This includes the western portions of CMP's service area. Counties include:

- Oxford
- Franklin
- Somerset
- Piscataquis
- Kennebec

Future Exposure to Heavy Precipitation and Inland Flooding

Projections show increases to precipitation and temperature throughout CMP's service area which are particularly prominent during the winter season. These changes indicate a higher potential for rain-on-snow events, and snowmelt driven flood frequency across the state. In addition, 1- and 5-day precipitation totals are projected to increase coupled with increases to storm intensity discussed previously, the exposure to inland flooding was identified as high.

Asset Exposure of Heavy Precipitation and Inland Flooding					
Impact: Increased heavy precipitation and flooding conditions can lead to asset damage and failure from contact with vegetation or submersion in water.					
Heavy Precipitation Variables	Baseline	Mid-Century Exposure	Late-Century Exposure	Impacted Service Areas	Exposure Score
1-day Max Precip. (inches)	2.1	Medium	Medium	All Medium	Medium
5-day Max Precip. (inches)	4.1	Medium	Medium	Farmington (High)	

[15]https://www.nrcs.usda.gov/resources/data-and-reports/publications-of-the-national-water-and-climate-center, 2023, accessed February 5, 2025, https://www.nrcs.usda.gov/sites/default/files/2023-03/iMap_Glossary.pdf.

Inland Flooding	High	High	High	All	High

Chronic Exposure:	Extreme precipitation and flooding events are acute events that do not have a chronic component. Trends do show that annual/seasonal precipitation is projected to increase; however changes to annual precipitation quantities are not directly impactful to utility assets.
Acute Exposure:	Exposure to acute events with significant precipitation quantities, including the potential for compound rain-on-snow events that are projected to increase.

3.5.2 Coastal Flooding

Key Findings

- Current levels of routine coastal flooding have not been impactful to CMP assets.
- Current day 1-in-100 year coastal storm surge including high-tides does not directly impact major CMP facilities.
- Sea-level rise projections as well as the potential for more intense storms is expected to increase coastal flood depths and extents exposing more CMP facilities; but major facilities are projected to be secure from current 1-in-100 year events coupled with sea level rise until after 2050.

Coastal flooding poses a severe risk for utility assets that if submerged in water, are subject to instant failure, or can become damaged by corrosion over time after floodwaters recede. Flooding can also lead to increased rotting or scouring of the soil around the base of a structures, such as poles, which can compromise their structural integrity and stability. Flooding also has the ability to inhibit repair and restoration work as it creates potentially unsafe conditions for crews.

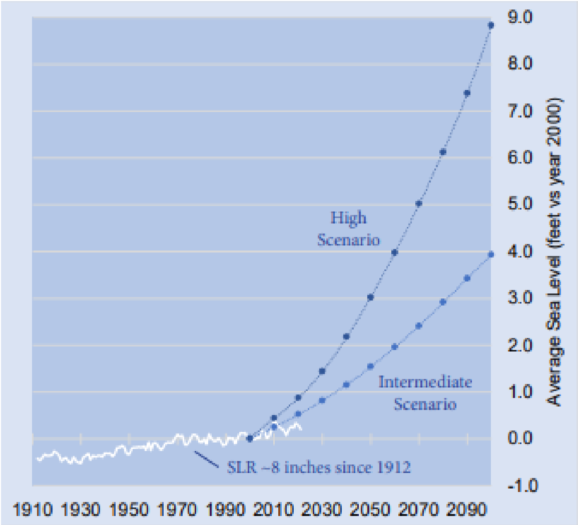


Figure 9. Historical and sea level rise projections for Maine (Source: GOPIF 2021)

Sea Level Rise. As sea level rises over the coming century, exposure to coastal flooding is anticipated to increase. By end of century, future annual sea level in Maine may rise by 9 feet under a high scenario and 4 feet under an intermediate scenario relative to 2000. Note that just 1 foot of sea level rise may increase the frequency of nuisance flooding and coastal storm impacts by 10 times.[16]

Maine Climate Council (MCC) has recommended adoption of two thresholds for the State of Maine for managing risks: 1.5 feet of relative sea level rise by 2050, and 3.9 feet of relative sea level rise by 2100. In addition, MCC suggests a lower risk threshold in order to "prepare to" manage the risks: 3.0 feet of relative sea level rise by 2050, and 8.8 feet of relative sea level rise by 2100

Being conservative, the study team adopted 2 feet by 2050 of relative sea level rise for the vulnerability assessment of this study. It's understood that both coastal flood depth as well as geographic extent of flood waters will increase under these higher sea levels. To assess future

[16] Gov. Office of Policy Innovation and the Future and Dept. of Environmental Protection, "Sea Level Rise in Maine: An Accelerating Problem."

vulnerability, CMP added sea level rise to the FEMA base flood elevation (BFE) included in FEMA coastal flood maps.

Tidal Flooding. The study team inspected NOAA's Sea Level Rise Viewer for a screening of impacts associated with 2 feet of sea level rise along the coastline within the CMP service area during higher high tides. Low-lying areas along the rivers and coastal waterbodies were projected to be inundated, though very minimal flooding was observed for the built environment. A few exceptions were identified around the towns of Scarborough and Old Orchard Beach. The 2 feet of sea level rise will amplify storm surge of coastal events, increasing surge depth and likely allowing water to travel further inland. In addition, the study team evaluated exposure to 10 feet of sea level rise as an exposure boundary (this is the highest amount of rise provided in NOAA's GIS layers).

Coastal Storm Flooding. Currently, there are 2 substations exposed to the 100-year and 500-year coastal floodplain. In addition, there are pad mount distribution transformers, distribution circuits, transmission lines, and other structures located in coastal flood plains. For a present day 100-year storm scenario the number of potentially affected substations increases to 7 under 2 feet of sea level rise and 16 in the 10 feet of sea level rise scenario. The future extent and depth of these flooding scenarios are driven by storm intensity and sea level; both of which climate change is projected to increase; increasing the exposure to this hazard.

Table 4. Number of Substations Exposed to Coastal Flooding

CMP Substation Coastal Flooding Exposure

Asset & Hazard	Substations Exposed	Total Number of Substations	Percentage Exposed
Substations & 100-year Floodplain	2	228	0.88%
Substations & 500-year Floodplain	2	228	0.88%
Substations & NOAA 2' Sea Level Rise	7	228	3.07%
Substations & NOAA 10' Sea Level Rise	16	228	7.02%

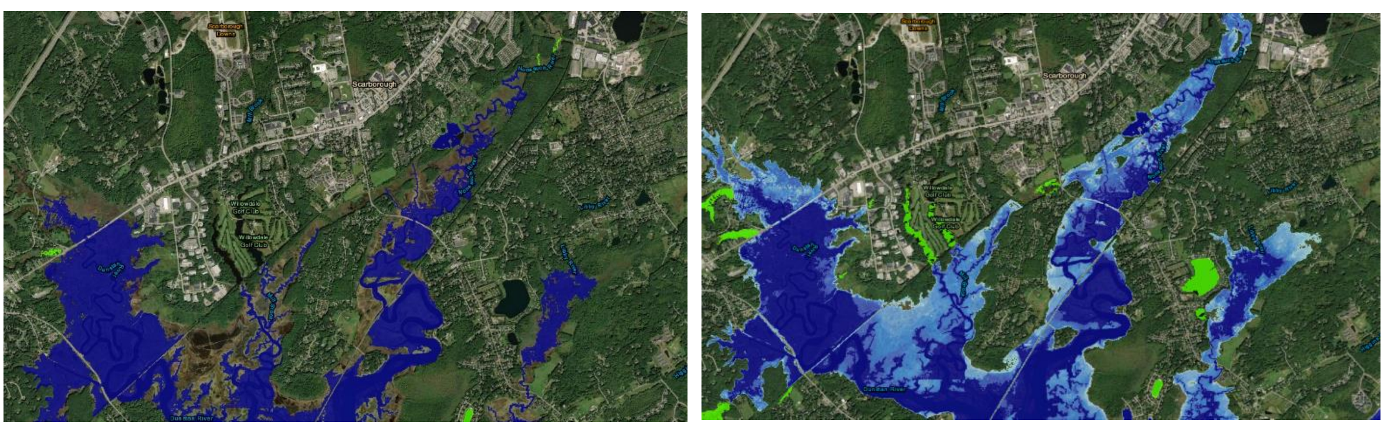


Figure 10. Coastal inundation under current mean higher high water and 2 feet of sea level rise (right) around Scarborough Maine along the Dunstan River, (NOAA, accessed October 2024).

Asset Exposure to Coastal Flooding					
Impact: Flooding can lead to asset damage and failure from contact or submersion in water. Increasing sea level rise, and storm intensity is projected to cause more significant flooding conditions in the future.					
Hazard	Baseline	Mid-Century Exposure	Late-Century Exposure	Impacted Service Areas	Exposure Score[17]
Coastal Flooding	High	High	High	All Coastal Service Areas	High
Chronic Exposure:	Sea-level is projected to rise by 1.5' by 2050, and 3.9' by 2100. Sea-level rise alone does not have direct impact on CMP assets.				
Acute Exposure:	High exposure score is based on acute coastal flooding events typically occurring during major storms, particularly those with storm surge that occurs co-incident with high-tides. These acute events are exacerbated by sea-level rise.				

[17] The CCVS found that chronic sea level rise coupled with normal tides and weather is not currently expected to impactful to CMP assets.

3.6 Hazard Projections and Exposures: Extreme Heat

Key Findings

- Currently, heat is not considered a substantial high risk for CMP assets and operations.
- Heat events are projected to increase in frequency and magnitude over the coming century.
- By 2050 under the moderate planning scenario and using variables tailored for CMP, heat events shift from a low exposure rating to a moderate exposure rating.
- The exception is Alfred service area which is projected to experience a high exposure rating.

Heat is a growing hazard for utilities across North America. Many assets are designed with specific operating temperatures, when these thresholds are exceeded asset functionality, such as capacity, may be impacted or physical damage may occur leading to a shortening of the asset's lifespan; these type of temperature exceedances rarely lead directly to asset failure though it can occur. Due to its potential to reduce equipment capacity, heat events are compounded by increases in demand driven by increased co-incident usage of air-conditioning usage during hot days and other demand growth driven by electrification and high demand customers (e.g., paper mills, healthcare, semiconductor manufacturers, etc.).

Over the past few decades, Maine has not experienced a significant number of heat events. According to national FEMA data, historically, Maine has not routinely experienced impactful heat waves compared to other parts of the country.[18,19] For example, data from a census tract around Portland suggests about a 18% chance of a notable heat wave in any given year (or tendency towards an event occurring every 5 years)[20]. Of the hazard mitigation plans reviewed during this study, only Androscoggin County identified heat as a top hazard in their county. As climate change and its future impacts progress future extreme heat events are expected to intensify and may become identified as a more frequent hazard in Maine.

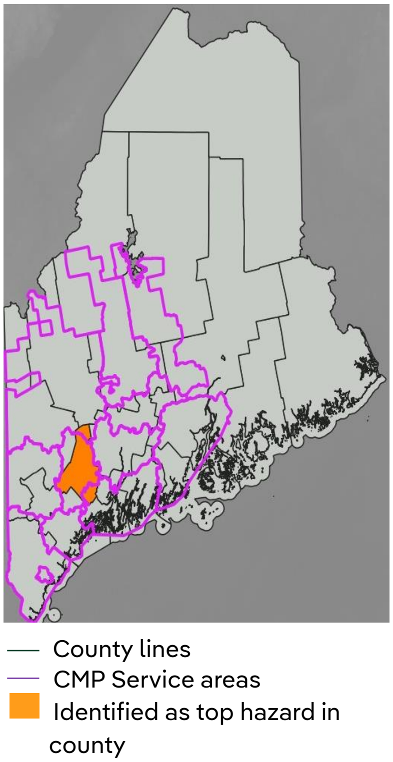


Figure 11. Counties with heat as a top hazard in their hazard mitigation plan

To project future conditions for the CMP service area, this study assessed future change in hot days and heat events, including specific temperature thresholds meaningful for a wide-range of CMP assets or processes: days per year with average temperature above 86°F, days per year with average temperatures above 95°F, days per year with maximum temperatures above 104°F, duration of consecutive days with maximum temperatures above 90°F, and the number of times per year maximum temperature exceeded 90°F over a three-day period.

The number of high temperature days consistently increased across all variables and scenarios evaluated. As expected, the most significant increases, for all variables, occur under the SSP5-8.5 90th percentile scenario– it is the only scenario that indicates non-zero number of days with the average temperature exceeding 95°F. Similarly, days with maximum temperatures above 104°F are also comparatively substantially higher under this scenario than 50th percentile scenario. Heat wave events are expected to increase in frequency and duration under all scenarios. These increases vary in intensity but are consistent with increased emissions and percentiles of results.

[18] Note the FEMA data focuses on heat waves that impact crops, mortality/injury, and lead to substantial costs in damages. See "Disasters and Other Declarations | FEMA.gov," October 20, 2024, https://www.fema.gov/disaster/declarations.
[19] Heat wave is defined as two or more days with temperatures above the historical averages that have impacted agriculture, health, costly damages.
[20] Census tract 23005000500

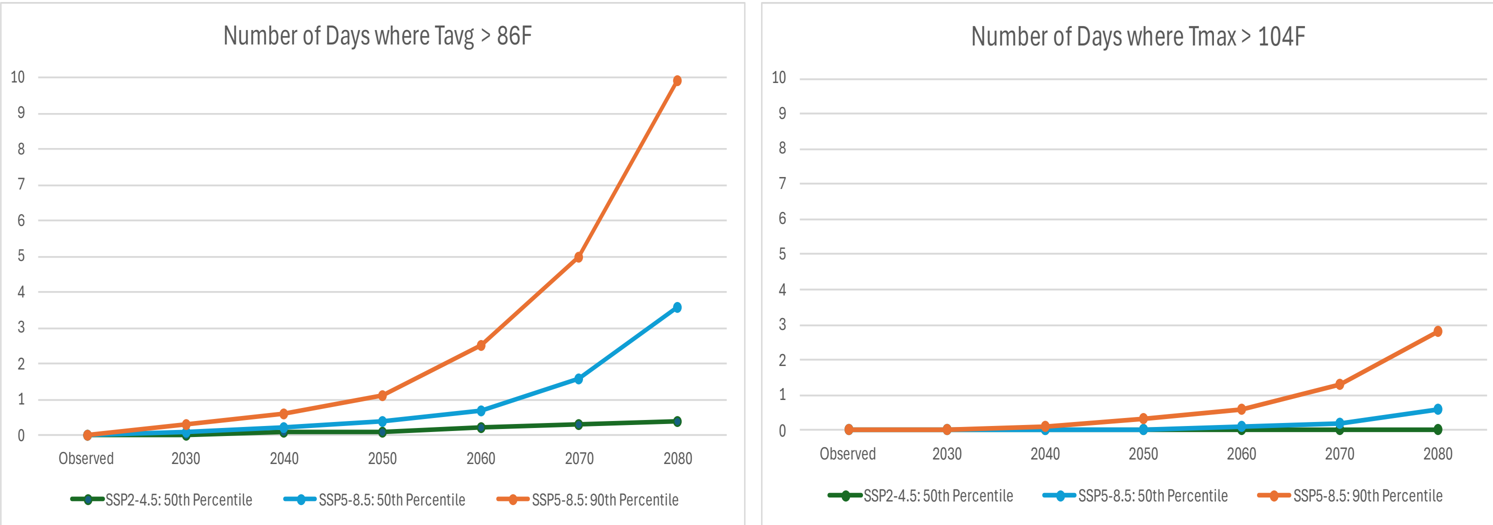


Figure 12. Days per year with avg. temperature above 86F and max temperatures above 104˚F

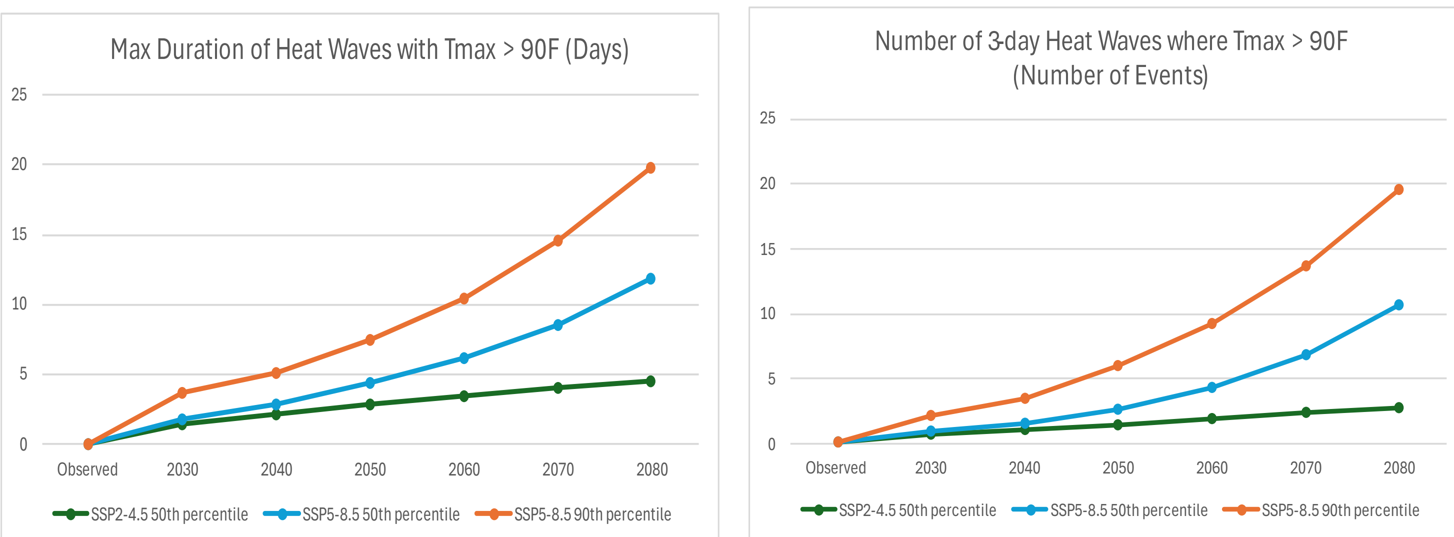


Figure 13. Heat wave occurrence and max duration per year (max temperature exceeding 90°F)

Asset Exposure to Extreme Heat

Impact: Extreme heat can lead to equipment damage, shortening an asset's life span, or in extreme instances leading to asset failure. Increased temperatures can also lead to decreases in asset capacity (while also causing increases in demand), potentially forcing utilities to shed load in the most extreme events.

Heat Wave Variables	Baseline	Mid-Century Exposure	Late-Century Exposure	Impacted Service Areas	Exposure Score
3-day heat waves	Low	Medium	High	Alfred (2050) All (2080)	High for Alfred Service Area
Maximum duration of heat waves	Low	Low	High	None (2050) All (2080)	

Hot Day Variables	Baseline	Mid-Century Exposure	Late-Century Exposure	Impacted Service Areas
Number of days Tavg > 86F (30C)	Low	Low	Medium	None
Number of days Tavg > 95F (35C)	Low	Low	Low	None
Number of days Tmax > 104F (40C)	Low	Low	Low	None

Chronic Exposure:	Annual or season changes to average temperatures are not directly impactful to utility assets.
Acute Exposure:	Exposure to acute events such as extreme heat days, or heat waves are projected to increase in both intensity and severity. Initially first observed in the Alfred Division by 2050.

3.7 Hazard Projections and Exposures: Cold Events

Key Findings

- Chronic exposure to cold temperatures is projected to improve based temperatures projections, including a warming trend for the coldest day of the year.
- Extreme cold events caused by polar vortex events will still occur, with some studies showing that this phenomenon may occur more frequently due to impacts from climate change.

Extreme cold temperatures have limited direct impacts on most distribution and transmission assets; however, over time, freezing conditions can cause asset damage or failure and create hazardous conditions that may lead to customer outages (e.g., iced-over tree branches making contact with overhead lines) or situations that may hinder power restoration (e.g., icy roads).

Maine is impacted by cold events with exposure increasing further inland away from the moderating impacts of the proximity to the Gulf of Maine. Though cold can be damaging, this hazard is not explicitly mentioned in county-scale hazard mitigation plans. This suggests it is integrated into the normal state of business for the county emergency management teams.

The coldest day of the year was used to assess future changes in cold events. As expected under future conditions, the coldest day of the year decreases substantially over the coming century.

Across scenarios, the coldest day of the year is projected to increase in temperature from the -14°F observational baseline. The degree of warming varies depending on scenario. By 2080, the coldest day of the year may increase by 6°F to the annual coldest temperature of -8°F under the SSP2-4.5 50th percentile scenario, and may increase by 16.6°F to an experienced coldest temperature of 2.6°F in 2080 under the SSP5-8.5 90th percentile scenario.

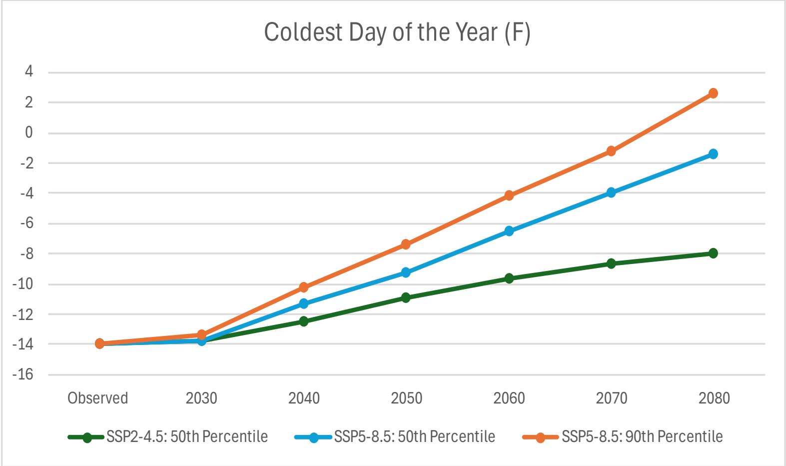


Figure 14. Coldest day of the year

In addition to the chronic changes there are acute cold events frequently caused by cold artic air infiltrating past the jet stream. In the upper atmosphere above the Arctic around 60°N, a circular band of very strong winds forms in the winter months, termed the polar vortex. The polar vortex originates in response to the very large temperature change between the bitter cold Artic circle and the warmer mid-latitudes. The greater the temperature difference, the stronger the winds. A very strong stable polar vortex serves as a protective boundary keeping the Artic air at the poles. In response, the jet stream, which is a narrow fast moving air current that travels around the Earth at around 50-60°N and drives mid-latitudes storms, tends to be farther north leading to warmer temperatures in Maine.

The polar vortex can weaken in response to sudden upper atmospheric warming, this occurs on average every other year. If the polar vortex weakens, shifts or splits, the jet stream becomes wavy bringing warmer air into the Arctic and sinking colder air into the mid-latitudes, chilling Maine. However, cold Artic air can reach the mid-latitudes without a break in the polar vortex. The findings from climate model experiments are mixed on whether warming and sea ice loss will result in a stronger or weaker polar vortex and is an area of active research. These acute polar vortex events represent some of the coldest temperatures experienced in Maine; as they are expected to occur in the future CMP will continue to consider cold events in its near-term planning.[21,22]

Asset Exposure of Cold Events					
Impact: Cold temperatures can lead to increase demand for heating, lead to icing on equipment which can cause asset malfunction or failure and can hinder restoration abilities.					
Variable	Observed	Mid-Century Exposure	Late-Century Exposure	Impacted Service Areas	Exposure Score
Coldest day of the year	-14.0°F	Low	Low	None (all Low)	Low
Chronic Exposure:	Text				
Acute Exposure:	Polar vortex and potentially other anomalous and acute cold weather events are expected to continue occurring through the coming century; though the change in the frequency of events is unclear.				

[21] "Understanding the Arctic Polar Vortex," NOAA Climate.gov, March 5, 2021, https://prod-01-asg-www-climate.woc.noaa.gov/news-features/understanding-climate/understanding-arctic-polar-vortex.
[22] "Another Blast of Arctic Air: This Time, With a Stretched but Strong Polar Vortex," NOAA Climate.gov, January 16, 2025, https://www.climate.gov/news-features/blogs/polar-vortex/another-blast-arctic-air-time-stretched-strong-polar-vortex.

3.8 Hazard Projections and Exposure: Drought and Wildfire

Key Findings

Chronic Conditions

- Historically, Maine has not routinely experience significant droughts or wildfires.
- In CMP service area, drought conditions are projected to remain similar to current conditions. Seasonal precipitation is projected to increase over the coming century, while temperatures are not projected to be so high as to create multiple consecutive drought years.

Acute Events

- Maine currently experiences periods of high, very-high or extreme Fire Weather Index; indicating that conditions conducive to wildfire are presently occurring. Interannual precipitation and temperature variability can cause periods where conditions conducive to wildfire can be exacerbated.

Drought

Drought has limited direct impacts on most transmission and distribution grid assets but can create conditions that increase the likelihood or severity of other hazards. This includes potentially increasing risk of conditions conducive to wildfire, or when paired with sudden extreme precipitation after drought conditions, there can be increased risk of flooding, landslides, or mudslides. Three counties identified drought in their hazard mitigation plan.

To develop projections for future drought specific to the CMP service territory the Standardized Precipitation Evapotranspiration Index (SPEI) was utilized after confirming its suitability as a reasonable proxy for drought in Maine with Maine Climate Council (MCC) Science and Technical Subcommittee (STS) representatives. The projections for SPEI were utilized to show what change from the existing baseline conditions could be expected. These projected found a less than 1% increase in probability that a mild or moderate drought may occur in all scenarios and throughout all timeframes. This suggests that there will be minimal change in future chronic drought conditions when viewed across 30-year averages. Specifically, projections show minor droughts may experience a very small increase across all decades and scenarios; moderate droughts are projected to remain similar to current conditions. These findings may be due to projected increases in precipitation balancing or slightly reducing the potential increase in vegetation drying caused by the projected rising temperatures. However, when specific conditions align the severity of drought can experience highly unusual years that are not apparent when observing 30-year averages.

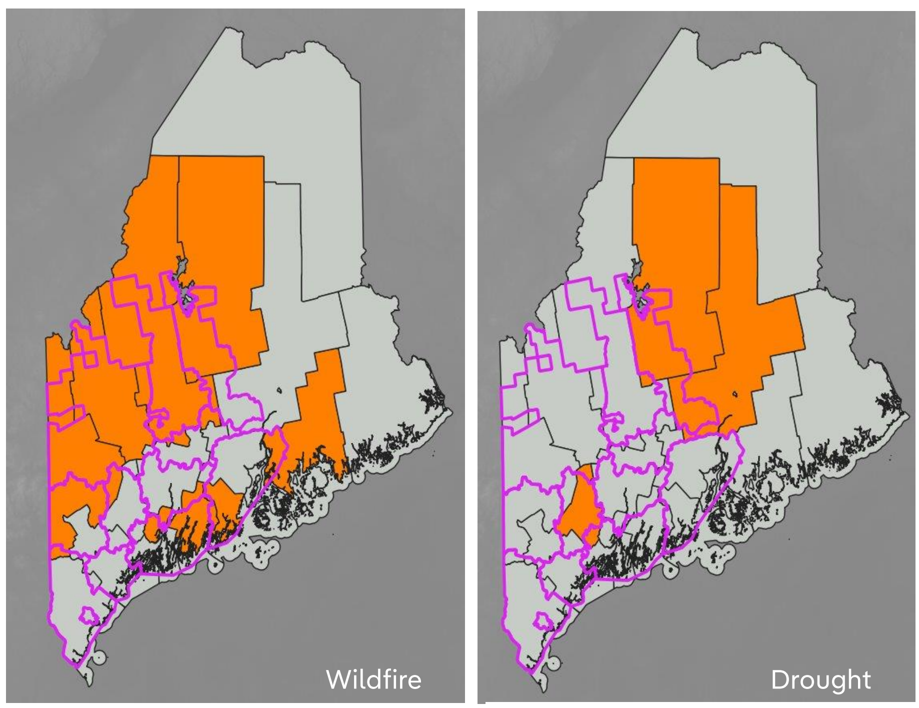


Figure 15. Counties that have identified wildfires and drought as hazards.

Climate change it is anticipated to cause the warm season to lengthen, and the cold season shorten, leading to a reduction in snowpack and a decrease in spring runoff. This combination of conditions can lead to drier soil conditions in the Spring, Summer, and Fall potentially causing a period that is dryer than average. These anomalously dry conditions could lead to an increase in wildfire conditions, particularly in Maine's areas of wildland-urban interface (WUI) which are comprised of approximately 3.2 million acres of forest and nearly 80% of the homes in Maine.[23,24]

Wildfire

Though the FEMA National Risk Index (NRI) suggests a low annual occurrence of impactful wildfires; many Maine counties have identified wildfires as significant hazards in their hazard mitigation plans. Utility equipment is generally not designed to be exposed to fire; accordingly, wildfire poses a threat to many assets as it has the potential to cause significant damage or destruction. To assess current day conditions CMP performed an assessment of the conditions conducive to wildfire by calculating the Fire Weather Index (FWI) across its service territories from 2013 through 2023. FWI uses temperature, precipitation, relatively humidity and windspeed to classify an area's potential for wildfire intensity; the ratings developed for FWI are (from least to most severe): Low, Moderate, High, Very High, and Extreme.[25] The extensive analysis included calculating the maximum FWI experienced in each area of the system, and the frequency that conditions conducive to wildfire occurred. Importantly, nearly all areas of the service territory were found to have experienced at least one day at a high or very-high FWI rating; with some experiencing more than 20. As a point of comparison, a high fire-risk state like California can experience 200 or more days of high, very-high, or extreme fire risk in a single year. While comparatively Maine faces hazardous fire weather much less frequently, conditions conducive to wildfire do occur.

Based on historical observations there have been periods of time where areas of Maine that have experienced conditions where the risk of drought and wildfire is elevated. In addition, findings from climate change projections indicate that these conditions may not improve; and during certain periods of time could become more severe.

Asset Exposure to Drought and Wildfire				
Impact: Drought can cause conditions conducive to wildfire to occur more frequently. If wildfires occur they can cause significant damage, particularly in areas near the wildland/urban interface.				
Drought Variable	Mid-Century Exposure	Late-Century Exposure	Impacted Service Areas	Exposure Score
Summer Mild Drought Conditions	Low	Low	None (all Low)	Low
Summer Moderate Drought Conditions	Low	Low	None (all Low)	Low
Chronic Exposure:	Climate change projections show minimal changes to conditions calculated 30-year averages.			
Acute Exposure:	If circumstances align (e.g., mild winter followed by a hot summer) drought conditions more significant than normal can occur leading to conditions more conducive to the formation or spread of wildfires.			

[23] Maine Forest Service: https://www.maine.gov/DACF/mfs/forest_protection/downloads/WildfireMFS.LUPC.pdf
[24] US Department of Agriculture: https://www.fs.usda.gov/nrs/fia/htmlTables/Maine2018/Table1.html
[25] Fires are twice as likely to occur on high- risk days compared to moderate risk days, and 10 times more likely compared to low-risk days

3.9 Hazard Projections and Exposure: Wood Decay

Wood decay has direct and indirect impacts on transmission and distribution assets. Decay can destabilize and weaken both wooden built structures and surrounding tree cover – particularly a tree that may be diseased or dead. This weakening can lead to damaged or failure of wooden poles and crossarms, as well as increased likelihood of impacts from falling branches or trees impacting line during storm events, both of which often lead to damage to assets and customer outages.

Scheffer Wood Decay Hazard Index

Key Findings

- Current conditions for CMP's service territory suggests high exposure to wood decay.
- Scheffer Index and the rate of wood decay is projected to increase.
- This increase has the potential reduce the lifespan of wooden components and increase impact of vegetation to utility assets.

The Decay Hazard (Scheffer) Index indicates potential wood decay for above-ground untreated wood and wooden structures exposed to the outdoors. [26] It identifies which outdoor conditions are warm and wet enough to cause decay in outdoor wood, woody debris, and standing dead trees[27]. Increases in the decay hazard index may also be related to causes of some disease in some tree species. [28]

This analysis studied changes in Scheffer Index Values to develop projections for wood decay potential across CMP's service territory. The projections suggest minimal change in potential decay in the near-term, but these changes are expected to become more significant later in the century across all scenarios. These increases are likely largely driven by increased temperatures expanding the "decay" season into what are currently colder months, in combination with an increased precipitation during these warmer months. Temperature and precipitation projections within CMP's service mirror these trends.

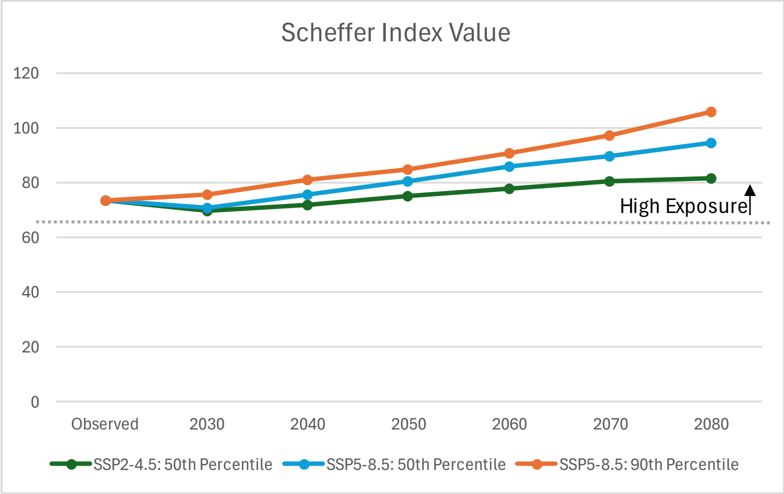


Figure 16. Projected Scheffer Index Value

[26] Charles G. Carll and United States Department of Agriculture Forest Service Forest Products Laboratory, "Decay Hazard (Scheffer) Index Values Calculated From 1971–2000 Climate Normal Data," *General Technical Report FPL-GTR-179* (U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, 2009), https://www.fpl.fs.usda.gov/documnts/fplgtr/fpl_gtr179.pdf.
[27] Wang and Morris. Effect of Climate Change on Above-Ground Decay Hazard for Wood Products According to the Scheffer Index, CWPA Proceedings, 2008, pp.99-103. Microsoft Word - wang29.doc (woodpreservation.ca)
[28] Wang and Morris. Effect of Climate Change on Above-Ground Decay Hazard for Wood Products According to the Scheffer Index

Asset Exposure to Wood Decay					
Impact: Wood decay may lead to accelerated decay for outdoor wooden components and dead or diseased vegetation.					
	Observed	Mid-Century Exposure	Late-Century Exposure	Impacted Service Areas	Exposure Score
Wood Decay Hazard Index	High	High	High	All	High
Chronic Exposure:	Projections show increases to precipitation and temperature throughout the century. These changes are expected to result in increases to decay rate of wooden components in the future.				
Acute Exposure:	This hazard does not have an acute component.				

Asset Vulnerability Assessment

4. Asset Vulnerability Assessment

4.1 Framework

This assessment adopts a framework to assess vulnerability that has been utilized by the other Avangrid utilities performing similar vulnerability analysis. This framework is rooted in industry best practices that stem from work performed by the IPCC.

This approach determines asset vulnerability by combining the projected exposure to climate hazards with an asset's sensitivity to a given hazard, and the criticality of the asset. The Avangrid utilities share many common design standards and technical resources; however, to ensure that sensitivity and criticality scores reflected any necessary differences, the CMP core team that supported the development of this study reviewed these evaluations. For the purposes of this study:

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

The vulnerability approach follows a two-step process (as seen in the figure below). Step 1 utilizes the climate projections described in Section 4 of the CCVS and applies them to assets. The raw data of the climate hazard projections are further interpreted into scores on a Low/Medium/High exposure scale. The thresholds that define these scores were determined by a combination of industry standards, data distribution, climate science thresholds, and SME input. Each asset assumes the exposure score of the climate hazard that it is overlaid with and receives separate exposure scores for each climate hazard evaluated. At the conclusion of this step, only exposed assets were selected for further analysis.

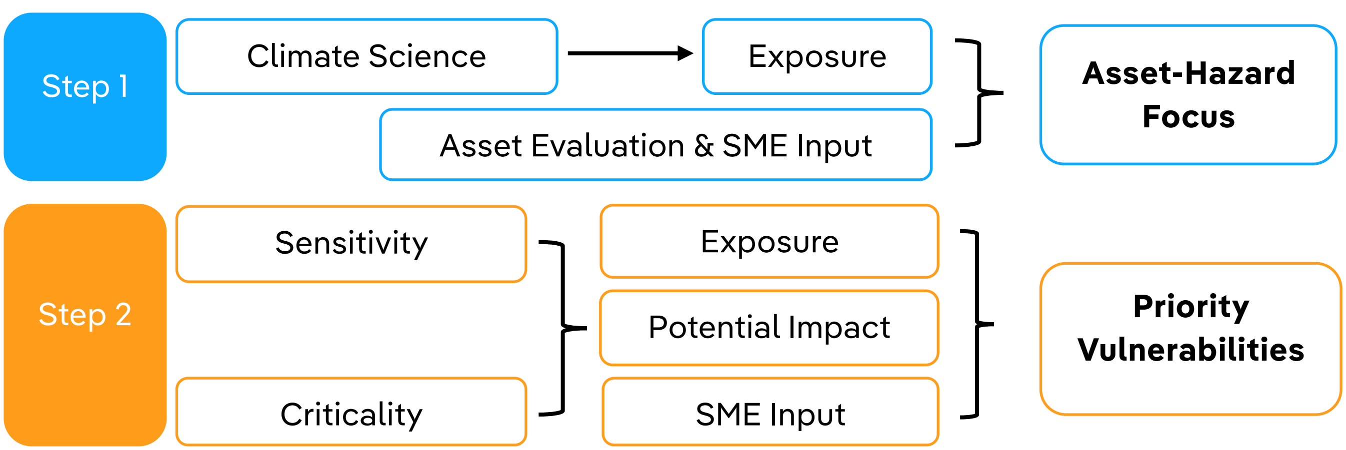


Figure 17. Vulnerability Study Process

Step 2 of this process began with the study team reviewing the sensitivity and criticality scores including a vetting and review process performed by the CMP core team to ensure that all assumptions made were representative of CMP assets, existing resilience measures, or other unique characteristics of the CMP system. After necessary adjustments were made, the study team combined sensitivity and criticality scores to create potential impact scores for each asset-hazard combination. The Study team then combined potential impact with exposure to produce vulnerability scores for each asset-hazard combination. The study team utilized the following coloring scheme to score assets and impacts across exposure, criticality, sensitivity, potential impact, and the resulting vulnerability. The specific framework used to determine each rating is included in its respective section.

Table 5. Asset Scoring Color Scheme.

Not Applicable	Minimal	Low	Medium	High	Severe

Less Severe → More Intense

After all vulnerability scores were calculated, the study team identified the high or severe vulnerabilities; these asset-hazard combinations were classified as "priority vulnerabilities". These priority vulnerabilities will be the focus of the CCRP.

4.2 Asset Vulnerability Methodology

Assets

The CCVS vulnerability assessment included transmission, substation, and distribution asset families. The study team worked with the CMP core team and others to identify a list of assets that provided a representative overview of the CMP system for grouping into their respective asset families. Transmission assets include grid infrastructure that carries electricity at high voltages over longer distances, including from generation facilities. Distribution assets are the most plentiful asset type, they originate at area substations and provide power delivery to customers at a local level. Substations are part of both the distribution and transmission system and serve as vital connectors, separating circuits, modulating voltages and managing load. Within the asset families, the following assets were identified for inclusion in this study:

Table 6. Assets and Asset Families

Transmission Asset Family	Distribution Asset Family	Substation Asset Family
Structures	Structures	Transformers
Overhead Conductors	Overhead Conductors	Regulators
Underground Conductors	Underground Conductors	Instrument Transformers
Reclosers (subtransmission)	Transformers (Overhead)	Circuit Breakers
	Transformer (Pad-Mounted/Underground)	Support Structures
	Regulators (Overhead)	Dynamic Reactive Devices (e.g., STATCOM/SVC)
	Capacitors (Overhead)	Control House
	Surge Arrestors	
	Reclosers	

Exposure Ratings

Based on the findings provided in Section 4, four hazards were identified at a high exposure rating including extreme heat for Alfred service area, inland flooding & extreme precipitation, storm events & wind for the entire entire region, and coastal flooding for the coastal areas within CMP service area. As a reminder these scores are developed to view future conditions with a score of "Low" indicating either an improvement (e.g., less severe) or no change to severity – an item with a "Low" score does not indicate it is not currently impactful.

Table 7. Exposure Ratings for each climate hazard.

Extreme Heat	Extreme Cold	Frozen Precipitation	Drought & Wildfire	Inland Flooding & Extreme Precipitation[29]	Coastal Flooding[29]	Storms Events & Wind
High (Alfred area)	Low (Improvement)	Low (Improvement)	Low (minimal change)	High	High	High

Sensitivity Ratings

Sensitivity is the degree to which assets could be negatively affected by exposure to a climate hazard. For example, pole-mounted distribution transformers are not sensitive to flooding because of their elevated position, but the pole itself would be sensitive to flooding. The sensitivity ratings for assets were characterized through collaboration between SMEs and the study team and are defined as follows:

Table 8. Sensitivity Rating Rubric

Not Applicable: Assets that are not sensitive a climate hazard.

Minimal: Assets that have minimal sensitivity or experience minimal adverse impact when exposed to a climate hazard. Typically not an environmental hazard considering during design or specification of the asset.

Low: Assets that have low sensitivity or experience low adverse impact when exposed to a climate hazard. The hazard may be considered during design or specification of the asset; but is generally not impactful.

Medium: Assets that have medium / moderate or experience medium adverse impact when exposed to a climate hazard. A hazard that is routinely considered during design or specification of an asset.

High: Assets that may be subject to major or sudden failure in the event of exposure to a climate hazard. A hazard that is always considered during specification or design of an asset; intensity of the hazard has direct linkage to asset performance.

Criticality Ratings

Criticality is defined as the magnitude or extent of negative outcomes for the CMP systems, personnel, or customers, when an asset is damaged. It can range from low, when the negative outcome extent is minor and localized, to high when impacts can be widespread. For example, the failure of a pole or pad-mounted

[29] The sensitivity of assets to the "extreme precipitation, & inland flooding" and "coastal flooding" hazards are identical. To simplify they are discussed jointly throughout Section 4 under the grouping titled "Extreme Precipitation and Flooding".

distribution transformer may cause a localized power outage, while the failure of a substation transformer may result in a more significant impact based on the number of customers served. Unlike sensitivity ratings, criticality ratings are independent of exposure to climate hazards. As consumers and commercial and industrial customers increasingly adopt electrified technologies, criticality will correspondingly increase. The shift toward electrification is evidenced both in the models used for the Governor's Energy Office's *Pathways to 2040* report and Maine Energy Plan, as well as CMP's own integrated grid plan, in which CMP was directed by the MPUC to base its models on ISO New England's 2040 CELT forecast. The criticality ratings utilized are defined as follows:

Table 9. Criticality Rating Rubric

Low: Assets that if damaged would result in localized minor or minimal adverse outcomes.
Medium: Assets that if damaged could result in localized adverse outcomes, including outages restored in under 24 hours, and/or moderate complexity asset repairs.
High: Assets that if damaged could potentially result in widespread outages lasting more than 24 hours, and/or highly complex asset repairs.

Potential Impact Rating

Potential impact reflects the potential for negative outcomes to result in the event of climate hazard exposure. Potential impact was determined by combining the asset's sensitivity to each climate hazard and its criticality rating. The color-coded cells in Table 10 show the rubric for potential impact rating, ranging from "not applicable" to "severe".

Table 10. Potential Impact rating rubric.

Criticality \ Sensitivity	Minimal	Low	Medium	High	Not Applicable
Low	Minimal	Minimal	Low	Medium	N/A
Medium	Minimal	Low	Medium	High	N/A
High	Low	Medium	High	Severe	N/A

Vulnerability Scores

An asset's vulnerability rating to a climate hazard was calculated by combining the asset's exposure to each climate hazard with its potential impact rating. Vulnerability communicates if an asset is exposed to a climate hazard and the implications upon being impacted. The vulnerability ratings for each asset–hazard combination ranged from "deprioritized" to "higher priority". The color-coded cells in Table 11 show the vulnerability rating rubric.

Table 11. Vulnerability rating rubric.

Exposure \ Potential Impact	Minimal	Low	Medium	High	Severe	Not Applicable
Low	De-prioritized	De-prioritized	Lower Priority	Medium Priority	Medium Priority	N/A
Medium	De-prioritized	Lower Priority	Medium Priority	Medium Priority	Priority	N/A

High	Lower Priority	Medium Priority	Medium Priority	Priority	High Priority	N/A

4.3 Asset Vulnerability Results

Utilizing the methodology outlined in the previous parts of Section 4, asset/hazard combinations across the three asset families were tabulated. Combinations that received a high vulnerability score in the at least one area of the service territory were identified as a priority vulnerability and include a narrative discussion in their respective section below. The priority vulnerabilities in this assessment include:

Table 12. Asset-Family/Hazard Priority Vulnerabilities.

Transmission Asset Family	Distribution Asset Family	Substation Asset Family
Storm Events & Wind	Storm Events & Wind	Storm Events & Wind
	Flooding - Extreme Precipitation & Inland Flooding, Coastal Flooding	Flooding - Extreme Precipitation & Inland Flooding, Coastal Flooding
		Extreme Heat

Substation Vulnerability

Electrical substations are facilities where one or more generation, transmission, or distribution systems interconnect to distribute electricity to other parts of the power system. Substations often include complex pieces of interconnected electrical assets, like transformers and circuit breakers, that are crucial to the function of the grid. The priority vulnerabilities for substation assets are extreme heat (Alfred service area), coastal flooding, inland flooding and extreme precipitation, and wind. The vulnerability of each component is scored below followed by discussion on selected climate hazards.

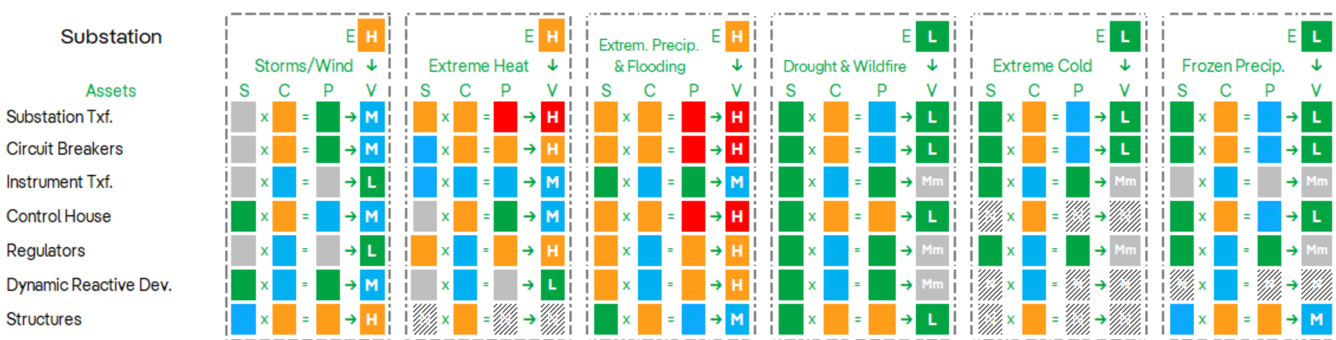


Figure 18. Substation Summary Vulnerability Table

High Vulnerability Score Discussion

Substation Asset Vulnerability to Extreme Heat: Increasing ambient temperatures reduce the ability of substation assets to effectively dissipate heat, which can adversely affect their operation. For example, high temperatures coupled with high usage can cause components to exceed their maximum operating temperature and suffer damage and accelerated aging of insulation. Heat is projected to be at a high level of exposure in the Alfred service region. The rest of service territory is projected to experience lower levels of heat exposure, and thus lower levels of vulnerability until late century.

Substation Asset Vulnerability Extreme Precipitation and Flooding: Substation assets are often located outdoors for the entirety of their multi-decade service lives. Most substation assets are highly sensitive to flooding when installed at or near ground level, in addition many of these assets have a high criticality rating. Substations are often not vulnerable to shallow flood depths, though changes in flood characteristics could lead to significant disruption or asset failure. There is an elevated risk of exposure to flooding for substations that are in or near floodplains or bodies of water, at low-lying elevations within the watershed, or near steep slopes. Coastal flooding differs from inland flooding because high-tides, wave action, and storm surge push water further inland and at increased depths. Substations asset at coastal facilities are vulnerable in similar ways to those located inland; though contamination from salt water represents an additional issue compared to freshwater flooding. Surface runoff from extreme precipitation can accumulate in low-lying elevations and reach enough velocity and depth to drag debris and cause structural damage upon collision.

Higher flood inundation depths may reach equipment control cabinets or other accessories like fans, pumps, and external wiring connections, causing significant damage. While control rooms and houses may have some flood protection measures, such as trench pumps/drains and flood-resistant doors, those built at or near ground level and can be inundated by floodwater. If floodwaters breach the control house, protection, and control assets, which are highly sensitive to water, are likely to be damaged.

Substation Asset Vulnerability to Storm Events & Wind: Substation asset vulnerability to wind is primarily driven by asset criticality; most substation assets have a lower sensitivity to wind because they are located close to the ground and are generally not exposed to higher windspeeds that can occur at higher elevations. The general exception to this are elevated substation structures that connect to incoming transmission lines; however these facilities are typically constructed to withstand extreme windspeeds. Finally, substations typically have vegetation surrounding the perimeter of the facility removed, decreasing the likelihood of the direct effect that nearby vegetation damaged by wind can have on a substation.

Distribution Vulnerability

Distribution assets originate at a substation and deliver electricity to customers at voltages lower than transmission assets. The priority vulnerabilities for distribution assets are inland flooding and extreme precipitation, coastal flooding, and storms/wind. The vulnerability of each component is scored below followed by discussion on selected climate hazards.

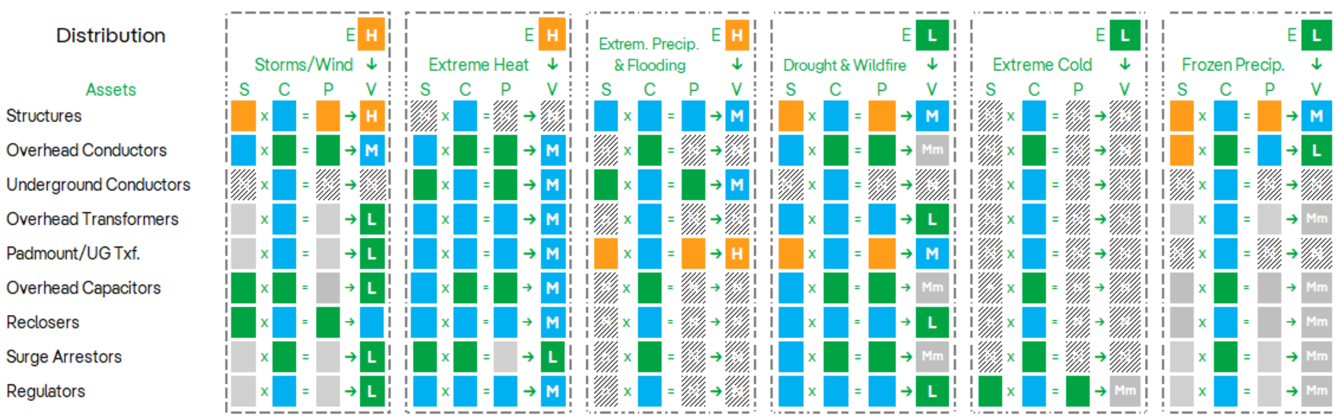


Figure 19. Distribution Summary Vulnerability Table

High Vulnerability Score Discussion

Distribution Asset Vulnerability Extreme Precipitation and Flooding: Most distribution assets are mounted above ground and are not notably susceptible to flooding; however, pad mount transformers or other underground equipment that is typically installed at or below grade and can be damaged by flooding. Equipment that is located underground (e.g., urban networks) are designed to be submerged; however repeated flooding, particularly if it includes brackish floodwaters, can have impacts over time. If floodwaters are flowing versus standing, there are opportunities for equipment to be struck by floating debris, or the dirt around a structure to be scoured away potentially destabilizing the structure. Coastal flooding poses a unique hazard as salt water can cause corrosion and further damage assets even after flood waters have receded.

Distribution Asset Vulnerability to Storm Events & Wind: Most distribution assets were rated with a low vulnerability to wind due to their limited cross-section or height from ground. However, wind also affects vegetation and can lead to events such as downed trees, which can then affect distribution assets, particularly distribution conductors and structures. Contact with vegetation or wind-blown debris can affect all or part of a distribution circuit and its customers. The sensitivity of overhead line structures is particularly acute, especially for aging or damaged infrastructure (such as wooden poles with rot or woodpecker damage), which may be less resilient to this hazard. The impacts from vegetation as well as the wind-loading on structures resulted in this receiving a high vulnerability rating. Accordingly, the combination of wind and distribution assets was determined to be a priority vulnerability.

Transmission Vulnerability

Transmission assets carry electricity at high voltages over longer distances and/or from generation stations to the distribution system. Transmission assets must connect through a substation before meeting distribution assets in order to step down their voltage. Wind is the only priority vulnerability for transmission assets, driven by the sensitivity of tall overhead assets and their accompanying criticality. Other than wind there are no other priority vulnerabilities for transmission assets. While exposure to some hazards are high, the sensitivity or criticality scores are lower. The vulnerability of each component is scored below.

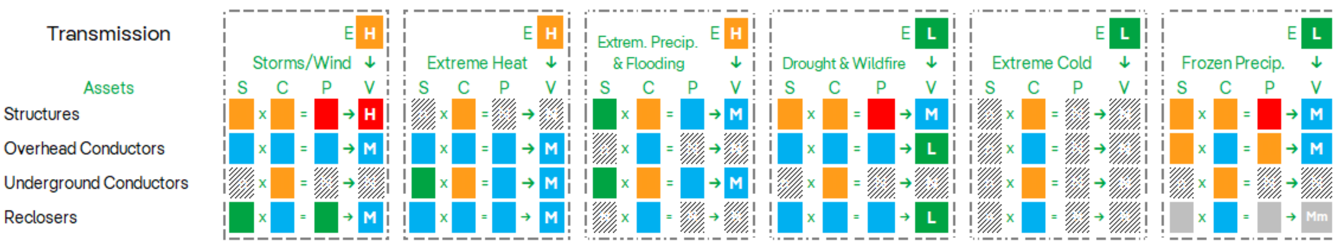


Figure 20. Transmission Summary Vulnerability Table

High Vulnerability Score Discussion

Transmission Asset Vulnerability to Storm Events & Wind: Transmission line structures, including towers and poles, are highly vulnerable to wind and can fail in extreme circumstances when winds exceed equipment design parameters. This can be exacerbated when a pole is damaged or aged (e.g., a wooden pole experiencing rot). Underground transmission conductors are sheltered from wind impacts and were rated as not applicable, and conductors and reclosers have some sensitivity to wind but are not as sensitive as structures nor as critical based on the ease of repair compared to structures. Overall, due to their sensitivity to wind and their high criticality of failure, transmission line structures and wind were identified as a priority vulnerability.

4.4 Summary of Asset Hazard Combinations with High Scores

The vulnerability screening of all CMP asset types identified extreme precipitation and flooding, storms events & wind, and extreme heat as the highest priority hazards with impacts to transmission, distribution, and substation assets. Extreme precipitation and inland flooding, as well as coastal flooding, impact the most asset types, with multiple substation assets receiving high vulnerability scores driven by both the criticality and sensitivity of the assets. While most distribution assets are not highly vulnerable to flooding, pad mount transformers are the exception, due to their high sensitivity to damage from flood waters (because they may be installed only slightly above grade) paired with their criticality. Heat also emerged as a priority vulnerability but only affects heat-sensitive and highly critical substation asset types, including circuit breakers, transformers, and regulators. However, this vulnerability is likely to be limited only to the southernmost region of the service territory through 2050, with the potential for more widespread vulnerability by late century. Storm events & wind event are also a priority vulnerability, affecting primarily overhead assets across all three asset families. The following table outlines the priority vulnerabilities across all hazards and asset families.

Table 13. Asset Priority Vulnerabilities

Climate Hazard	Transmission	Distribution	Substation
Extreme Precipitation and Flooding		• Pad mount transformers	• Transformers • Circuit Breakers • Dynamic Reactive Devices • Control House • Regulators
Extreme Heat			• Transformers • Circuit Breakers • Regulators
Storm Events & Wind	• Structures	• Structures	

Climate Change Operational Vulnerabilities

5. Operational Vulnerabilities

As part of CMP's assessment of climate vulnerability and risk, the study team conducted an evaluation of the Company's operational vulnerabilities in addition to its assets. The study team worked with the CMP core team to identify seven affected operational processes including Asset Management, Facility Rating, Load Forecasting, Vegetation Management, Reliability Planning, Workforce Safety, and Emergency Management. Utilizing the climate projections produced during the asset vulnerability assessment, TRC in-house experts, relevant CMP subject matter experts (SMEs), and the study team were able to assess the relative vulnerability of each of the operational groups. As noted earlier in this report, this assessment focuses on emerging and/or amplified climate vulnerabilities. For example, exposure to extreme cold is not projected to increase on average through to 2050. This suggests that CMP's existing processes should continuing to remain effective and are not expected to require significant changes to accommodate increases in future climate risks. The following table and proceeding sections summarize the key operational challenges and examples of how resilience to climate hazards can be increased for each of the operational groups.

Table 14. Summary of Future Vulnerabilities for Operations.

Operation Processes	Extreme Heat	Frozen Precipitation	Inland Flooding & Extreme Precipitation, Coastal Flooding	Wildfire & Drought	Extreme Cold[30]	Storm Events & Wind
Asset Management	✓	✓	✓	✓		✓
Facility Ratings	✓					
Load Forecasting	✓					
Vegetation Management	✓	✓	✓	✓		✓
Reliability Planning	✓	✓	✓	✓		✓
Workforce Safety	✓		✓	✓		✓
Emergency Management	✓	✓	✓	✓		✓

5.1 Asset Management

Vulnerability Summary

The Asset Management group at CMP is responsible for tracking and evaluating health and risk of failure of substation and transmission assets. CMP performs routine inspections of substations every two weeks and transmission lines every ten years, with flyover inspections occurring more frequently (multiple times a year, particularly after major storms). Due to the wide range of assets that the group monitors, its processes may be impacted by multiple climate hazards. While some climate impacts may adversely affect some assets more than

[30] Extreme cold temperatures are projected to trend in a favorable direction; accordingly existing Operational Processes are expected to remain effective into the future.

others, the wide range of potential impacts from these hazards threaten asset health and may pose issues for existing monitoring, evaluation, and repair/replacement practices.

Climate Challenges

Based on the exposure to climate hazards and sensitivities of the group's practices and processes that were determined through interviews with SMEs, the following climate challenges were identified:

- Potential equipment damage caused by the emergence of hazards, such as heat and flooding, may challenge current inspection and monitoring efforts.
- Woodpecker damage to poles may increase as increasing temperatures caused by climate change are projected to increase woodpecker populations in Maine.
- Current limited use of advanced technologies to monitor asset health and predict failure may create risk as impacts to asset health are expected to increase due to climate change, technological insights into the asset's health may become increasingly important.
- Supply chain issues pose a risk to the grid as immediate availability of new and replacement equipment can be challenging. Climate change may further threaten supply chains and increase the demand for replacement assets (e.g., a coastal flooding event in a region may cause a widespread need for pad mount transformers).

Growing Future Resilience

- Increasing the use of satellite imagery, additional sensors, AI, predictive analytics, and other technologies could greatly improve the ability to model acute and chronic climate impacts, in-person inspections, and better allocate resources for repair and replacement.
- While individual asset risk scores are calculated using in-house tools, use of an asset management software platform that combines inspection data to calculate risk of failure and provide additional system insights could greatly aid the efficiency and decision-making abilities, which may become increasingly important as the impacts from climate change become more severe.
- Using location specific climate projections to prioritize areas of the transmission system to conduct additional inspections based on asset vulnerability, could assist in identifying assets that may fail between existing inspection cycles.
- Reviewing, and potentially increasing, spare asset inventories may enhance recovery from climate impacts, especially large regional events that may further constrain the market for transformers and other high-demand assets.

5.2 Facility Ratings

Vulnerability Summary

The Ratings and Modeling group at CMP determines the ratings of all CMP transmission lines, transformers, and all other devices connected in series to the transmission system. Facility ratings refer to the maximum operating limit that an electrical asset can safely handle (expressed in power units, such as voltage or current). Extreme Heat poses the largest risk to facility ratings compared to many other hazards. High temperatures can limit capacity of assets, cause wear and shorten lifespans, and in extreme circumstances lead to outages through line sag/clearance violations, load shedding, or equipment failure.

Climate Challenges

Based on the exposure to climate hazards and sensitivities of the group's practices and processes that were determined through interviews with SMEs, the following climate challenges have been identified:

- CMP's current seasonal transmission line ratings could become inadequate to confront shifts brought on by climate change, as projected warming may reduce the conductor capacity. However, much of this risk is mitigated as CMP is currently in the process of changing how they rate transmission assets to provide Ambient Adjusted Ratings as required in FERC Order 881.
- Warming by 2050 in the Alfred region of the service territory may prevent some transmission assets with lower temperature ratings to be adequately adjusted to provide the capacity to meet warming conditions, particularly during extreme heat events. By 2070, additional warming throughout the service territory may increase this risk.
- Much of CMP's current efforts to introduce ambient adjusted ratings focus on transmission facilities. Expanded heat impacts may make it critical to include other assets, particularly load serving transformers, in this type of program.

Growing Future Resilience

- Incorporating Dynamic Line Ratings (DLR) in addition to Ambient Adjusted Ratings can greatly increase resilience to extreme heat. DLR allows for greater insight into real-time conditions of an asset (e.g., line sag), potentially allowing for greater capacities and more accurate adjustments to the increasing variability of weather caused by climate change.
- Incorporating climate projections into long-term transmission planning can ensure that hazards continue to be mitigated in future planning as well as present day in the facility rating practices.
- Ensuring dynamic rating practices extend to as many transmission assets as possible (e.g., transformers) can greatly increase the resilience of all transmission assets to heat and other climate impacts.

5.3 Load Forecasting

Vulnerability Summary

The Load Forecasting group at CMP is responsible for projecting peak and base loading of the CMP system. While base loading may increase with electrification of heating and transportation, population growth, and emerging high-usage customers, peak loading will be also be impacted by climate change. Customer demand is heavily dependent on ambient temperature and the effect on the heating and cooling of habitable spaces; extreme heat is expected to pose a vulnerability to the group's processes. Projected increases in high heat days, especially in the Alfred service area, will over time likely lead to increased use of energy for cooling and may challenge a lot of current assumptions and practices. If forecasting models do not account for future temperatures, incorrect forecasting can result in inefficient grid operations, unnecessary costs, and in extreme instances, outages.

Climate Challenges

Based on the exposure to climate hazards and sensitivities of the group's practices and processes that were determined through interviews with SMEs, the following climate challenges have been identified:

- Air conditioning usage is expected to rise as temperatures increase, resulting in an increase in demand and an emergence of a significant summer peak in parts of the service territory. This may be further exacerbated by a shrinking diurnal temperature range, increasing demand in summer evenings as well.

- The current load forecasting process utilizes a weather dataset to forecast peak loads based on a rolling thirty-year sample of design weather. Because the dataset does not include forward-looking temperature projections, it may not completely capture projected increases in temperature, particularly as more deviations from historical trends occur.
- Climate change is projected to increase weather variability, including increased heatwaves, sudden unexpected cold snaps (from the weakening of the polar jet stream and polar vortex)[31], and greater variability of unseasonable temperatures that are difficult to model, especially when relying on historical data, and may result in deviations from the forecasted assumptions.
- While not directly related to the impacts of climate change, efforts to reduce GHG emissions in the heating and transportation sector through electrification are poised to have significant impacts to load forecasts, and their development.

Growing Future Resilience

- Directly incorporating the use of future temperature projections into load forecasting model can greatly increase the group's ability to accurately forecast load amidst changes in temperature related to climate change.
- Additional staffing of experienced forecasters and other professionals with data science and climate science backgrounds can assist the load forecasting team in continuing to adjust their procedures to utilize big data, adopt best practices, and incorporate climate science into forecasting models.
- Continuing to find opportunities to integrate technology, such as additional sensors or AI, could also be useful in maintaining a dynamic and adaptive load forecasting practice that is most adaptable to the impacts of climate change.

5.4 Vegetation Management

Vegetation Management Vulnerability Summary

The Vegetation Management group at CMP is responsible for monitoring and maintaining vegetation along the CMP Right-of-Way (ROW). Vegetation coming into contact with assets and causing damage, particularly during severe weather events, is one of the leading causes of outages for CMP and utilities nationwide. Climate change is projected to cause increases in severe storms/strong winds, flooding, and droughts, all of which may increase the likelihood or impact of vegetation coming into contact with lines and other grid assets. Climate change is also projected to change vegetation growth cycles and introduce invasive species which can lead to additional hazard trees, or in some cases, increased vegetation growth. A wide range of climate hazards can interact with vegetation, as such, vegetation management is vulnerable to most climate hazards that the service territory is exposed to.

Climate Challenges

Based on the exposure to climate hazards and sensitivities of the group's practices and processes that were determined through interviews with SMEs, the following climate challenges have been identified:

- Increasing extreme storms have the potential to cause widespread outages from vegetation coming into contact with grid assets. Vegetation management will be an increasingly important component in mitigating the impacts of extreme weather events.

[31] Massachusetts Institute of Technology. (May 21, 2024). *The polar jet stream and the polar vortex*. MIT Climate Portal. Retrieved November 21, 2024 from https://climate.mit.edu/explainers/polar-jet-stream-and-polar-vortex

- Changes in the climate, especially in temperature, are expected to alter vegetation growth response. These changes may result in increased encroachments of ROWs and the need for additional resources.
- Projected increases in extreme precipitation may cause additional stress on ecosystems, leading to increased hazard trees. Additionally, droughts can weaken tree roots, leaving them more vulnerable to toppling over during heavy winds, floods, and storms.
- Invasive plant species have increased in prevalence in the service territory and are projected to continue to increase with climate change. This can pose access issues for vegetation management crews because of their dense growth, as well as their ability to weaken and weigh-down trees.

Growing Future Resilience

- As vegetation growing cycles change from increasing temperatures and potential vegetation risk grows from climate change-related increases in wind, flooding, and wildfire, increased frequency of trimming cycles and/or augmenting with condition-based trimming may help to control growth into the ROW and prevent future outages.
- Technology could greatly assist in vegetation management practices, especially in confronting climate change. AI and risk analysis software can help identify and prioritizing high-risk areas for trimming.
- Incorporating climate projections into vegetation management planning, budgeting, and operations can aid the group in confronting climate impacts and proactively addressing emerging risks.

5.5 Reliability Planning

Reliability Planning Vulnerability Summary

Reliability Planning spans across several disciplines at CMP, including Distribution Operations and Operational Performance. Operational Performance staff analyze the data associated with the system's performance, helping CMP interpret outage trends, and provide valuable data-driven insights into how asset performance, investment, and capital projects impact reliability. Engineers focused on the design and operation of the distribution system rely on this data to prioritize reliability investments. Overall, climate change is expected to greatly impact reliability as increasingly severe and frequent hazards may strain the system and are anticipated to increase the frequency of outages. These changes may pose a challenge to current assumptions in reliability planning and will require the creation of additional insights to inform climate-related decision making. Because of the wide range of assets that the group monitors, reliability planning is exposed to the impacts of multiple climate hazards.

Climate Challenges

Based on the exposure to climate hazards and sensitivities of the group's practices and processes that were determined through interviews with SMEs, the following climate challenges have been identified:

- Climate change is projected to increase the frequency and severity of storms, likely resulting in an increase in the magnitude and frequency of outages and impacting the reliability of the system. Overall, climate change is projected to lead to an increase of both short-term and long duration outages, causing reliability issues for CMP, and potentially threaten the utility's ability to meet their regulatory reliability performance requirements.
- Emerging hazards, such as heat and flooding, may cause new impacts to reliability that have not previously been impactful. Currently, reliability planning evaluates historical hazards and outages.
- Electrification-induced increases in demand may come into conflict with decreases in capacity caused by high heat events, potentially leading to reliability issues.

Growing Future Resilience

- The implementation of additional resilience measures will be crucial to maintain and improve reliability and should ideally move beyond traditional storm hardening to include a holistic, multi-hazard approach to mitigate the impacts of climate change to infrastructure, operations, staff, and customers.
- Implementing the use of climate projections paired with historical weather and outage data can potentially be used to model climate impacts on reliability and assist in the planning of resilience measures.

5.6 Workforce Safety

Workforce Safety Vulnerability Summary

The workforce safety group at CMP determines and provides policies, procedures, trainings, and evaluations to ensure that CMP maintains safe working conditions for its staff. As multiple hazards intensify across the service territory, the safety of CMP's staff, especially those in the field, is expected to be challenged. Workforce safety standards and practices must be adapted to the heightening and diversifying threat landscape. All climate hazards can pose a threat to worker safety, but not all hazards are projected to intensify; storm events & wind, extreme heat, inland flooding and extreme precipitation, coastal flooding, and wildfire and drought are expected to be increasingly impactful to workforce safety.

Climate Challenges

Based on the exposure to climate hazards and sensitivities of the group's practices and processes that were determined through interviews with SMEs, the following climate challenges have been identified:

- Climate change is projected to lead to a changing threat landscape, with the intensification of existing hazards (i.e., storms and floods), the emergence of new hazards (i.e., heat), and the lessening of risk posed by other hazards that have historically caused safety issues (i.e., extreme cold and frozen precipitation). Heat poses a particularly serious risk to worker safety. Without proper training, workers may experience heat exhaustion or heat stroke. If not accounted for, these shifts in hazards and associated risks may leave crews unprepared with a lack of appropriate equipment, technology, training, or PPE.
- While CMP gives its workers the ability to determine unsafe conditions, site-specific real-time information will be increasingly critical to inform decisions regarding staff safety while in the field.
- Climate change may lead to more instances where work needs to be stopped to ensure the safety of staff, potentially leading to delays in capital project work, routine maintenance and inspections, as well as increase response times and delayed restoration efforts.

Growing Future Resilience

- Implementing climate projections into safety planning and new standards to address emerging hazards before they become problematic would help ensure that new risks are handled proactively. This is especially important for heat risk and increasingly severe storms and flooding.
- Ensuring the use of additional PPE, such as fire-resistant cooling vests, can help provide workers with additional protection to intensifying and emerging risks.
- The use of technology, including sensors to monitor air quality and heat, could help more accurately inform safety decision making by workers in the field.

5.7 Emergency Management

Emergency Management Vulnerability Summary

The Emergency Management group at CMP is responsible for coordinating emergency preparedness and responses to extreme weather and other emergency events. The group has historically been most practiced in responding to winter and convective storms.

The electric system and a majority of its equipment is designed to be operated outdoors and subjected to a variety of weather conditions; changes to precipitation or temperatures on mild weather days are for the most part, not expected to have a significant effect. In contrast to this, climate change driven intensification of acute climate events, like severe storms, flooding or wildfire, that may occur a few times a year or decade are expected to have significant impacts. These changes to the most acute climate events are anticipated to expand the threat landscape that must be managed by CMP and its emergency management group.

As extreme weather events become more frequent and intense, emergency management may become strained to respond to a wide array of intense hazards, while simultaneously becoming more critical to ensure that the system is able to triage outage events and restore power quickly and safely. Because a wide variety of extreme events can cause outages and/or emergency conditions, the emergency management group is vulnerable to all hazards present in the service territory.

Climate Challenges

Based on the exposure to climate hazards and sensitivity of the group's practices and processes that were determined through interviews with SMEs, the following climate challenges have been identified:

- Climate hazard induced emergency events are projected to increase in frequency and magnitude, increasing the operating costs of labor, private contractors, fuel, supplies, and spare parts.
- Climate change may lead to more emergency activations, which often require staff to assume storm roles and/or work extended hours. If emergency activations increase, staff fatigue may worsen, leading to burnout, human-error/clouded decision-making ability, and retention issues. Frequent activations of storm roles may also limit staff capacity to perform their normal functions.
- Extreme weather events may increase CMP's reliance on mutual assistance. In severe circumstances, mutual assistance may become limited if the hazard impacts a larger region.
- Current emergency preparedness procedures are informed by past events. As climate change is projected to bring unprecedented extreme weather events, relying on historical experience may not adequately account for preparation activities necessary for future extreme weather events.

Growing Future Resilience

- Ensure adequate staffing to avoid staff burnout, fatigue, and shortages due to the projected increasingly frequent and severe extreme weather events.
- Incorporate climate projections into emergency preparedness plans and tabletop exercises to ensure that scenario planning includes both historical events as well as future risks.
- Ensure that Incident Command Center (ICS) teams are 2-3 layers deep and teams have adequate training and current contact information and protocols when activations are needed to ensure sufficient levels of preparedness to confront increasingly large and frequent hazard events.
- Formalize a practice of documenting after-action reports to analyze and formalize lessons learned and best practices to inform future emergency preparedness and response procedures and continue to adapt to the growing risks of climate change.
- Continue to invest in enhanced customer outreach and communication capacity, including investing in outreach technologies and culturally knowledgeable stakeholder engagement specialists to ensure customers understand outage risks and take proactive steps to protect themselves during an outage.

5.8 Operational Vulnerability Summary

The study team assessed future and emerging vulnerabilities for the 7 identified CMP operational groups considering the climate projections produced in the asset vulnerabilities assessment, TRC In-House Expert advice, and crucial CMP SME input.

Key Takeaways include:

- Many current operational practices are based on historical climate conditions. A changing climate is likely to threaten or strain many of these practices if not updated to consider climate impacts, and if sufficient staffing levels are not maintained to forecast, plan for, respond to, mitigate, and recover from the climate hazards discussed in this study.
- Because of the cross-cutting nature of many operational groups, many face risk from multiple hazards; with all hazards posing a risk to at least one operational asset, except extreme cold, which is projected to decrease from current levels by mid-century.
- Asset Management, Vegetation Management and Reliability Planning are at risk from the largest amount of climate hazards, with projected impacts from storm events & wind, extreme heat, frozen and extreme precipitation, inland and coastal flooding, and wildfire and drought.
- Continued investment in new technologies, modeling and monitoring capabilities, and the incorporation of climate data into future planning and investments is crucial for mitigating climate risk across operational groups.

Risk Screening

6. Risk Screening

The following vulnerabilities were identified by the study team as risk topics for further exploratory analysis for heightened awareness and to provide further level of information for future planning:

- Heat impacts on CMP staff. Many CMP staff are exposed to outdoor conditions. As the Maine population is not acclimated to heat such as experienced routinely by southern states, this poses a new and emerging risk in the near-term for CMP staff.
- Flood risk of vulnerable CMP substations. The vulnerability screening presented in Section 4, identifies any substation within the 100-meter buffer of FEMA's 100-year flood plain. Further analysis of which substations are directly located or adjacent to flooded areas provides better understanding of the potential level of risk.

The study team also conducted two additional analyses outside of the main CCVS document to inform future planning. The first was focused on woodpeckers, notorious for damaging CMP wood poles, and potential changes to their habitats. The study team evaluated and found that the future conditions are favorable for the woodpecker population, which could lead to increasing the wood pole damage. The second study evaluated climate conditions for tree species in the CMP region and found some tree species may be at increased risk to damage and pest invasions. These findings suggest an amplified impact on CMP operations and can inform long-term planning for vegetation and asset management.

6.1 Quantitative Risks

CMP Substations and Inland Flood Risk

The study team conducted further evaluation of the relative flood risk for CMP substations assets flagged as potentially vulnerable to inland flooding. The substations, along with a surrounding buffer of 100 meters, were compared to the digital FEMA 100-year floodplain. The team evaluated the data through visual inspection and assigned relative risk on the basis of proximity of the flood plain to critical access roads, any present flood mitigation/barriers, and whether the substation itself could become partially or completely inundated.

This study assigned the following definitions to each substation based on flood exposure maps (see figure below for examples):

- "Warning": Floodplain within a 100-meter buffer of the substation. An event with severity exceeding the return period of the flood-plain (e.g., 1-in-100) due to climate change could cause extent of floodplain to increase placing substation at risk.
- "Access Obstructed": Critical access roads and/or the ability to perform repairs may become obstructed in the case of a flood event. An event with severity exceeding the return period of the flood-plain (e.g., 1-in-100) due to climate change could cause extent of floodplain to increase placing substation at risk.
- "High Flood Risk": Substation with all or portions of the facility located in the flood plain.

Of the 51 inland substations where the buffer zones at least partially overlapped with flood zones, 26 were identified to be at a warning level, 18 at risk of obstructed access, and 7 at a high risk of flooding. The table provides a list of CMP substations at the highest of 3 tiers of flood risk.

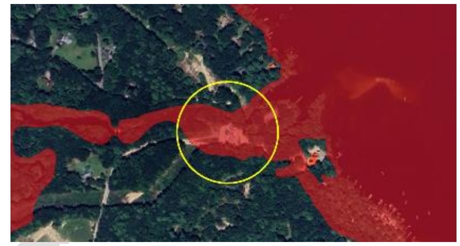
Table 15. CMP Inland Substations with High Flood Risk

CMP Inland Substations at High Flood Risk	
Keyes Waterville	Brunswick Hydro

Mechanic Falls	Kennebunkport
Bridgton	South Berwick
Bethel	

"Warning"

"Access Obstructed"



"High Flood Risk"

Figure 21. Examples of Flood Definitions

Coastal Flood Risk

The study team utilized a similar satellite-imagery-based approach to evaluate relative coastal flood risk. The study team classified coastal substations as "Warning," "Access Obstructed," or "High Flood Risk" using the same methodology of verifying flood exposure with satellite imagery and flood hazard GIS data. To capture both current and future coastal flood risk, the team evaluated both the FEMA 100-year coastal floodplain and the NOAA 2ft sea level rise projections.

Two coastal substations were identified as exposed to the FEMA 100-year floodplain, of which one substation, Cape 115 kV was identified as at high flood risk.Seven coastal Substations were identified as exposed to the NOAA 2 ft SLR scenario, of which one substation, Cape 115 kV was identified as at high flood risk.

Figure 22. Cape 115 kV Substation overlaid with FEMA's 100-year coastal and inland floodplains

To assess future conditions, NOAA sea level rise depth data was used to identify whether substations may be exposed to coastal inundation under a scenario including 2-feet of sea level rise. This is a proxy for changes in the extent and depth of coastal flooding as the NOAA sea level rise data is based on sea levels rising above mean higher high water (i.e., higher high tides). The analysis showed that both at-risk coastal sites avoid inundation in the 2 ft of sea level rise scenario.

Table 16. CMP Coastal Substation Flood Risk

CMP Coastal Substation Flood Risk		
Asset Name	100 Year Floodplain (2025)	NOAA 2-ft SLR Scenario Flood Risk (2050 Proxy)
Cape 115 kV	High Flood Risk	High Flood Risk
WF Wyman	Warning	Warning
Brunswick Hydro	None	Access Obstructed
Damariscotta Mills	None	Warning
Factory Island	None	Warning
Kennebunk[32]	None	Warning
South Berwick	None	Access Obstructed

6.2 Qualitative Risks

Heat Impacts on CMP Staff

Globally, heat is considered the most dangerous to human health of all climate hazards. Heat is the leading cause of weather-related deaths and can worsen preexisting conditions including heart disease, diabetes, mental health issues, and asthma.[33] Without proper precautions, climate change may case extreme heat to become a significant risk to CMP worker safety.

Maine is expected to have far lower exposure to extreme heat in response to climate change than many other parts of the country. For CMP, the Alfred service area is the only region within CMP's service territory projected to have high asset vulnerability to heat by 2050 (other service areas become vulnerable post-2050). However, human vulnerability to heat is more complicated and, as shown below, may be more difficult for CMP staff operating in the hotter regions of the CMP service territory.

The Maine Center for Disease Control and Prevention acknowledged that heat risk is a particularly serious threat for Mainers because it has historically not been an issue, and many people are unprepared to cope with the hazard. CMP staff that are in the field are most exposed to extreme heat conditions. While all trucks are equipped with air conditioning and staff use lightweight PPE during hot days, the development of clear guidelines on temperature and humidity conditions that also take into consideration operational conditions (e.g., the use of heavy, fire-resistant clothing) are crucial to mitigating heat stress.

The wet bulb globe temperature is an indicator for heat stress and is based on ambient temperature and humidity, assuming direct exposure to sunlight, see the figure below. According to OSHA recommendations, wet bulb globe temperatures (WBGT), as low as 77 ˚F can pose a danger for unacclimatized workers conducting strenuous work.[34] During the summer, relative humidity can average above 80%[35], suggesting that a WBGT of 77˚F can occur when ambient temperatures reach about 72˚F. Based on the table below and an average relative humidity of 80%, exposure risk for nonstrenuous work could begin around 80˚F (WBGT) and become extreme by 90˚F (WBGT).

[32] Majority of equipment at Kennebunk station owned by Kennebunk Light & Power

[33] World Health Organization. (2024). *Climate change, heat, and health*. Retrieved from https://www.who.int/news-room/fact-sheets/detail/climate-change-heat-and-health.

[34] Occupational Safety and Health Administration. (2024). *Heat Hazard Recognition*. Retrieved from https://www.osha.gov/heat-exposure/hazards.

[35] Summertime relative humidity is not projected to change significantly by mid-century, according to the Multivariate Adaptive Constructed Analogs (MACA) dataset visualization tool. This tool draws on a 20 climate model ensemble under a moderate scenario (RCP4.5) and high scenario (RCP8.5) for 2040-2069 relative to 1971-2000.

Workers that must wear protective gear or other clothing that prevents heat release will be warmer than the included table and adjustments can be made based on the protective clothing worn.

WBGT / RISK	IMPACTS	ACTIONS
80-85 F / Low	Body stressed after 45 minutes	Take at least 15 minutes of breaks each hour if working or exercising in direct sunlight, Stay hydrated.
85-88 F / Moderate	Body stressed after 30 minutes. HEAT CRAMPS likely (painful contraction of muscles, weakness)	Take at least 30 minutes of breaks each hour if working or exercising in direct sunlight. Drink ½ to 1 quart of water per hour.
88-90 F / High	Body stressed after 20 minutes. HEAT EXHAUSTION likely (dizziness, nausea, vomiting, headache, fainting, disorientation, weakness)	Take at least 40 minutes of breaks each hour if working or exercising in direct sunlight. Reduce work, exercise intensity. Drink up to 1 quart of water per hour.
> 90 F / Extreme	Body stressed after 15 minutes. HEAT STROKE likely (extremely high body temp, confusion, convulsions, unconsciousness, death)	Take at least 45 minutes of breaks each hour if working or exercising in direct sunlight. Suspend all strenuous outdoor activities. Drink at least 1 quart of water per hour.
Adapted from U.S Army and OSHA guidelines and recommendations		

Figure 23. Non-Location Specific WBGT Heat Risk Levels[36]

Risk Management. There are number of potential activities that can or are being to reduce heat risks for CMP staff[37]:

- Protect new unacclimatized staff during the first 1-2 weeks of warm-weather work by providing additional breaks, modified workdays, training on heat-related symptoms, and establishment of a system for monitoring new staff.
- Train supervisors and staff on heat illness, first aid, fluid replacement guidelines, effect of protective clothing on heat stress, and recommended work/rest cycles.
- Provide fluids and onsite cooling options such as shade canopies and air-conditioned vehicles.

[36] National Weather Service. (n.d.). *Wet Bulb Globe Temperature (WBGT)*. National Oceanic and Atmospheric Administration. Retrieved December 16, 2024, from https://www.weather.gov/sgf/WBGT

[37] Occupational Safety and Health Administration. (n.d.). *Heat exposure prevention*. U.S. Department of Labor. Retrieved December 16, 2024, from https://www.osha.gov/heat-exposure/prevention

Potential Resilience Measures

7.Potential Resilience Measures

CMP is deeply committed to building and maintaining a reliable and resilient power grid that can confront the challenges posed by climate change. While this report and the resulting actions represent a major enhancement of these efforts providing key insights into specific risks and outline targeted strategies to address them, CMP has already taken explicit steps to adapt its system to the impacts of climate change. Current investments in climate adaptation measures, as well as storm hardening and extreme weather preparedness to mitigate current hazards have already made the system more resilient to climate impacts. These strategies are meant to improve reliability and maintain high safety standards. While a suite of future measures are identified for exploration in the CCRP, current measures that are already underway in the CMP system are described below.

Hardening & Infrastructural Improvements

CMP has already taken steps to harden its infrastructure to the impacts of storms and other extreme weather events. This includes adopting new standards as part of routine asset replacement, such as using steel poles for transmission construction or in targeted areas on of distribution lines. In addition, CMP is targeting hardening measures in problematic areas or on critical circuits and transmission line spans by increasing pole classes and utilizing fiberglass cross arms. CMP has also performed substation upgrades to improve their capacity and replace ageing or damaged assets. These improvements will continue to increase the capacity of the CMP system, increase resilience, and improve overall reliability.

Figure 24. Replacement of Wooden Poles with Steel Poles Along Section 80 Transmission Line

Operational Resilience

Many of CMP's departments have implemented varying forms of climate adaptation measures. These include utilizing robust data analytics process to help analyze outages and target resources to areas in most need of improvement, empowering staff to assess and leave unsafe conditions, the use of SCADA and AMI throughout the system, routine inspections of assets and vegetation along the ROW, and the on-going implementation of Ambient Adjusted Ratings, among others.

Resilience Framework for Climate Change Resilience Plan

The study team envisions that climate resilience of CMP's system can be enhanced through use of a multi-pronged resilience strategy that seeks to identify resilience measures that achieve at least one of the four objectives listed below.

1. Strengthen CMP's assets and processes to **withstand** the adverse impacts of a climate hazard event.
2. Increase CMP's ability to anticipate when a climate hazard event may occur and increase the electric system's ability to **absorb** the effects.
3. Bolster CMP's ability to quickly respond and **recover** in the aftermath of a climate hazard event.

4. **Advance and adapt** the CMP electric system to address continuous changes from climate change and to perpetually improve resilience.

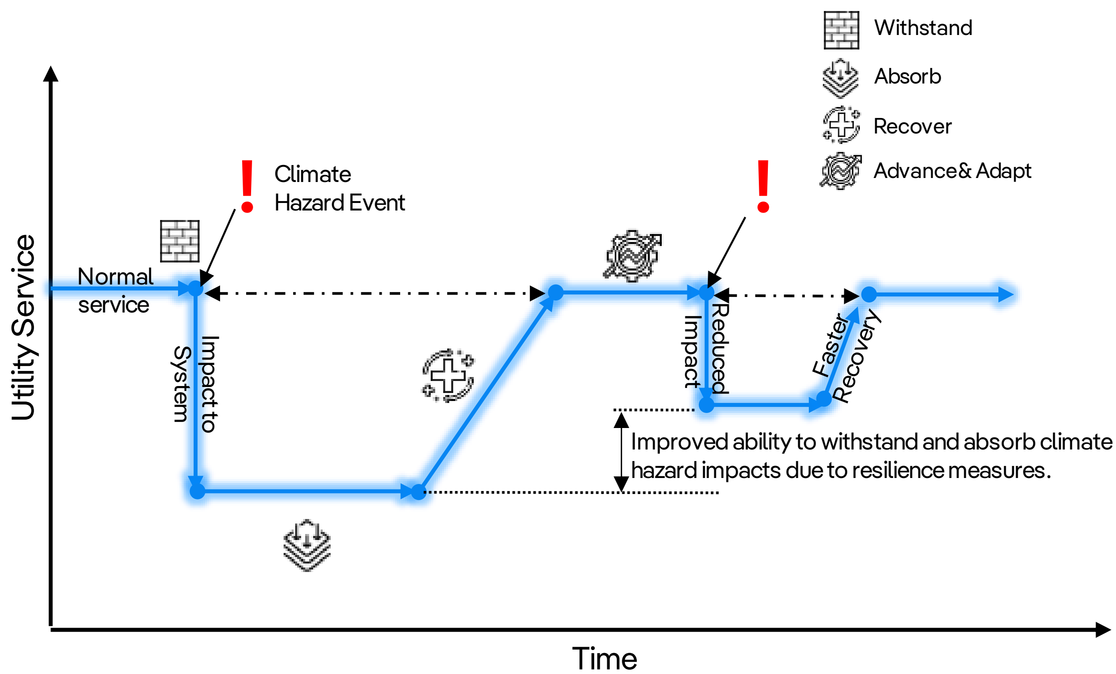


Figure 25. Multi-pronged resilience strategies.

Strategic and Site-Specific Resilience Measures

The electric grid is undergoing numerous other major changes and transitions including, but not limited to, electrification of heating and transportation, interconnection of distributed energy resources and renewables, and addressing aging infrastructure. Introducing climate resilience measures proactively, but gradually, into the CMP system can efficiently build climate resilience while also minimizing the cost. When possible, CMP will incorporate resilience measures into business-as-usual activities to capture multiple benefit streams simultaneously through the use of Strategic Resilience Measures.

Strategic Resilience Measures: This type of resilience measure would include activities like updating equipment specifications and/or internal processes with the goal of gradually incorporating climate resilience into the electric system through business-as-usual activities.

However, there may be cases where the CCRP identifies a climate hazard event that can be reasonably expected to occur in the near-term, in these cases CMP will identify a Site-Specific Resilience Measure.

Site-Specific Resilience Measures: These resilience measures would address acute climate hazard vulnerabilities for a specific site or group of assets.

These Site-Specific Resilience Measures would be included in CMP's typical project planning and prioritization processes alongside other system investments like reliability, capacity, and/or asset condition projects. Like the Strategic Resilience Measures, the goal would be to maximize benefits to the system by meeting multiple needs simultaneously.

Sample Resilience Measures

A summary of the hazard and the resilience measures are grouped by hazard and asset family in the tables below. Initially the CCRP will focus on the asset-hazard combinations were identified as priority vulnerabilities identified in Section 4; in cases where a resilience measure can impact multiple hazards it will be noted in the CCRP. Some of the following sample resilience measures are already being implemented by CMP. The CCRP process will evaluate these and other potential resilience measures to determine an optimal approach and future framing of measures using a Multi Criteria Decision Analysis framework. This methodology will ensure that selected measures effectively and efficiently address CMP's most pressing climate risks while also aligning with the utility's other priorities and constraints. In addition, selected measures will inform and align with the upcoming General Rate Case to ensure that they are committed to in future planning, investment, and funding decisions.

7.1 Storms Events & Wind

Storms and the high winds they bring challenge the physical robustness of equipment either through direct impacts to equipment or through secondary effects by causing vegetation to impact equipment. Overhead transmission towers and conductors can fail in extreme winds, or events that include the coincident effects of both wind and icing. Table 17 includes resilience measures identifying the National Electrical Safety Code (NESC) requirements that CMP's facilities are designed to withstand at a minimum. The most recent NESC became effective February 1, 2023, and contains numerous updates, including new vertical and horizontal wind clearances.

Table 17. Resilience measures to combat Storm Events & Wind by asset type.

	Resilience Measure Description	Resilience Dimension
Transmission	Utilize steel poles for construction. Increases resilience to major wind events and/or vegetation impact. Impervious to rot and woodpecker damage.	Withstand
	Evaluate which aspects of transmission line design can be modified to build additional resilience to storms/wind events.	Withstand, Absorb, Advance and Adapt
Distribution	Enhanced Vegetation Management or "Ground-to-Sky" trimming.	Absorb, Advance and Adapt
	Targeted undergrounding of circuit portions particularly susceptible to outage.	Withstand, Absorb, Advance and Adapt
	Use new materials and construction techniques including anti-cascading composite poles and crossarms.	Withstand, Recover
	Harden the distribution system with expanded use of tree wire, spacer cable construction, and fiberglass crossarms	Withstand
Substations	Increase substation cutback distances to nearby vegetation.	Withstand, Absorb, Advance and Adapt

Withstand Absorb Recover Advance and Adapt

7.2 Extreme precipitation & Inland Flooding; Coastal Flooding

Flooding can cause significant damage to electric system assets. Pad-mount transformers—which are typically installed at or near grade—can be damaged by flooding. Distribution poles are also susceptible to floating debris from floodwaters or destabilization from scouring of the area at the base of a structure. Substations components built at or near ground level are especially vulnerable; if flooding reaches substation equipment control cabinets or other equipment inside of the control house, the entire facility may need to be deenergized. Assets exposed to salt water in a coastal flooding event can experience additional corrosion and long-lasting impacts. Table 18 mentions “FEMA BFE + Freeboard.” BFE, or base flood elevation, is the elevation of surface water for 1-percent annual chance floods. Freeboard is the extra height above the BFE to ensure an additional margin for flood safety.

Table 18. Resilience measures to combat flooding by asset type.

	Resilience Measure Description	Resilience Dimension
Distribution	Utilize underground or ground-mounted equipment designed with saltwater contamination resistance equipment in sea level rise zone.	
	Utilize FEMA 500-year floodplain as proxy extent for future flooding events.	
	Utilize high strength poles/construction in non-stationary floodplains.	
	Ground-mounted equipment in floodplain is either elevated at FEMA BFE + Freeboard, or is designed to be submersible.	
Substations	Coastal substation flood mitigation projects.	
	Flood mitigation measures for 1-in-100-year events at exposed substations.	
	Update design guidelines to utilize sea level rise projections, as applicable, during solutions designs in lieu of 3’ or5’ additions to BFE.	
	Design for FEMA 500-year inland flooding (proxy for future).	
	Update specification to include SLR; e.g., design to FEMA BFE + 50 years SLR projections.	

Withstand Absorb Recover Advance and Adapt

7.3 Extreme Heat

Extreme heat can pose a risk to transmission lines, the distribution system, and substations. Transmission lines are affected by extreme heat by increasing the component operating temperature and causing conductors to sag further during time periods of high temperature and customer usage. Distribution conductors are affected similarly, and distribution utilization transformers can experience accelerated aging or even failure in extreme heat scenarios. In substations increased ambient temperatures reduce the ability of components to dissipate heat, causing damage and accelerated aging.

The resilience measure in the table below, Work with ISO-NE on revisions to Planning Procedure #7, refers to collaborating with the Independent System Operator New England (ISO-NE) on revising Procedures for Determining and Implementing Transmission Facility Ratings in New England. This measure could adjust the ambient temperature assumptions used in facility rating calculations, ensuring that the utilized ratings are appropriate for the expected future conditions. The third resilience measure for transmission refers to the forthcoming North American Electric Reliability Corporation (NERC) TPL-008 standard, which is the Transmission System Planning Performance Requirements for Extreme Temperature Events. This standard was recently approved and require that high voltage transmission systems to be routinely evaluated for its performance during extreme weather events, including heat waves.

In addition to the identified resilience measures there are further options available that could be selected if the needs arise in emergent situations. This could include activities like the use of specialty high-temperature conductors, installation of additional feeders to offset loading, and implementing additional cooling measures for substation assets.

Table 19. Resilience measures to combat extreme heat by asset type.

	Resilience Measure Description	Resilience Dimension
Transmission	Ambient Adjusted Ratings (AARs) to account for future ambient temperatures during operation.	
	Work with ISO-NE on revisions to Planning Procedure #7, including ambient temperature assumptions for rating calculations.	
	Evaluate the transmission system during extreme heat events through upcoming NERC TPL-008 standard.	
Substations	Increase substation transformer temperature specification.	
	Pilot project to explore use of advanced substation transformer temperature monitoring on heavily loaded transformers.	
Other	Perform periodic extreme heat event sensitivity assessments, including development of real-time/preparation of mitigation activities.	

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7.4 Multiple Hazards

Some identified resilience measures cover multiple asset families or are part of a more holistic review of processes. The table below shows resilience measures designed to influence resilience across multiple hazards at once.

Table 20. Resilience measures to combat multiple hazards by asset type.

	Resilience Measure Description	Hazards	Resilience Dimension
Transmission	Enhance inspection process to include looking at foundation washout after extreme events.	Storm Events, & Wind, Flooding	
Other	Periodically update the CCVS and recommendations as new climate science or research becomes available.	All	
	Perform periodic extreme heat event sensitivity assessments, including development of real-time/preparation of mitigation activities.	Heat	
	Monitor location of critical facilities/town shelters and how climate hazards may affect their electric service.	All	
	Develop process for effective sharing of facilities used for community resilience.	All	

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Conclusions and Next Steps

8. Conclusions and Next Steps

8.1 Key Conclusions

The results of this study identified that climate change presents multiple risks and vulnerabilities that are expected to have adverse impacts on the CMP system. These risks are wide ranging and complex. Some risks are acuate and direct, like expected increases in flooding damaging sensitive substation assets, others are chronic or indirect, such as increases in temperatures causing increases in wood decay. Many hazards and their associated risks are also cross cutting, where a singular hazard can have multiple and/or cascading risks across the system. For example, extreme heat threatens the performance and health of multiple asset types, while also altering demand, load forecasting/capacity planning, changing growth patterns of vegetation, and potentially threatening the safety of outdoor workers.

Climate impacts are expected to cause challenges at CMP and should be monitored and addressed by resilience measures to prevent adverse impacts to CMP assets, operations, and customers. The most pressing hazards identified through this study include storm events & wind, and flooding (coastal and inland/extreme precipitation), with lesser but not insignificant risk posed by extreme heat and the potential for future conditions conducive to wildfire. Many hazards were all found to intensify by mid-century under the study's planning scenario - understanding and addressing these vulnerabilities and risks is critical to inform future investments and resilience planning. CMP has previously taken steps to both mitigate and understand its climate risk, but this study serves as a substantial new development in this effort and provides wide ranging detailed analysis that can be used throughout the company.

8.2 Study Limitations

While this study uses the latest and best available data to inform hazard projections, climate models and projections inherently have uncertainties including scientific, natural, and societal. Additionally, some localized or acute hazards, like wind gusts and significant frozen precipitation events, are not well represented in large-scale climate models, requiring inferences from literature reviews and historical patterns in order to project future change.

This study analysis relied on a series of assumptions about the nature of all of CMP's asset types and operational divisions as a whole. While the study presents a large amount of specific and actionable data, it is intended to help inform overall trends of climate change and prioritize investigation of resilience measures and system improvements. It is not intended to replace a location specific analysis needed to design a large capital improvement (e.g., a substation flood resilience retrofit).

8.3 Next Steps

The results of this study will directly inform the development of the Climate Change Resilience Plan (CCRP), which will identify specific strategic and site-specific resilience strategies, through utilization of a prioritization framework for implementation in order to best address the risks and vulnerabilities outlined in this report.

Climate Change Protection Plan will be updated as required, including introduction of the latest climate science, to ensure that the available projections remain as accurate as possible such that CMP is positioned to understand climate change's impact on the company, and maintain its ability to provide safe and reliable power to its customers.

References

9. References

Arnold, Susie, Stephen Dickson, Ivan Fernandez, Jessica Reilly-Moman, Island Institute, Maine Geological Survey, University of Maine, School of Forest Resources, Climate Change Institute, School of Food and Agriculture, et al. "Scientific Assessment of Climate Change and Its Effects in Maine - 2024 Update." Report. Maine Climate Council. Maine Climate Council, 2024.

Carll, Charles G. and United States Department of Agriculture Forest Service Forest Products Laboratory. "Decay Hazard (Scheffer) Index Values Calculated From 1971–2000 Climate Normal Data." *General Technical Report FPL–GTR–179*. U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, 2009. https://www.fpl.fs.usda.gov/documnts/fplgtr/fpl_gtr179.pdf.

Cleland, E, I Chuine, A Menzel, H Mooney, and M Schwartz. "Shifting Plant Phenology in Response to Global Change." *Trends in Ecology & Evolution* 22, no. 7 (May 3, 2007): 357–65. https://doi.org/10.1016/j.tree.2007.04.003.

IPCC. "Climate Change 2021: The Physical Science Basis," n.d. https://www.ipcc.ch/report/ar6/wg1/.

Crimmins, Allison R. "Fifth National Climate Assessment." Fifth National Climate Assessment, November 14, 2023. https://nca2023.globalchange.gov/.

Curling, S. F., and G. A. Ormondroyd. "Observed and Projected Changes in the Climate Based Decay Hazard of Timber in the United Kingdom." *Scientific Reports* 10, no. 1 (October 1, 2020). https://doi.org/10.1038/s41598-020-73239-1.

"Disasters and Other Declarations | FEMA.gov," October 20, 2024. https://www.fema.gov/disaster/declarations.

Animal and Plant Health Inspection Service. "Emerald Ash Borer | Animal and Plant Health Inspection Service," n.d. https://www.aphis.usda.gov/plant-pests-diseases/eab.

"Flood Preparedness | Maine Emergency Management Agency," n.d. https://www.maine.gov/mema/hazards/natural-hazards/flooding/flood-preparedness.

"Flooding | Maine Emergency Management Agency," n.d. https://www.maine.gov/mema/hazards/natural-hazards/flooding.

Gov. Office of Policy Innovation and the Future and Dept. of Environmental Protection. "Sea Level Rise in Maine: An Accelerating Problem." *Maine Climate Council*, n.d. https://www.maine.gov/future/sites/maine.gov.future/files/2021-05/GOPIF_SLR_Factsheet_2021_05_06.pdf.

Harness, R.E., and E.L. Walters. "Woodpeckers and Utility Pole Damage." *Rural Electric Power Conference*, June 30, 2004, B3-7. https://doi.org/10.1109/repcon.2004.1307046.

"https://www.nrcs.usda.gov/resources/data-and-reports/publications-of-the-national-water-and-climate-center," 2023. Accessed February 5, 2025. https://www.nrcs.usda.gov/sites/default/files/2023-03/iMap_Glossary.pdf.

Iverson, Louis R., Anantha M. Prasad, Matthew P. Peters, and Stephen N. Matthews. "Facilitating Adaptive Forest Management Under Climate Change: A Spatially Specific Synthesis of 125 Species for Habitat Changes and Assisted Migration Over the Eastern United States." *Forests* 10, no. 11 (November 6, 2019): 989. https://doi.org/10.3390/f10110989.

Lepore, Chiara, Ryan Abernathey, Naomi Henderson, John T. Allen, and Michael K. Tippett. “Future Global Convective Environments in CMIP6 Models.” *Earth S Future* 9, no. 12 (November 11, 2021). https://doi.org/10.1029/2021ef002277.

Livneh, Ben, Theodore J. Bohn, David W. Pierce, Francisco Munoz-Arriola, Bart Nijssen, Russell Vose, Daniel R. Cayan, and Levi Brekke. “A Spatially Comprehensive, Hydrometeorological Data Set for Mexico, the U.S., and Southern Canada 1950–2013.” *Scientific Data* 2, no. 1 (August 17, 2015). https://doi.org/10.1038/sdata.2015.42.

Maine Climate Council. “Home | Maine Climate Plan,” 2020. Accessed February 5, 2025. https://www.maine.gov/climateplan/.

“Maine Climate Council Reports | Office of Policy Innovation & Future,” 2020. https://www.maine.gov/future/climate/reports 2024 Update

Maine Department of Agriculture, Conservation & Forestry, “Facts about Wildfires , https://www.maine.gov/dacf/mfs/forest_protection/firewise/wildfire_facts.html

Maine Department of Agriculture, Conservation & Forestry, “Maine fire-resistant plant list”, Maine fire-resistant plant list: Firewise USA: Forest Protection: Maine Forest Service: Protection Division - Forest Rangers

“Maine General Facts.” Accessed February 5, 2025. https://www.maine.gov/legis/general/facts/facts.htm.

Maine Forest Service, “The 1947 Fires.”

“Maine State Climate Summary.” *Https://Statesummaries.Ncics.Org/*. Accessed February 5, 2025. https://statesummaries.ncics.org/chapter/me/.

National Centers for Environmental Information (NCEI). “Daily Summaries Station Details: PORTLAND JETPORT, ME US, GHCND:USW00014764 | Climate Data Online (CDO) | National Climatic Data Center (NCDC).” Climate Data Online (CDO), n.d. https://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:USW00014764/detail.

National Park Service, Fires of 1947. https://www.nps.gov/acad/learn/historyculture/fireof1947.htm

NDIS Drought.gov https://www.drought.gov/sectors/wildfire-management

“New England and Northern New York Forest Ecosystem Vulnerability Assessment | USDA Climate Hubs,” n.d. https://www.climatehubs.usda.gov/hubs/northern-forests/topic/new-england-and-northern-new-york-forest-ecosystem-vulnerability.

“New England Peaks,” n.d. https://www.amc4000footer.org/newenglandfourk.html.

NOAA Climate.gov. “Another Blast of Arctic Air: This Time, With a Stretched but Strong Polar Vortex,” January 16, 2025. https://www.climate.gov/news-features/blogs/polar-vortex/another-blast-arctic-air-time-stretched-strong-polar-vortex.

NOAA Climate.gov. “Understanding the Arctic Polar Vortex,” March 5, 2021. https://prod-01-asg-www-climate.woc.noaa.gov/news-features/understanding-climate/understanding-arctic-polar-vortex.

Pierce, David W., Daniel R. Cayan, Daniel R. Feldman, and Mark D. Risser. “Future Increases in North American Extreme Precipitation in CMIP6 Downscaled With LOCA.” *Journal of Hydrometeorology* 24, no. 5 (March 23, 2023): 951–75. https://doi.org/10.1175/jhm-d-22-0194.1.

Pierce, David W., Daniel R. Cayan, and Bridget L. Thrasher. “Statistical Downscaling Using Localized Constructed Analogs (LOCA)*.” *Journal of Hydrometeorology* 15, no. 6 (September 8, 2014): 2558–85. https://doi.org/10.1175/jhm-d-14-0082.1.

"Red-bellied Woodpecker - Trends Map - eBird Status and Trends," n.d. https://science.ebird.org/en/status-and-trends/species/rebwoo/trends-map.

Ropeik, Annie, and Annie Ropeik. "As Maine Sees More Extreme Heat, Air Conditioning Is More Than Just a Luxury." The Maine Monitor, January 30, 2025. https://themainemonitor.org/as-maine-sees-more-extreme-heat-air-conditioning-is-more-than-just-a-luxury/.

Sambou, Simon, Laurice Codou Faye, Fatimata Niang Diop, Sara Danièle Dieng, and Cheikh Mbow. "Importance Value Index and Species Relative Contribution to Carbon Stocks in Savanna Ecosystems : Implications for Climate Change Mitigation and Forest Management in Patako Forest (Senegal)." *Zenodo (CERN European Organization for Nuclear Research)*, September 27, 2022. https://doi.org/10.5281/zenodo.7114845.

MIT Climate Portal. "The Polar Jet Stream and Polar Vortex | MIT Climate Portal," n.d. https://climate.mit.edu/explainers/polar-jet-stream-and-polar-vortex.

US Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service. "PF Map: Contiguous US," n.d. https://hdsc.nws.noaa.gov/pfds/pfds_map_cont.html.

Walsh, Eric S., Kerri T. Vierling, Eva Strand, Kristina Bartowitz, and Tara W. Hudiburg. "Climate Change, Woodpeckers, and Forests: Current Trends and Future Modeling Needs." *Ecology and Evolution* 9, no. 4 (February 1, 2019): 2305–19. https://doi.org/10.1002/ece3.4876.

Wang, Jieying, and Paul I. Morris. "EFFECT OF CLIMATE CHANGE ON ABOVE-GROUND DECAY HAZARD FOR WOOD PRODUCTS ACCORDING TO THE SCHEFFER INDEX." *CWPA Proceedings*, 2008. https://woodpreservation.ca/wp-content/uploads/2021/09/wang29.pdf.

"Wildfires | Maine Emergency Management Agency," n.d. https://www.maine.gov/mema/hazards/natural-hazards/wildfires.

Maine Emergency Management Agency. (2023). *Maine State Hazard Mitigation Plan 2023*. Retrieved from https://www.maine.gov/mema/sites/maine.gov.mema/files/inline-files/Maine_SHMP2023_Final_full.pdf

County Hazard Mitigation Plans

Androscoggin County Emergency Management Agency, 2024. "Androscoggin County Hazard Mitigation Plan Update, Element B: Risk Assessment." https://androscoggincountyema.gov/docs/Hazard%20Mitigation%202024%20Plan%20Update_ELEMENT%20B.pdf

Cumberland County Emergency Management Agency, 2022. "Cumberland County Hazard Mitigation Plan." https://www.cumberlandcountyme.gov/departments/emergency_management_agency/hazard_mitigation_plan.php

Franklin County Emergency Management Agency, 2023. "Hazard Mitigation Plan for Franklin County, Maine." https://www.franklincountymaine.gov/wp-content/uploads/2024/03/Franklin-County-2023-Hazard-Mitigation-Plan-Revised-06.2023-1.pdf

Hancock County Emergency Management, 2024. "Hancock County Hazard Mitigation Plan – 2024 Update Element B. Risk Assessment." https://hancockcountymaine.gov/wp-content/uploads/pdfs/EMA/HazardMit2024/Element%20B%20-%20RISK-Hancock.11%20Dec%202023.pdf

Knox County Maine Emergency Management Agency, 2019. "Knox County HMP Section 4: Risk Assessment." https://webgen1files1.revize.com/knoxcntyme/Documents/County%20Departments/Emergency%20Management%20Agency/Hazard%20Mitigation%20Plan%20Page/4._SECTION_4_-_Risk_-_FINAL_June_21_2019.pdf

Lincoln County Emergency Management Agency, 2021. "Lincoln County Hazard Mitigation Plan Update 2021." https://www.lincolncountyema.net/_files/ugd/bdd8c4_578bf605e1eb4ad1ade515a136247bf4.pdf

Oxford County Emergency Management Agency, 2024. "Oxford County Maine Hazard Mitigation Plan 2024 Update – Element B: Risk" https://www.oxfordcountyema.org/documents/plans

Penobscot County Emergency Management Agency, 2021."Hazard Mitigation Plan Section IV - Risk Assessment." http://static1.1.sqspcdn.com/static/f/547079/28497164/1643036798823/Section+4+-+RISK_FINAL_012422.pdf?token=NhAkS78BQMmbdrObhVU3Se5ZSH4%3D

Piscataquis County, Maine Emergency Management Agency, 2023. "Piscataquis County, Maine Hazard Mitigation Plan." https://www.piscataquis.us/wp-content/uploads/2023/04/HazMit-Plan-2023-Approved.pdf

Sagadahoc County Emergency Management Agency, 2021. "Sagadahoc County Hazard Mitigation Plan 2021 Update – Section 4. Risk Assessment." https://cms8.revize.com/revize/sagadahoc/SECTION%204%20Risk.pdf

Somerset County Maine, 2017. "Somerset County Hazard Mitigation Plan – 2017 Update." https://somersetcounty-me.org/documents/other/hazard-mitigation-plan/

Waldo County Emergency Management Agency, 2011. "2011 Hazard Mitigation Plan for Waldo County, Maine." https://lincolnvilleme.govoffice3.com/vertical/Sites/%7B0EE09280-1571-4126-B77C-44B66AF5BC58%7D/uploads/2011_Waldo_County_Hazard_Mitigation_Plan.pdf

York County Emergency Management Agency, 2022. "York County, Maine Hazard Mitigation Plan 2022." https://www.yorkcountymaine.gov/_files/ugd/869b12_6776ed75c01148bda77ff847bbb4095d.pdf

Appendices

(Internal Use Only)

Appendix A CMP Service Area Climate Background

The following section outlines the historical geographic and climatic conditions of the study area (and greater Maine), drawing on literature, studies, and public information. This review was used to identify priority hazards to be included for further evaluation of projected future conditions.

Geographic Background

Maine is the northeastern-most state in the contiguous 48 states. It is geographically and topographically diverse. Maine's topographical features vary across its 33,000 square miles of land area including 14 peaks over 4,000 feet in elevation[38], 5,100 rivers and streams, and over 6,000 lakes and ponds.[39] The state is around 89% forested at an estimated 17 million acres – the highest forest cover percentage in the US. Maine also has over 3,500 miles of coastline.

Maine can be divided into two high-level ecoregions: the Northeastern Highlands and Mixed Wood Plains (indicated below in Figure 7). The Northeastern Highlands includes the northwestern, inland state area. It is generally higher elevation, cooler, and features a higher density of coniferous and boreal forest – in line with Maine's Northern climate region. In contrast, the Mixed Wood Plains is lower-elevation and has a milder, ocean-moderated climate (Southern Interior and Coastal zones). The Mixed Wood Plains can be further divided into two sub-regions. The Acadian Plains and Hills zone tends to be rockier and cooler than its counterpart, the Northeastern Coastal Zone, which can only be found in the southernmost portion of the state.

Maine's three climate zones: Northern (green), Southern Interior (pink), and Coastal (blue). Source: Whitman et al., (2013).

Regional Climate

Maine's geography and topographical diversity lend themselves to climatic variation across the state. It's latitude and geographic location expose the state to several climatic influences: Atlantic influences which moderate temperature and contribute to humidity; the state additionally experiences the effects of hot and cold air masses from North America's continental interior. As such, NOAA and State data resources identify three distinct climate zones within Maine: North, South Interior, and Coastal (see Figure 7).

The Northern zone's climate is continental, with cold winters influenced by air masses from the west and north; the Southern Interior zone is influenced by air masses from the south and west, and thus has the warmest

[38] "New England Peaks," n.d., https://www.amc4000footer.org/newenglandfourk.html.
[39] "Maine General Facts," accessed February 5, 2025, https://www.maine.gov/legis/general/facts/facts.htm.

seasonal summer weather. The Coastal zone has a maritime climate that moderates seasonal temperature extremes. The CMP service area extends across all three climate zones.

All three zones generally fall under a larger umbrella - the Humid Continental climate zone (Dfb). The Humid Continental climate zone is generally characterized by warm summers and cold winters - however, winter temperature severity varies across Maine because of its northern location and topographical diversity. Inland, northerly, and higher-elevation regions generally tend to experience more extreme cold than coastal regions, which are regulated by ocean proximity. Historical average temperatures range from 38°F in the North to 43.6°F in the Coastal zone. According to NOAA's Maine State Climate Summary, average winter temperatures range from 25°F in the far south to under 15°F in the north and state interior. Summer averages range from around 60°F in the far north to about 70°F in the south.

Small pockets of subarctic climate (Dfc) can be found at the western edges of the state – largely in higher elevation areas like the portion of the white mountains located in Maine. This climate zone is characterized by short, cool summers and longer, cold winters, and year-round precipitation.

Study Area Priority Hazards According to Maine Counties

CMP's service area includes portions of both Maine ecoregions, Maine's three regional climate zones (Northern, Southern Interion, and Coastal), and it spans the humid continental and subarctic climate zones. CMP's 11,000 square mile service territory spans across 14 counties in southern and central Maine serving more than 650,000 electricity customers, with nearly two-thirds living within 20 miles of the coast. As CMP's service territory spans a variety of geographic locations, there are a wide variety of physical and climate-related hazard events that are experienced. Accordingly, the climate hazards within CMP's service area vary depending on the region and associated characteristics, including vegetation and terrain.

The priority climate hazards identified by documentation prepared by each of Maine's counties inside of CMP's service territory provide an indication of what current day challenges challenge these counties:

- Extreme Temperatures (Heat and Cold): Maine historically and currently experiences cold winters and mild summers; however minimum and maximum average temperatures are projected to increase across the state annually and seasonally – particularly during the winter. This will lead to shortening of the winter season. Heat events are projected to intensify and become more common while cold events reduce.
- Severe Storms (Summer and Winter) / Severe Wind: Maine is located within the primary mid-latitude storm track. As such, it is impacted by events like nor'easters, cold-season coastal storms, summer thunderstorms, and extra-tropical events. Maine coastal areas are also susceptible to hurricane remnants from summer through fall. According to the recently completed Scientific Assessment of Climate Change and its Effects in Maine[40], winter storms are projected to intensify and have been responsible for recent severe wind events (though the number of storms per year is unclear).
- Drought: Drought impacted trees throughout the southern two-thirds of Maine in 2022 – preceded by low precipitation and dry growing season the previous two years. USDA previously declared Aroostook County a Drought Disaster Area in 2020. According to the recently completed Scientific Assessment of Climate Change and its Effects in Maine, it is unclear how the frequency of drought may change under future scenarios. However, there is concern that as drought conditions develop, the rising temperatures will exacerbate the drying conditions through increased evapotranspiration.
- Wildfire: Debris burning is the number one cause of wildfires in Maine. Around 92% of all wildfires in Maine are man-made (intentionally or accidentally), according to Maine's Emergency Management Agency[41]. Maine's forests are a significant natural and economic resource - a major forest fire would have a long-term economic and community impact.

[40] Maine Climate Council Science and Technical Subcommittee – 2024 Update
[41] "Wildfires | Maine Emergency Management Agency," n.d., https://www.maine.gov/mema/hazards/natural-hazards/wildfires.

- Flooding / Heavy Precipitation: According to Maine's Emergency Management Agency, the State's most common hazard is flooding. This includes coastal, riverine, and urban flooding[42]. Flooding occurs year-round in Maine and can lead to coastal and inland erosion. These floodings often occur in January, March, and April when snowpack is particularly vulnerable to natural variables like the "January Thaw" – i.e. an unseasonably warm period spanning a couple days in mid to late January – and seasonal rain that cause rapid snowmelt and subsequent runoff. Typically, rain-on-snow events that occur during the spring intensify flood threat because of excessive runoff production. Ice jams can also produce flooding during the similar timeframes. Maine State Emergency Management Agency specifically links snowmelt and ice jams as components of riverine flood, small river and stream flooding, and potentially pluvial flooding across the state[43].

Changes to Annual Temperature and Precipitation – Backdrop of Events

Maine's climate is becoming warmer and wetter. Over the coming century, the CMP service territory is projected to continue to experience increases in annual and seasonal precipitation and temperature.

- As temperatures rise, Maine's warm season is lengthening, and the cold season is shortening.
- By 2080, the CMP service territory[44] is projected to experience warming of 5.7°F to 9.4°F, depending on scenario, relative to 1985-2014 baseline.
- The average increase in maximum temperatures ranges from 5.6°F to 12.1°F and average increase in minimum temperature ranges from 5.7°Fto 12.9°F, depending on scenario relative to 1985-2014 baseline.
- Minimum temperatures are projected to increase at a slightly greater rate than maximum temperatures.
- By 2080, annual precipitation projections suggest an increase of about 9% to 24% above baseline conditions and depending on scenario, relative to 1985-2014 baseline.
- All seasons are projected to experience increased precipitation.

These conditions may lead to less freezing conditions, less opportunity for nighttime cooling temperatures during heat waves thereby extending peak energy demand, as well as reduction in summertime soil moisture affecting vegetation. And may have implications for flooding and other potential environmental changes. For example, if seasons become wetter and warmer, soils may absorb more rainfall becoming saturated. If a heavy precipitation event occurs on the backdrop of increased soil saturation, then more runoff may occur increasing stream levels and the risk of flooding.

These future conditions are based on 30-year averages of climate projections (e.g., 2016 to 2045). This longer-term climate statistic of 30-years is not intended to capture extreme year-to-year anomalies where colder/hotter and/or wetter/drier conditions could occur. Masked within the 30-year period can be extreme chronic conditions that could lead to an increased wildfire year. In fact, Maine already experiences swings in precipitation. For example, the 2020 growing season was the driest on record, and summer 2023 was the wettest. Therefore, though this report largely focuses on future conditions of 30-year averages where there is greater confidence in the results, it does not preclude the possibility that hazards driven by extreme changes in chronic conditions could occur; these will be discussed in each of the following sections as appropriate.

[42] "Flood Preparedness | Maine Emergency Management Agency," n.d., https://www.maine.gov/mema/hazards/natural-hazards/flooding/flood-preparedness.

[43] "Flooding | Maine Emergency Management Agency," n.d., https://www.maine.gov/mema/hazards/natural-hazards/flooding.

[44] Future temperatures across the entire state of Maine, including northern areas, which may experience slightly higher warming compared to the more southern CMP service area.

Drought-Exacerbated Wildfire: Vegetation and Risk Management

In 1947, Maine suffered its largest wildfire disaster in modern history. The state experienced over 90 consecutive days of record-breaking high temperatures and drought. By mid-October, small wildfires started and spread. These fires burned over 220,000 acres and 1,000 homes statewide and left 2,500 people homeless and 16 dead. The damages totaled over $11 million at that time.

Most wildfires in Maine are surface fires that spread along the ground – tree crown fires are rare. Maine's wildfire season usually begins in March in coastal and southern sections, gradually extending to central, western and northern areas. The wildfire season usually ends in late November. However, factors like drought and pest presence can negatively impact tree and forest health, and subsequently increase fire risk in affected areas.

Drought can dry out vegetation including trees and understory foliage, making it more flammable, and increase both ignition probability and the rate at which fire spreads. It can be intensified by high temperatures - extreme heat can lead to decreased streamflow, dry soils, and large-scale tree deaths in combination with low precipitation. These conditions create increased potential for wildfires that spread rapidly.

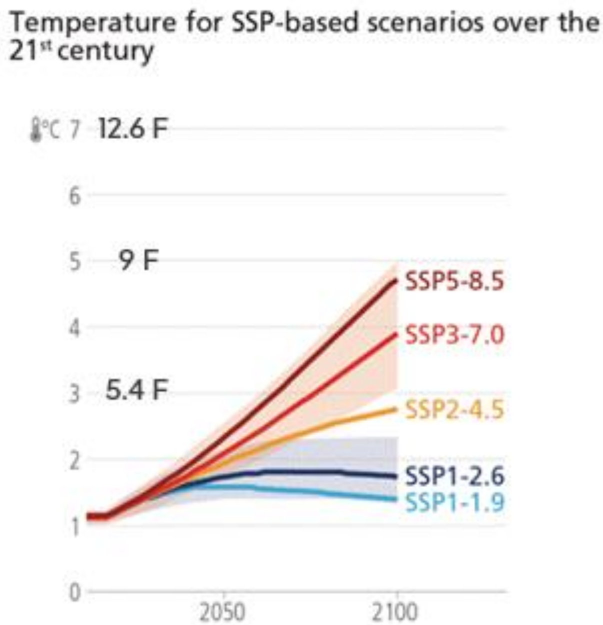
In tandem, trees stressed by drought may become more vulnerable to spreading pests and diseases that weaken, damage and/or kill them. Ash species, for instance, are impacted by both drought and pest expansion - the Emerald Ash Borer is one of the most serious invasive pest species threatening Maine's ash resources and forests. Dead trees and foliage contribute to fuel build up, which allows fires to burn hotter, larger, longer, and faster.

Wildfire potential can be reduced by thinning stand density, using prescribed burning, and letting some fires burn if they will not affect people. In some instances, drought can reduce wildfire potential by limiting vegetation growth.

The CMP region is anticipated to experience higher temperatures and increased precipitation which will likely increase vegetation growth overall. For higher confidence in the study results, changes in climate variables were based on future 30-year averages. However, 30-year averages smooths out the year-to-year variability in projections. Therefore, it's important to realize that even though overall indication is that drought conditions over 30-year periods is not expected to change significantly from current conditions; there will be some years where drought conditions, even possibly an extreme drought, is experienced in Maine. Source: NDIS, Maine Forest Service, NPS

Appendix B CMP Service Area Climate Background

Primer: Projecting Future Climate



Global warming for SSP pathways. Source: IPCC 2021

The projections presented in this document are derived from daily global climate model data statistically downscaled using Localized Constructed Analogs (LOCA 2). This climate model data was sourced from up to 22 World Climate Research Programme (WCRP) Coupled Model Intercomparison Project 6 (CMIP6) global climate models (GCMs) and evaluated for two future greenhouse gas emissions pathways. The WCRP CMIP6 climate ensemble was released in 2022 and used to inform the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6) and is considered the current state-of-art climate projections. WCRP CMIP6 was released approximately seven years after its predecessor WCRP CMIP5.

Climate models simulate a range of climate futures that in part represent how global society may evolve over the coming century. To inform IPCC's AR6 report (2021), five concentration pathways were developed based on potential socioeconomic and emissions behaviors. They provide a range of plausible climate futures that could be used to "drive" models and estimate projected climatic changes. Each pathway, termed Shared Socio-economic Pathway (SSP), has a complex narrative describing alternative socio-economic developments, including sustainable development, regional rivalry, inequality, fossil-fueled development, and middle-of-the-road development.

The pathways utilized by this study are (IPCC 2021):

- SSP2-4.5: Pathway that assumes carbon dioxide emissions remain around current levels until 2050 then reduce. This scenario limits warming to under 3˚C (5.4˚F). It takes moderate emissions reduction challenges into account, as well as future impact adaption, with slow progress towards sustainability goals.
- SSP5-8.5: Pathway where carbon dioxide emissions continue to increase until late into the 21st century with warming exceeding 4˚C (7.2˚F) by 2100. It incorporates optimistic trends for human development coupled with an energy-intensive fossil fuel-based economy.

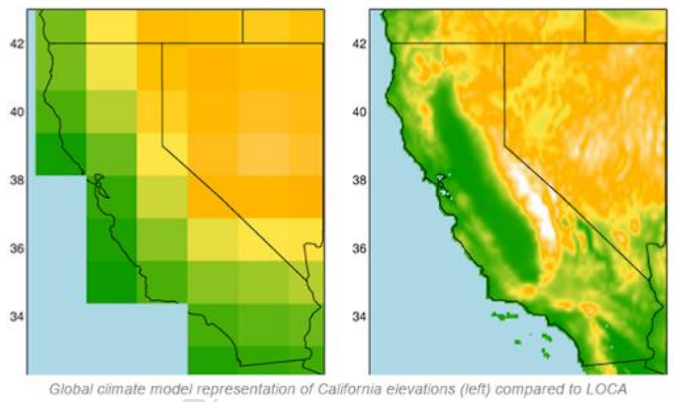
From these two pathways, this study developed three scenarios: (1) the climate model ensemble median or 50th percentile results under the SSP2-4.5; (2) the climate model ensemble median or 50th percentile results under the SSP5-8.5 scenario; and (3) the climate model 90th percentile results under the SSP5-8.5 (considered very unlikely, but possible). Though it is uncertain at which rate the global economy will decarbonize the SSP5-8.5 50th percentile of results was selected as the CCVS' planning scenario as the planning scenario as it represents a possible climate future for comparison with baseline conditions. The climate model ensemble median provides higher levels of confidence than other percentiles, as it represents the average across all climate models integrated into the study. The climate projections were averaged over 30-year periods for each decade from 2030 to 2080 (e.g., the 2030's are represented by data derived from 2016 to 2045).

Climate Models

Climate models mathematically represent the Earth's climate system. These models are very complex as they account for the dynamics of atmospheric motion, the chemistry in cloud production and precipitation, changes in surface albedo, natural climate fluctuations such as the Earth's tilt and the Sun's radiation, amongst many other phenomena. Climate models have been developed and are run by government and academic institutions around the world.

Downscaling

As computing the results of climate model simulations requires significant processing power and data storage, the geographic spatial resolution that is often utilized grid-spacing ranges from 60 miles by 60 miles up to 100 miles by 100 miles. At this spatial resolution, CMP's entire service territory would be comprised of a small number of future projections. To reveal the finer topography and local processes that cannot be accounted for in this coarse modeling, government entities have invested in providing downscaled climate data useful for more localized studies such as for impact studies across the CMP service area. Downscaling is the process of transforming the larger climate model grid cell to finer spatial resolution using techniques that introduce local phenomena into the results. See Figure 9 for an example improvement in projection resolution introduced by downscaling climate data.



Example downscaling from climate model resolution (left) to localized resolution (right)
Source: USGS

Appendix C. Climate Hazard Exposure Approach and Ratings

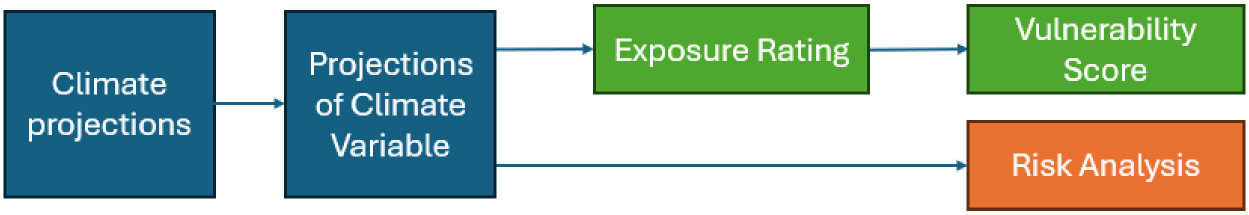
A set of climate variables were identified through prior Avangrid studies as hazards that could cause potential damage or disruption to CMP assets, services, and/or operations including: extreme heat, extreme cold, frozen precipitation, drought and wildfire, inland flooding, and coastal flooding. In addition, the Scheffer index was used to consider if wood exposed to outdoor conditions could experience accelerated decay over time.

This analysis evaluated the future change projected across three future scenarios for each of the CMP service areas[45]:

- 50th percentile of SSP2-4.5 Scenario: Median across all of the climate model results for the SSP2-4.5 future
- 50th percentile of SSP5-8.5 Scenario: Median across all of the climate model results for the SSP5-8.5 future
- 90th percentile of SSP5-8.5 Scenario: 90th percentile across all of the climate model results for the SSP5-8.5 future

Per discussion with CMP stakeholders and given the size of the CMP service area, it was determined that aggregating results across the entire CMP service would lead to significant smoothing, masking areas of concern. Therefore, this analysis evaluated these climate variables by CMP service area, as well as providing aggregated results across the CMP service area.

The projected values for each of the examined climate variables were then translated into exposure ratings presented below for each climate variable. The exposure ratings that are based on the values from the 50th percentile of SSP5-8.5 Scenario and are ranked at "low", "medium" and "high." The exposure ratings are then combined with potential impact ratings to screen potential vulnerabilities. The projected values presented in the sections below were directly used in the more quantitative risk assessment.



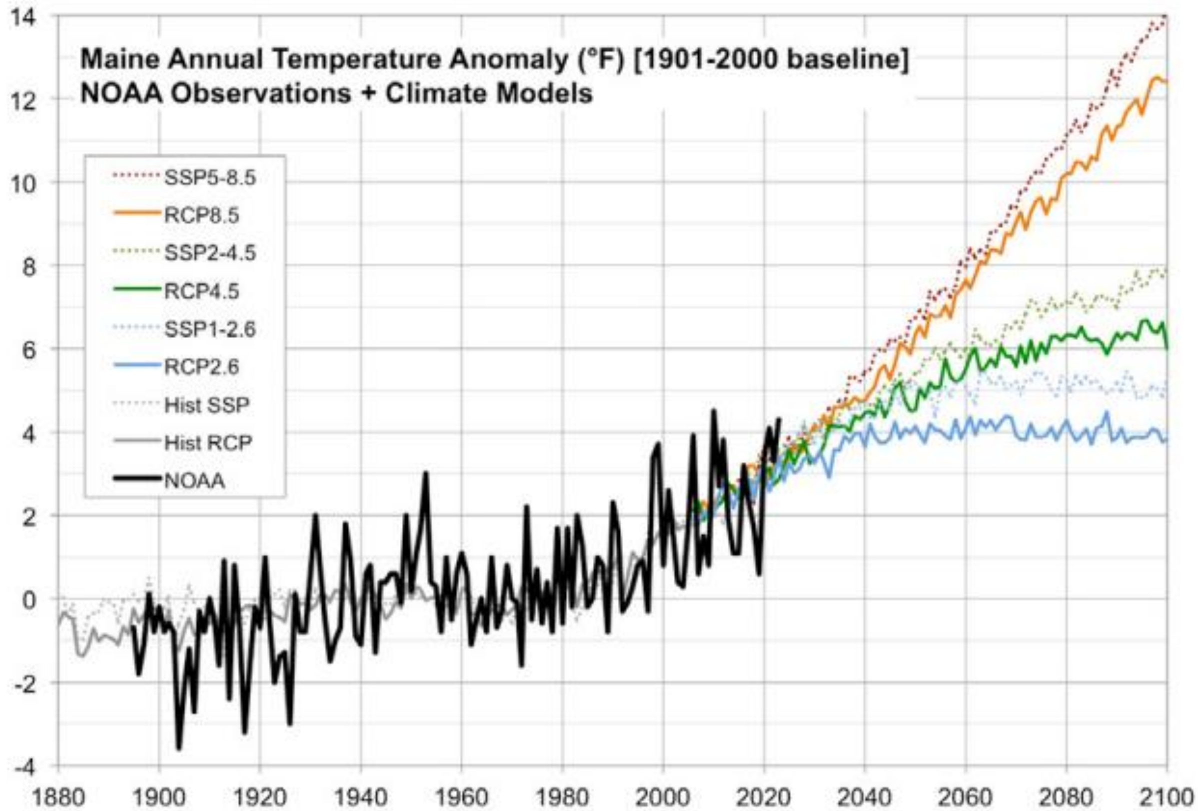
Annual Changes in Temperatures and Precipitation

Maine's climate is becoming warmer and wetter. The Maine Climate Council's State of the Science 2024 Update report identified the past four years (2020-2023) ranked among the ten warmest on record, in line with global trends. Maine is also experiencing more high-intensity precipitation. Maine now receives 1–2 additional days per year with 2+ inches of precipitation. Precipitation (rain and snow) variability, as well as annual precipitation variability are also increasing – for example, the 2020 growing season was the driest on record, and summer 2023 was the wettest. Winter storms are projected to become more intense, but their frequency remains uncertain. Drought has not increased in the historical record.

[45] For most variables the 90th percentile value suggests a more adverse condition than the 50th percentile.

As temperatures rise, Maine's warm season is lengthening – its winter season is shortening. The average warm season for 2010–2023 is about two weeks longer than a 1901–2000 historical climate baseline, and winters are about two weeks shorter. Maine's warm season is lengthening more towards late summer and early fall, which may be associated with Arctic summer sea ice decline delaying the arrival of cold air masses to New England. Recent "southeaster" storms in December 2023 and January 2024, in addition to major wind events in fall 2017 and 2019, have also generated concern for future storm trends.

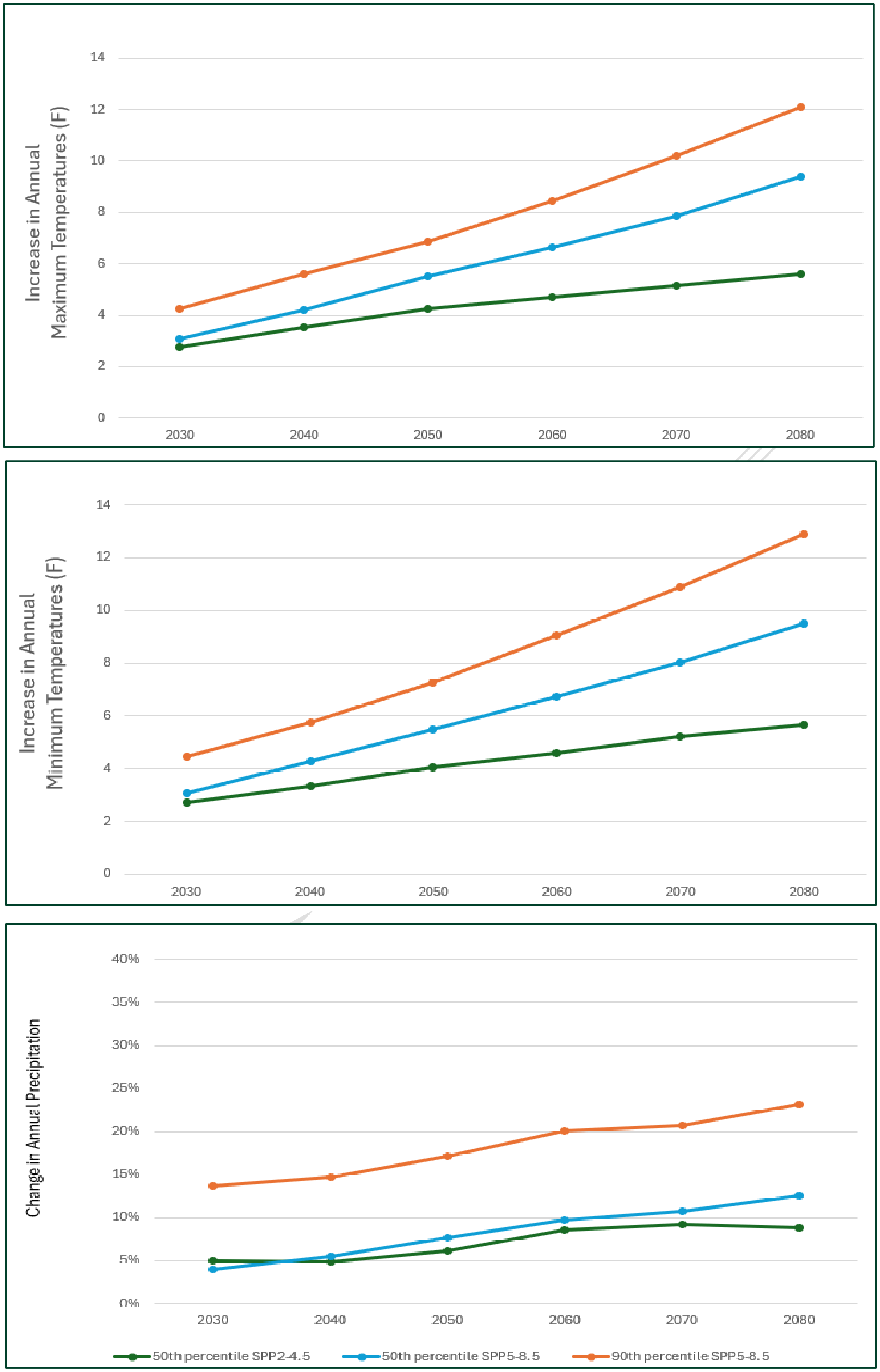
Maine is projected to experience significant annual warming through the end of the century from close to 8°F˚under the moderately-low scenario (SSP2-4.5) to about 14˚°F under the higher scenario (SSP5-8.5). This averages future temperatures across the entire state of Maine, including northern areas, which may experience slightly higher warming compared to the more southern CMP service area.



Maine annual temperature change from 1901-2000 mean climatology. Observed 1895-2023 (black line), projections of the 50th percentiles across climate models through 2100 (colored lines), historical simulation from models (grey line). (Source: MCC STS 2024)

By 2080, the CMP service territory is projected to experience warming of 5.7°F under the 50th percentile SSP2-4.5 scenario to about 9.4°F under the 50th percentiles SSP5-8.5 scenario relative to 1985-2014 baseline (note comparing future temperature rise against the more recent baseline where some warming has already occurred provides a slightly reduced future change). The average increase in maximum temperatures ranges from 5.6°F to 12.1°F and average increase in minimum temperature ranges from 5.7°Fto 12.9°F, depending on scenario. Minimum temperatures are projected to increase at a greater rate than maximum temperatures. This may lead to less freezing conditions in the early morning, less opportunity for nighttime cooling temperatures during heat waves thereby extending peak energy demand, as well as reduction in summertime soil moisture affecting vegetation. The greatest temperature increases are projected for CMP's Dover, Farmington, Skowhegan, Fairfield, Lewiston, and Augusta service areas.

Annual precipitation is also projected to increase steadily through the end of century under all three scenarios. By 2080, the projections suggest an increase of about 9% to 24% above baseline conditions and depending on scenario. These findings suggest that in general, the CMP in service territory will experience warmer and wetter conditions in the future. This does not preclude year-to-year variability where colder and/or drier conditions could occur. The projected changes in climate may have implications for flooding, soil moisture, vegetation growth, and other potential environmental changes.



Projected Increases in Annual Maximum Temperatures, Minimal Temperatures, and Precipitation.

Seasonal Changes in Temperatures and Precipitation for CMP Region

On average, temperatures and precipitation are projected to increase across Maine under all three study scenarios and across all decades. However, the magnitude of the projected changes vary by season:

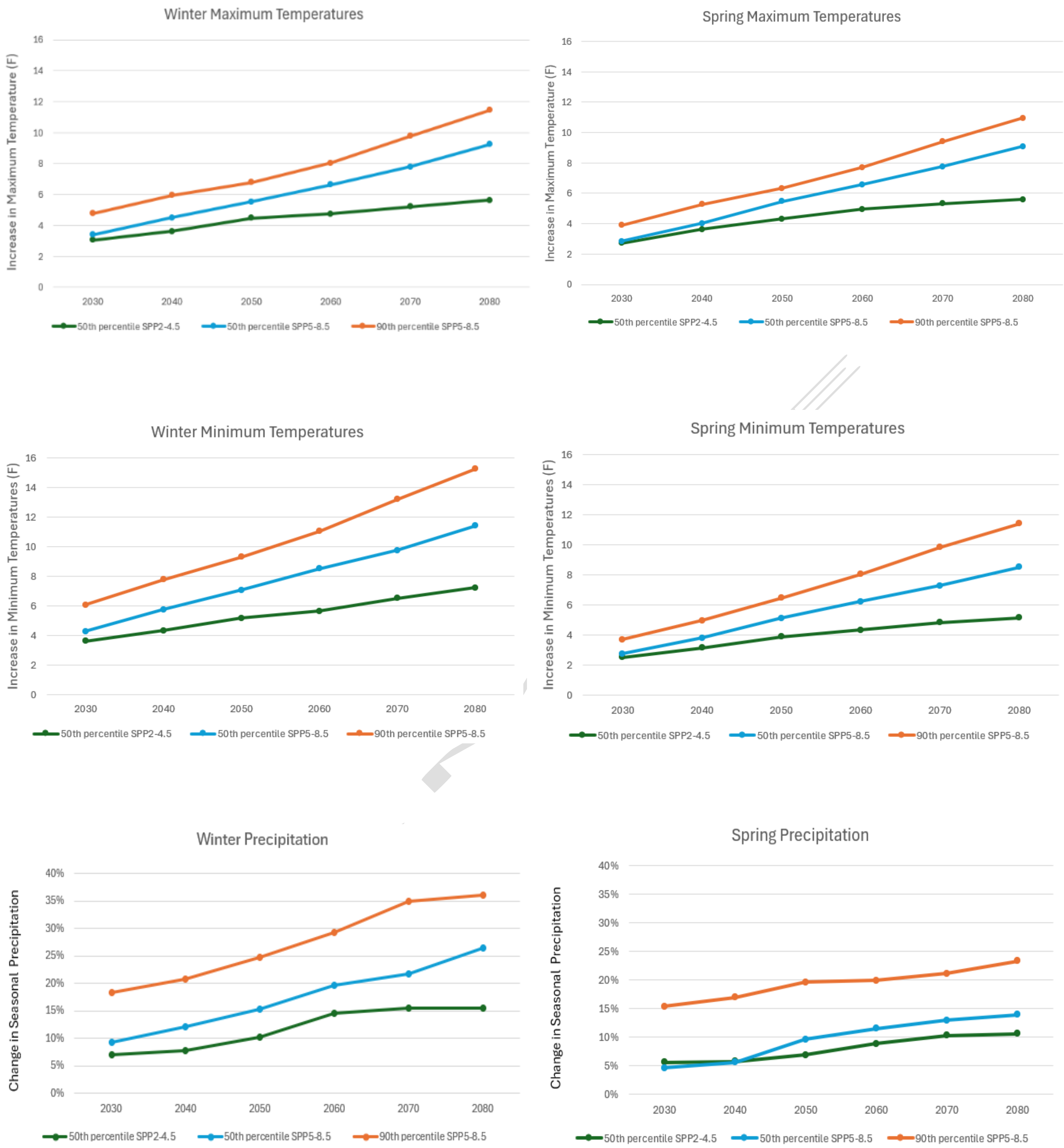
- Winter – Suggests the greatest increase in precipitation and annual minimum temperatures of all the seasons across all study scenarios, as well as notable increase in average maximum temperatures.
- Spring – Indicates maximum and minimum average temperature and precipitation increases across all study scenarios.
- Summer – Indicates both maximum and minimum average temperature increases across all study scenarios, with precipitation fluctuations under SSP2-4.5 and precipitation increases under the SSP5-8.5 90th percentile scenario.
- Fall – Indicated the greatest increase in maximum temperature across all seasons under the SSP5-8.5 90th percentile scenario. Precipitation increases vary by study scenario.

Projected seasonal temperatures and precipitation patterns are generally consistent with statewide average observed trends with projections showing that average temperatures and precipitation are increasing. The precipitation increase and rate of change in temperature vary by season. These seasonal climatic changes are particularly apparent during winter. Winter average minimum temperatures show the greatest increase across all scenarios compared to spring, summer, and fall. Similarly, winter precipitation increases by the highest relative percentage, and most consistently, between scenarios. Winter average maximum temperatures also increase across all scenarios; however to a smaller degree than the other three seasons.

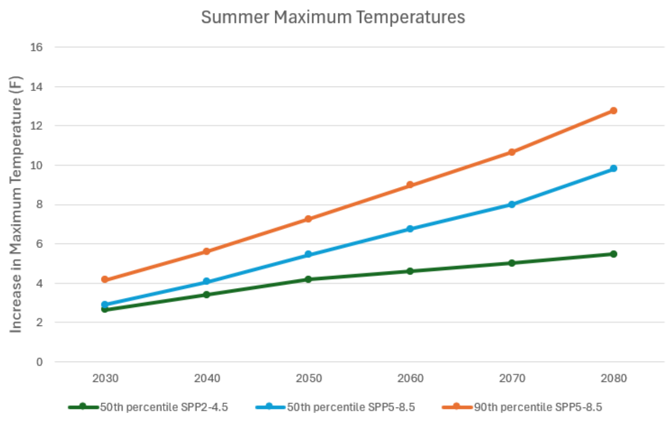
Fall and summer are projected to experience the greatest increase in maximum temperature compared to spring and winter under all scenarios. Conversely, fall and summer may experience the lowest precipitation increase rates under all three scenarios, remaining relatively consistent across decades under both the SSP2-4.5 and SSP5-8.5 50th percentile scenarios. Spring maintains consistent increases in both average maximum and minimum temperatures across all scenarios; however at a lower rate compared to fall or winter. These trends indicate a potential increase in heat events during the summer and fall seasons, and a reduction in cold events during both the winter and spring.

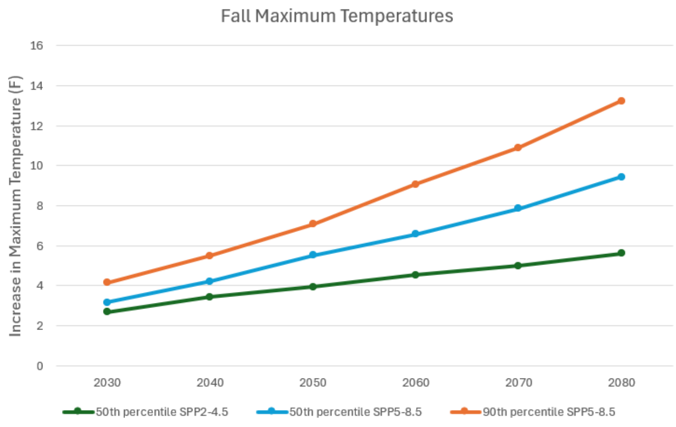
Similarly, as temperatures rise through the end of century, winter and spring precipitation may gradually shift causing a decrease in snow events and an increase in either frozen (ice or sleet) and liquid precipitation events. The shift from snow to frozen or liquid precipitation events increases the potential for rain-on-snow events during the and overall reductions in annual snowpack in colder, higher elevation regions of CMP's service area. Rain-on-snow events can be directly linked to riverine flooding during the winter and spring, having contributed to recent and historical flood events (as indicated in Section 3). Decreasing annual snowpack also reduces spring runoff, which in conjunction with rising annual temperatures, may contribute to increased drought potential across the state.

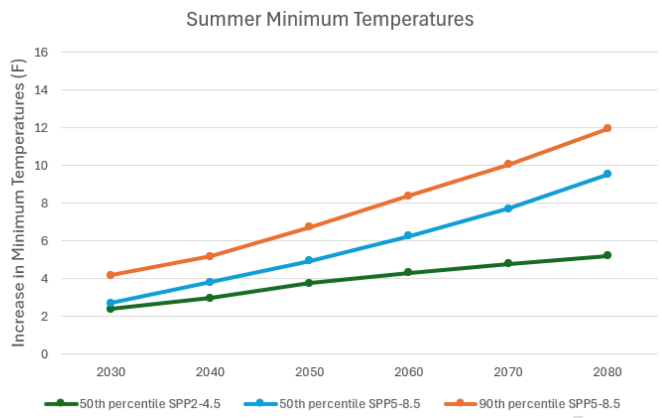
The changes in seasonal and annual conditions sets a changing backdrop for the impacts of hazard events such as heavy precipitation events and extreme heat. For example, heat events occurring during periods of reduced precipitation can lead to increased drought conditions and reduced soil moisture. Heavy precipitation events occurring during a wetter-than-normal season may lead to significant runoff and flooding. Therefore, when considering the hazard events that follow in this section, it is important to keep the overall trend of warmer and wetter conditions in mind.

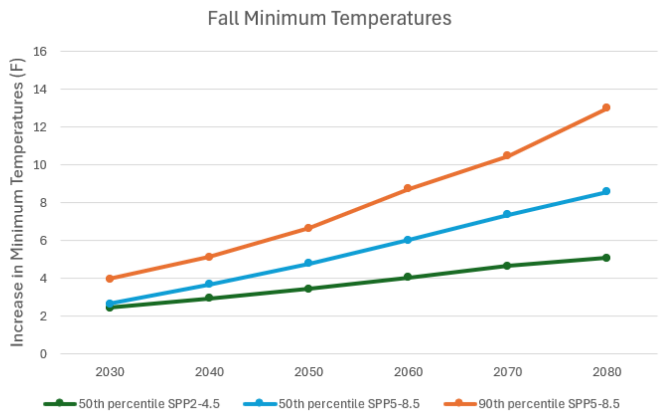


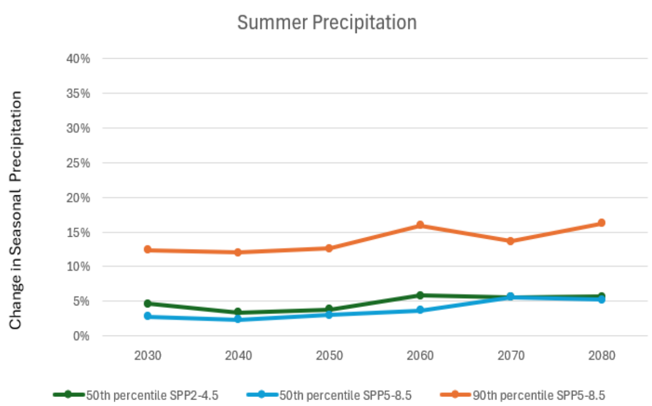
Projected Increases in Seasonal Temperatures and Precipitation for CMP Region – Winter and Spring

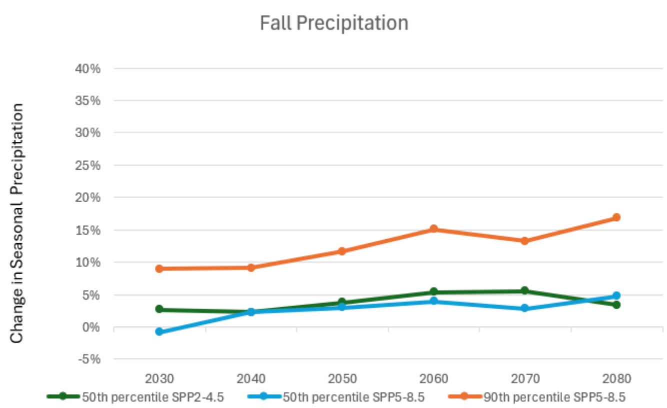












Projected Increases in Seasonal Temperatures and Precipitation for CMP Region – Summer and Fall

Extreme Heat: High Rating

To assess future changes in heat, this study evaluated five impactful heat variables as shown in the table below. The thresholds used to define the exposure ratings of low, medium, and high vary by heat variable.

Heat Variable	Methodology	Impacts	Low	Medium	High
Hot Days					
Days per year with daily average temperatures above 86°F (30°C)	Counts the number of days per year and averages over 30 years	Specified by IEEE in the C57.12-2021 standard used for design and operation of power transformers	Less than 1 day	1 to 15 days	More than 15 days
Days per year with daily average temperatures above 95°F (35°C)	Counts the number of days per year and averages over 30 years	Avangrid ambient temperature rating used for CMP conductors.	Less than 1 day	1 to 5 days	More than 5 days
Days per year with daily maximum temperatures above 104F (40C)	Counts the number of days per year and averages over 30 years	Ambient temperature threshold used in IEEE and Avangrid internal standards for multiple types of transmission, distribution, and substation equipment.	Less than 2 days	2 to 3 days	More than 4 days
Heat Waves					
Number of 3-day heat waves with daily maximum temperatures above 90°F (32°C)	Counts the number of times there are at least 3 days in a row per year and averages over 30 years	Common heatwave definition used by the National Weather Service. Heat waves can cause impacts on demand as well as impacts on human health.	Less than 2 events	2 to 5 events	More than 5 events
Maximum duration of heat waves with maximum temperatures above 90°F (32°°C)	Determines the greatest number of consecutive days with maximum temperatures above 90F per year and averages over 30 years	Common heatwave definition used by the National Weather Service. Heat waves can cause impacts on demand as well as impacts on human health.	Less than 5 days	5 to 10 days	More than 10 days

The results are summarized below for CMP service region along with identification of those CMP service areas that are above the threshold for high exposure. Given the Maine's northern location, the average daily temperature is rarely above 86F. Future warming under all three scenarios is not anticipated to raise average daily temperatures above the high threshold of exposure concern.

Heat Variable	Scenario	Units	Observed	2030	2040	2050	2060	2070	2080	CMP SAs with High Score 2050
Hot Days										
Days per year with daily average temperatures above 86°F (30°C)	SSP2-4.5 50th percentile	Days	0.0	0.0 (+0.0)	0.1 (+0.1)	0.1 (+0.1)	0.2 (+0.2)	0.3 (+0.3)	0.4 (+0.4)	None
	SSP5-8.5 50th percentile			0.1 (+0.1)	0.2 (+0.2)	0.4 (+0.4)	0.7 (+0.7)	1.6 (+1.6)	3.6 (+3.6)	None
	SSP5-8.5 90th percentile			0.3 (+0.3)	0.6 (+0.6)	1.1 (+1.1)	2.5 (+2.5)	5.0 (+5.0)	9.9 (+9.9)	None
Days per year with daily average temperatures above 95°F (35°C)	SSP2-4.5 50th percentile	Days	0.0	0.0 (+0.0)	0.0 (+0.0)	0.0 (+0.0)	0.0 (+0.0)	0.0 (+0.0)	0.0 (+0.0)	None
	SSP5-8.5 50th percentile			0.0 (+0.0)	0.0 (+0.0)	0.0 (+0.0)	0.0 (+0.0)	0.0 (+0.0)	0.0 (+0.0)	None
	SSP5-8.5 90th percentile			0.0 (+0.0)	0.0 (+0.0)	0.0 (+0.0)	0.0 (+0.0)	0.0 (+0.0)	0.1 (+0.1)	None
Days per year with daily maximum temperatures above 104°F (40°C)	SSP2-4.5 50th percentile	Days	0.0	0.0 (+0.0)	0.0 (+0.0)	0.0 (+0.0)	0.0 (+0.0)	0.0 (+0.0)	0.0 (+0.0)	None
	SSP5-8.5 50th percentile			0.0 (+0.0)	0.0 (+0.0)	0.0 (+0.0)	0.1 (+0.1)	0.2 (+0.2)	0.6 (+0.6)	None
	SSP5-8.5 90th percentile			0.0 (+0.0)	0.1 (+0.1)	0.3 (+0.3)	0.6 (+0.6)	1.3 (+1.3)	2.8 (+2.8)	None
Heat Events										
Number of 3-day heat waves with daily maximum temperatures above 90°F (32°C)	SSP2-4.5 50th percentile	Number of events	0.2	1.0 (+0.8)	1.3 (+1.1)	1.7 (+1.5)	2.1 (+1.9)	2.6 (+2.4)	3.0 (+2.8)	None
	SSP5-8.5 50th percentile			1.2 (+1.0)	1.8 (+1.6)	2.9 (+2.7)	4.5 (+4.3)	7.0 (+6.8)	10.9 (+10.7)	Alfred (4.9)
	SSP5-8.5 90th percentile			2.4 (+2.2)	3.7 (+3.5)	6.2 (+6.0)	9.4 (+9.2)	13.9 (+13.7)	19.7 (+19.5)	Dover (5.5), Fairfield (8.9), Bridgton (6.7),

										Brunswick (5.1) Portland (6.5) Alfred (8.8) Skowhegan (4.9) Lewiston (6.6) Augusta (7.9)
Maximum duration of heat waves with maximum temperatures above 90°F (32°C)	SSP2-4.5 50th percentile	Days	0.0	1.5 (+1.5)	2.2 (+2.2)	2.9 (+2.9)	3.4 (+3.4)	4.0 (+4.0)	4.5 (+4.5)	None
	SSP5-8.5 50th percentile			1.8 (+1.8)	2.9 (+2.9)	4.4 (+4.4)	6.2 (+6.2)	8.5 (+8.5)	11.9 (+11.9)	None
	SSP5-8.5 90th percentile			3.7 (+3.7)	5.1 (+5.1)	7.5 (+7.5)	10.4 (+10.4)	14.6 (+14.6)	19.8 (+19.8)	Fairfield (9.8)

The projections largely suggest moderate increases in heat variables by late century under the SSP5-8.5 scenarios. Given that at least one CMP service area is projected to experience a high exposure for the number of 3-day heat waves with maximum temperatures exceeding 90F variable under the 2050 SSP5-8.5 90th percentile, the extreme heat exposure is rated as high.

Extreme Cold: Low Rating

To assess future changes in extreme cold, this study evaluated the coldest day of the year as shown in the table below, along with the thresholds used to define the exposure ratings of low, medium, and high.

Cold Variable	**Methodology**	**Impacts**	**Low**	**Medium**	**High**
Coldest day of the year (°F)	Identify maximum cold day each year and average over 30 years	Cold temperatures can lead to icing and increases in demand.	Increasing temperature	No change	Decreasing Temperatures

The results are summarized below for CMP service region and show all scenarios and CMP service areas score in the low rating through late century. This is expected as temperatures are projected to rise. This does not imply extreme cold overall will not be a concern, rather that projections suggest the exposure to this cold event will reduce over time. See Appendix B for more information.

Cold Variable	**Scenario**	**Units**	**Observed**	**2030**	**2040**	**2050**	**2060**	**2070**	**2080**	**CMP Sas in High Score**

Coldest day of the year (°F)	SSP2-4.5 50th percentile	F	-14.8	-14.6 (+0.2)	-13.3 (+1.5)	-11.7 (+3.1)	-10.4 (+4.4)	-9.5 (+5.3)	-8.8 (+6.0)	None
	SSP5-8.5 50th percentile			-14.6 (+0.2)	-12.1 (+2.7)	-10.1 (+4.7)	-7.3 (+7.5)	-4.8 (+10.0)	-2.2 (+12.6)	None
	SSP5-8.5 90th percentile			-14.2 (+0.6)	-11.0 (+3.8)	-8.2 (+6.6)	-5.0 (+9.8)	-2.0 (+12.8)	1.8 (+16.6)	None

Given the warming projected for future conditions, impacts related to extreme cold are projected to either be similar to today's conditions or improve over time.

Frozen Precipitation: Low Rating (minimal change from baseline)

To assess future changes in frozen precipitation, this study evaluated the future change in maximum daily frozen precipitation intensity as shown in the table below, along with the thresholds used to define the exposure ratings of low, medium, and high. The exposure ratings as defined suggest whether the frequency and intensity of the hazards will increase or decrease with time compared to current conditions. Increases in this variable may occur if the number of precipitation days during cold days increase. Note that this variable is not necessarily representative of hail or frozen rain as that requires evaluating atmospheric layers above the surface, this analysis focuses on conditions at the surface.

Cold Variable	Methodology	Impacts	Low	Medium	High
Maximum Daily Frozen Precipitation Intensity (% change)	Sum annual precipitation for days above trace (0.01 inches) with average daily temperatures below 32F (0C) and average over 30 years	Icing can lead to downed vegetation and asset damage or failure	Decrease or no change	Above 0 to 10% increase	More than 10% increase
Number of Frozen Precipitation Days	Sum days with annual precipitation above trace (0.01 inches) with average temperatures below 32F (0C) and average over 30 years		Decrease or no change	Increase of 1 to 5 days	Increase of more than 5 days

The results are summarized below for CMP service region and show all scenarios and CMP service areas score in the low exposure threshold through late century. For areas that are currently a concern for frozen precipitation, this suggests a reduction of the frequency and intensity of these events. The results suggest a significant decrease in the number of frozen precipitation days per year. Note that this does not suggest precipitation freezing upon contact will reduce per say, as this variable examines average temperature conditions not minimum temperature conditions. Overall, these results are expected as temperatures are projected to rise. See Appendix B for more information.

Cold Variable	Scenario	Units	Observed	2030	2040	2050	2060	2070	2080	CMP Sas in High Score
Maximum Daily Frozen Precipitation Intensity	SSP2-4.5 50th percentile	%-Change	9.6	-13%	-19%	-22%	-24%	-25%	-26%	None
	SSP5-8.5 50th percentile			-16%	-22%	-26%	-33%	-38%	-47%	None
	SSP5-8.5 90th percentile			-4%	-10%	-15%	-21%	-28%	-34%	None
Number of Frozen Precipitation Days	SSP2-4.5 50th percentile	Days	47.3	-5.8	-7.4	-9.2	-9.8	-10.5	-11.0	None
	SSP5-8.5 50th percentile			-6.7	-8.9	-11.1	-13.6	-15.8	-19.1	None
	SSP5-8.5 90th percentile			-2.9	-5.4	-7.7	-10.1	-12.8	-14.3	None

Given the warming projected for future conditions, impacts related to freezing precipitation are projected to either be similar to today's conditions or improve over time.

Drought and Wildfire: Low Rating (minimal change from baseline)

To assess future changes in drought, this study evaluated the future change in the standardized precipitation evapotranspiration index (SPEI) as shown in the table below, along with the thresholds used to define the exposure ratings of low, medium, and high. Early in this analysis, the study team confirmed with the Maine Climate Council (MCC) the use of this index as a proxy to represent changes in future conditions that are conducive to wildfire spread and intensity. SPEI is a well-known standard index used to assess drought conditions that are also more favorable for wildfires. The SPEI considers the balance between precipitation and evapotranspiration, where higher temperatures will increase the moisture deficit. Positive SPEI value suggests wet conditions and negative value suggests dry conditions. This study evaluated the future change in mild drought conditions for summer (over 3-month period of June, July, and August) where the SPEI value is between -0.5 and -1.0, as well as the future change in moderate or greater drought conditions where the SPEI value is greater than -1.0.

Categorization	SPEI values
Extremely wet	$\text{SPEI} \geq 2$
Severely wet	$1.5 \leq \text{SPEI} < 2$
Moderately wet	$1 \leq \text{SPEI} < 1.5$
Mildly wet	$0.5 < \text{SPEI} < 1$
Normal	$-0.5 \leq \text{SPEI} \leq 0.5$
Mild drought	$-1 < \text{SPEI} < -0.5$
Moderate drought	$-1.5 < \text{SPEI} \leq -1$
Severe drought	$-2 < \text{SPEI} \leq -1.5$
Extreme drought	$\text{SPEI} \leq -2$

Drought Variable	Methodology	Impacts	Low	Medium	High

Summer SPEI (standardized precipitation evapotranspiration index)	Monthly water balance between precipitation and potential evapotranspiration (PET) using Thornwaite was assessed for summer each year and averaged over 30 year periods. Estimated change in number of mild (and moderate) summers for each decade was divided by 30 years to reflect probability of change in any given year.	Drought conditions can exacerbate wildfire, landslide, mudslide, and (when followed by extreme precipitation) flood risk. Wildfire can be highly destructive to assets.	Decrease or no change	Increase greater than 5%	Increase greater than 10%

The results are summarized below for CMP service region and show minimal change in future drought conditions. Minor drought has a very small increase in potential drought conditions across all decades and scenarios. Moderate drought is largely projected to decrease under the SSP2-4.5 50th and SSP5-8.5 50th percentiles in the near-term. Once temperature increases and surpasses the “input” from precipitation, then drought conditions increase by very small measures towards the end of century. The exception is the SSP5-8.5 90th percentile, where high temperatures increase earlier this century leading to drought conditions, reducing soil moisture and increasing evapotranspiration. (See Appendix B for more information).

Drought Variable	Scenario	Units	2030	2040	2050	2060	2070	2080	CMP Sas in High Score
Summer SPEI for Mild Drought (standardized precipitation evapotranspiration index)	SSP2-4.5 50th percentile	Change in the probability a mild drought occurs	0.3%	0.3%	0.4%	0.3%	0.3%	0.4%	None
	SSP5-8.5 50th percentile		0.2%	0.3%	0.3%	0.4%	0.4%	0.5%	None
	SSP5-8.5 90th percentile		0.5%	0.6%	0.6%	0.7%	0.7%	0.8%	None
Summer SPEI for Moderate Drought (standardized precipitation	SSP2-4.5 50th percentile	Change in the probability a moderate drought occurs	-0.2%	-0.1%	-0.1%	-0.1%	0.0%	0.1	None
	SSP5-8.5 50th percentile		-0.4%	-0.3%	-0.2%	0.0%	0.1%	0.2%	None

evapotranspiration index)	SSP5-8.5 90th percentile			-0.1%	0.0%	0.1%	0.3%	0.4%	0.5%	None

Extreme Precipitation: High Rating

Extreme precipitation can lead to excessive inland flooding through ponding , pluvial flooding, and riverine flooding. Areas currently at greater risk are likely candidates for worsening flood conditions in those CMP service areas where heavy precipitation is projected to increase.

To assess future changes in heavy precipitation, this study evaluated two impactful extreme precipitation variables shown in the table below, along with the thresholds used to define the exposure ratings of low, medium, and high.

Precipitation Variable	**Methodology**	**Impacts**	**Low**	**Medium**	**High**
1-day annual maximum precipitation (%-change)	Identify maximum precipitation for 1 day in a given year and average across all 30 years	Intense precipitation can overwhelm drainage systems and lead to flooding, damaging assets, and impeding operations.	Decrease or no change	Up to 20% increase	More than 20% increase
5-day annual maximum precipitation (%-change)	Identify maximum precipitation for 5 days in a given year and average across all 30 years		Decrease or no change	Up to 20% increase	More than 20% increase

The results are summarized below for CMP service region and show all scenarios and CMP service areas score in the medium to high rating with the precipitation depth increasing through the end of the century. See Appendix B for more information.

Precip Variable	**Scenario**	**Units**	**Observed**	**2030**	**2040**	**2050**	**2060**	**2070**	**2080**	**CMP SAs in High Score (2050)**
1-day annual maximum precipitation	SSP2-4.5 50th percentile	%-change	2.1 inches	7%	8%	11%	12%	13%	12%	None
	SSP5-8.5 50th percentile			5%	8%	10%	12%	16%	20%	None
	SSP5-8.5 90th percentile			14%	18%	20%	27%	30%	35%	Dover (22%), Framington (22%),

										Bridgton (25%), Alfred (21%), Augusta (22%)
5-day annual maximum precipitation	SSP2-4.5 50th percentile	%-change	4.1 inches	9%	8%	10%	11%	13%	12%	None
	SSP5-8.5 50th percentile			6%	9%	9%	12%	14%	17%	None
	SSP5-8.5 90th percentile			14%	17%	19%	23%	28%	33%	None

The results suggest that impacts related to extreme precipitation are projected to increase over time, and substantially so for the SSP5-8.5 90th percentile scenario. For the vulnerability screening which is based on the SSP5-8.5 50th percentile simulation, a high rating will be applied.

Inland Flooding: High Rating

To assess exposure to inland flooding , this study identified assets exposed to the 100-year and 500-year flood events as specified in Federal Emergency Management Agency (FEMA) FIRMs. The utility requires CMP to consider flooding using the FEMA FIRMs. The 100-year is described as the 1% chance of occurring in any given year and the 500-year is a 0.2% chance of occurring in any given year. These maps were developed based on historical information, with most of these maps last updated in 2024. There are limitations of these maps for this study as these maps do not consider future conditions and potential changes in flood extent and depth associated with the 100-year and 500-year flood events, and assume levees will not breach. The table below shows these flood layers along with the thresholds used to define the exposure ratings of low, medium, and high.

Flood Variable	**Methodology**	**Impacts**	**Low**	**Medium**	**High**
Flood extent	Overlay FEMA FIRM with CMP assets to identify exposure to 100-year and 500-year event	FEMA flood extents are used by Avangrid to evaluate flood risk to utility assets.	Not in 100-year or 500-year flood plain	500-year flood plain	100-year flood plain

The results are provided in the tables below.

CMP Structures Inland Flooding Exposure			
Asset Type	Number of Assets Exposed	Total Number of Assets	Percentage of Assets Exposed
Inland 100-year Floodplain			

CMP Poles	13,571	674,908	2.01%
Padmount Structures	389	30,922	1.26%
Underground Structures	18	1,942	0.93%
Inland 500-year Floodplain			
CMP Poles	16,108	674,908	2.39%
Padmount Structures	508	30,922	1.64%
Underground Structures	52	1,942	2.68%

CMP Transformer Inland Flooding Exposure			
Asset Type	Number of Assets Exposed	Total Number of Assets	Percentage of Assets Exposed
Inland 100-year Floodplain			
Padmount	280	19,635	1.43%
Overhead	3,966	220,200	1.80%
Inland 500-year Floodplain			
Padmount	346	19,635	1.76%
Overhead	4,721	220,200	2.14%

CMP Substation Inland Flooding Exposure			
Asset Type	Number of Assets Exposed	Total Number of Assets	Percentage of Assets Exposed
Inland 100-year Floodplain			
Substations	52	228	22.81%
Inland 500-year Floodplain			
Substations	59	228	25.88%

CMP Substation Exposure to Inland 100-year Floodplain	
SUBSTATION NAME	RELATIVE FLOOD RISK
Burnham	Warning
Rumford	Warning
Unity	Warning
Keyes Fiber Waterville	Warning
Keyes Waterville	Warning
Newry	Warning
Monmouth	Warning
Lewiston Lower	Warning
Great Falls	Warning

Coopers Mills SS	Warning
South China	Warning
Gardiner	Warning
Manktown	Warning
Warren	Warning
Thomaston Creek	Warning
Camden	Warning
Mason	Warning
Bath 115	Warning
Lisbon Falls	Warning
Westbrook	Warning
Vallee Lane	Warning
North Limington	Warning
Bonny Eagle	Warning
Biddeford Pump	Warning
Butlers Corner	Warning
High St	Warning
Andover	Access Obstructed
Rice Rips	Access Obstructed
Fort Halifax	Access Obstructed
Vassalboro	Access Obstructed
Gulf Island	Access Obstructed
Middle St	Access Obstructed
New Auburn	Access Obstructed
Bond Brook	Access Obstructed
Damariscotta Mills	Access Obstructed
Swett Rd	Access Obstructed
North Gorham	Access Obstructed
Shaws Mill Rd	Access Obstructed
Bar Mills	Access Obstructed
Old Orchard	Access Obstructed
Factory Island	Access Obstructed
Kennebunk	Access Obstructed

Sanford Switch	Access Obstructed
York Beach	Access Obstructed
Keyes Fiber Waterville Switch Yard	High Flood Risk
Bethel	High Flood Risk
Mechanic Falls	High Flood Risk
Bridgton	High Flood Risk
Brunswick Hydro	High Flood Risk
Kennebunkport	High Flood Risk
South Berwick	High Flood Risk
Cape 115 kV	High Flood Risk[46]

CMP Transmission Reclosers Inland Flooding Exposure			
Type	**Number of Assets Exposed**	**Total Number of Assets**	**Percentage of Assets Exposed**
Inland 100-year Floodplain			
Reclosers	**10**	**646**	**1.55%**
Inland 500-year Floodplain			
Reclosers	**10**	**646**	**1.55%**

CMP Circuit[47] Exposure to Inland Flooding		
Asset Type	Top 3 Most Exposed Circuits[48]	Total Number of Exposed Circuits
Inland 100-year Floodplain		
Overhead Circuits	424D6 (43.42%), 645D2 (38.18%), 641D3 (34.06%)	331
Underground Circuits	214D2 (100%), 617D4 (100%), 466D1 (50%)	15
Inland 500-year Floodplain		
Overhead Circuits	623D2 (71.92%), 424D6 (69.74%), 645D2 (38.18%)	339
Underground Circuits	214D2 (100%), 617D4 (100%), 611D1 (66.67%)	24

[46] Substation Cape 115 kV as exposed to the FEMA 100-year Inland Floodplain was identified to be at a "Warning" status; however, its exposure to the FEMA 100-year coastal floodplain and NOAA 2-ft SLR scenario identifies the asset to be at a "High Flood Risk" status.
[47] Circuit exposure is calculated by calculating the exposure of poles or underground structures in the floodplain. This is because conductors themselves are not sensitive to flood and/or will almost never be exposed to flood conditions unless the line is downed.
[48] As defined by the percentage of poles/underground structures exposed.

CMP Transmission Line[49] Exposure to Inland Flooding		
Asset Type	Top 3 Most Exposed Lines[50]	Total Number of Exposed Transmission Lines
Inland 100-year Floodplain		
Overhead Lines	S 10 N.O. Keys Fiber to S10A Tap (100%), S 90D 90D Tap – Bethel (100%), S 53 A Mechanic Falls - Mechanic Falls Hydro (98.19%)	233
Underground Lines	S 275 Fore River – Cape (7.19%), S 277 Sewall Street - Fore River (6.18%)	2[51]
Inland 500-year Floodplain		
Overhead Lines	S 10 N.O. Keys Fiber to S10A Tap (100%), S 90D 90D Tap – Bethel (100%), S 53 A Mechanic Falls - Mechanic Falls Hydro (98.19%)	239
Underground Lines	S 275 Fore River – Cape (7.19%), S 277 Sewall Street - Fore River (7.89%)	2[52]

Coastal Flooding: High Rating

This analysis identifies asset exposure to the 100-year and 500-year coastal base flood elevation depths (BFEs) in FEMA floodplains with results provided in the tables below. In addition, as a proxy for future exposure, assets exposed to NOAA 2 feet of sea level rise above mean higher high water (Maine recommended sea level rise for 2050) and 10 feeet of sea level rise (maximum provided by NOAA) are also included.

CMP Structures Costal Flooding Exposure			
Asset Type	**Number of Assets Exposed**	**Total Number of Assets**	**Percentage of Assets Exposed**
Coastal 100-year Floodplain			
CMP Poles	**1,041**	**674,908**	**0.15%**
Padmount Structures	**97**	**30,922**	**0.31%**
Underground Structures	**5**	**1,942**	**0.26%**
Coastal 500-year Floodplain			
CMP Poles	**1,041**	**674,908**	**0.15%**
Padmount Structures	**97**	**30,922**	**0.31%**
Underground Structures	**5**	**1,942**	**0.26%**
NOAA 2 ft Sea Level Rise			
CMP Poles	**522**	**674,908**	**0.08%**
Padmount Structures	**42**	**30,922**	**0. 14%**

[49] Transmission exposure is defined by the percentage of line miles within the floodplain
[50] As defined by the percentage of poles/underground structures exposed.
[51] Only 2 transmission lines are located underground
[52] Only 2 transmission lines are located underground

Underground Structures	4	1,942	0.21%
NOAA 10 ft Sea Level Rise			
CMP Poles	8,608	674,908	1.28%
Padmount Structures	674	30,922	2.18%
Underground Structures	106	1,942	5.46%

CMP Transformer Coastal Flooding Exposure			
Asset Type	Number of Assets Exposed	Total Number of Assets	Percentage of Assets Exposed
Coastal 100-year Floodplain			
Padmount	70	19,635	0.36%
Overhead	311	220,200	0.14%
Coastal 500-year Floodplain			
Padmount	70	19,616	0.36%
Overhead	311	219,948	0.14%
NOAA 2 ft Sea Level Rise			
Padmount	35	19,635	0.18%
Overhead	225	220,200	0.10%
NOAA 10 ft Sea Level Rise			
Padmount	451	19,635	2.30%
Overhead	2533	220220	1.15%

CMP Substation Coastal Flooding Exposure			
Asset Type	Number of Assets Exposed	Total Number of Assets	Percentage of Assets Exposed
Coastal 100-year Floodplain			
Substations	2	228	0.88%
Coastal 500-year Floodplain			
Substations	2	228	0.88%
NOAA 2 ft Sea Level Rise			
Substations	7	228	3.07%
NOAA 10 ft Sea Level Rise			
Substations	16	228	7.02%

CMP Transmission Reclosers Exposure to Coastal Flooding			
Type	Number of Assets Exposed	Total Number of Assets	Percentage of Assets Exposed
Coastal 100-year Floodplain			
Reclosers	0	646	0
Coastal 100-year Floodplain			
Reclosers	0	646	0
NOAA 2ft Sea Level Rise			
Reclosers	0	646	0.00%
NOAA 10ft Sea Level Rise			
Reclosers	3	646	0.46%

CMP Circuit[53] Exposure to Coastal Flooding		
ASSET TYPE	TOP 3 MOST EXPOSED CIRCUITS[54]	TOTAL NUMBER OF EXPOSED CIRCUITS
Coastal 100-year Floodplain		
Overhead Circuits	641D2 (11.34%), 239D8 (6.15%), 690D1 (3.71%)	50
Underground Circuits	641D2 (100%), 806D1 (100%), 239D8 (20%)	4
Coastal 500-year Floodplain		
Overhead Circuits	641D2 (11.34%), 239D8 (6.15%), 690D1 (3.71%)	50
Underground Circuits	641D2 (100%), 806D1 (100%), 239D8 (20%)	4

[53] Circuit exposure is calculated by calculating the exposure of poles or underground structures in the floodplain. This is because conductors themselves are not sensitive to flood and/or will almost never be exposed to flood conditions unless the line is downed.
[54] As defined by the percentage of poles/underground structures exposed.

CMP Circuit[53] Exposure to Coastal Flooding		
ASSET TYPE	TOP 3 MOST EXPOSED CIRCUITS[54]	TOTAL NUMBER OF EXPOSED CIRCUITS
NOAA 2 ft Sea Level Rise		
Overhead Circuits	681D3 (3.76%), 239D8 (3.08%), 645D3 (2.70%)	62
Underground Circuits	617D4 (100%), 806D1 (50%), 239D8 (20%)	4
NOAA 10 ft Sea Level Rise		
Overhead Circuits	645D2 (98.18%), 641D2 (82.27%), 623D2 (80.82%)	113
Underground Circuits	204D1 (100%), 214D2 (100%), 617D4 (100%), 623D2 (100%), 641D2 (100%), 653D5 (100%), 806D1 (100%)	27

CMP Transmission Line[55] Exposure to Coastal Flooding		
ASSET TYPE	TOP 3 MOST EXPOSED LINES[56]	TOTAL NUMBER OF EXPOSED TRANSMISSION LINES
Coastal 100-year Floodplain		
Overhead Lines	S 120,121,124 Cape - Union Street (31.63%), S 198 Elm Street - WF Wyman (3.69%), S 3039 Raven Farm - WF Wyman (3.6%)	9
Underground Lines	S 275 Fore River – Cape (7.19%)	1[57]
Coastal 500-year Floodplain		
Overhead Lines	S 120,121,124 Cape - Union Street (31.63%), S 198 Elm Street - WF Wyman (3.69%), S 3039 Raven Farm - WF Wyman (3.6%)	9
Underground Lines	S 275 Fore River – Cape (7.19%)	1[58]
NOAA 2 ft Sea Level Rise		
Overhead Lines	S 120,121,124 Cape - Union Street (43.32%), S 101 Spring St - Sewall St (9.41%), S 161 Moshers - Sewall Street (9.11%)	48

[55] Transmission exposure is defined by the percentage of line miles within the floodplain
[56] As defined by the percentage of poles/underground structures exposed.
[57] Only 2 transmission lines are located underground
[58] Only 2 transmission lines are located underground

CMP Transmission Line[55] Exposure to Coastal Flooding		
ASSET TYPE	TOP 3 MOST EXPOSED LINES[56]	TOTAL NUMBER OF EXPOSED TRANSMISSION LINES
Underground Lines	S 275 Fore River – Cape (22.75%), S 277 Sewall Street - Fore River (3.27%)	2[59]
NOAA 10 ft Sea Level Rise		
Overhead Lines	S 120,121,124 Cape - Union Street (51.23%), S 122,123 Forest Avenue - Union Street (13.60%), S 179 Pleasant Hill - Red Brook (12.98%)	58
Underground Lines	S 275 Fore River – Cape (88.47%), S 277 Sewall Street - Fore River (20.07%)	2[60]

Impact Stressor: Scheffer Index: High Rating

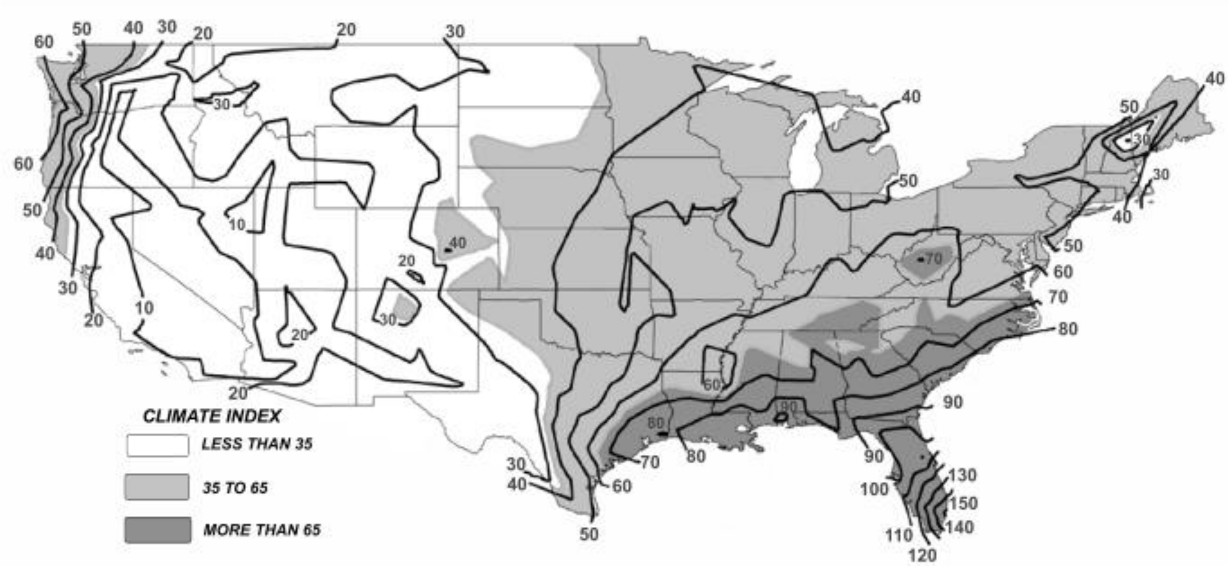
The Decay Hazard (Scheffer) Index provides an indication of potential wood decay for wood exposed to the outdoors and located above ground (Carll 2009). The index suggests whether the outdoor conditions are warm and wet enough to encourage wood decay for outdoor wood, woody debris, and standing dead trees (Wang 2009). In addition, increases in the decay hazard index may be related to causes of some disease in some tree species (Wand 2009).

This index is expressed as:

$$\text{Index} = \sum_{\text{Jan}}^{\text{Dec}} \left[(T - 35)(D - 3) \right] / 30$$

Where T is the mean monthly average temperature (F) and D is the mean number of days per month with at least 0.01 inches of precipitation. If T is below 35 for that month, then the value is set to 0. If D is less than 3 for that month, then the value is set to 0. Carll (2009) study suggests Portland Maine's decay hazard climate index was 41 for 1971-2000 (which was an increase of 5 units from a prior analysis by Scheffer (1971)). In Canada, some locations increased by as much as 10 units within a ten-year period (Wang 2009).

[59] Only 2 transmission lines are located underground
[60] Only 2 transmission lines are located underground



Scheffer (1971) suggests three levels of decay hazards: low hazard of less than 35, moderate hazard of 35 to 65, and high hazard over 65 (used recently by Curling and Ormondroyd, 2020). The UI study introduced an additional hazard threshold of very high for indices above 100 which will be used here. In 1971-2000, Maine was in a moderate hazard level.

Impact Variable	Methodology	Impacts	Low	Medium	High	Very High
Wood Decay Hazard (Scheffer) Index	See description above	Decay of outdoor exposed wood above ground	Less than 35	35 to 65	More than 65	More than 100

This study which uses the Livenah (2015) gridded observation data from 1985-2013 at approximately 6km resolution found a higher index for the Portland service area of 62, which is a moderate hazard level. This increase may be in part because of rising monthly temperatures year round and an extension of months averaging above the "35" threshold.

The overall hazard decay value averaged across the entire CMP service area is 73.4. The projections suggest minimal change in the near-term but significant rise in potential decay by late century. It is likely largely driven by increased temperatures expanding the "decay" season into what are now colder months. In addition, decay scores also increase with a greater number of precipitation days during warmer months.

Impact Variable	Scenario	Units	Observed (1985-2013)	2030	2040	2050	2060	2070	2080	CMP SAs in High Score (2050s)

Wood Decay Hazard (Scheffer) Index	SSP2-4.5 50th percentile	Index units	73.4	70.0	72.0	75.1	77.8	81.0	81.9	All CMP SAs
	SSP5-8.5 50th percentile			71.1	75.7	80.4	85.8	90.0	94.5	All CMP SAs
	SSP5-8.5 90th percentile			75.9	81.0	85.1	90.7	97.6	105.8	All CMP SAs

Appendix D. Climate Hazard Typology

Attached pdf

Appendix E. Risk Screening

C.1. Climate Change impacts on Woodpeckers in the Service Territory

Figure 34 CMP Line Worker Inspecting a Wooden Pole

Woodpeckers have historically created issues for wooden poles in the CMP service territory. Woodpeckers peck wooden transmission and distribution poles as part of their natural foraging, communication, nesting, and roosting activities. This pecking can result in both holes and cavities in the wood, weakening the structural integrity of the pole and exposing untreated parts of the pole, such as the core, creating conditions that can lead to increased pole rot. These issues compromise the capability of the pole causing an increased risk of outages due to pole failure.[61]

CMP is particularly vulnerable to these adverse impacts of woodpeckers. A large portion of CMP's wooden poles are located in forested right-of-way near or within woodpecker's habitats. Additionally, unlike normal wear and degradation, woodpecker damage can be sporadic and random, and it is currently impossible for CMP to track woodpecker pole damage without onsite physical inspections. The failure of damaged poles is also unpredictable, making it difficult for CMP to consistently replace damaged poles before they cause service disruptions.

The consequences of woodpeckers damaging poles are costly and widespread. Transmission line inspections from 2021 and 2022 found that 525 wooden transmission poles had signs of woodpecker damage. Damaged poles are difficult and expensive to repair. CMP previously relied on patching holes and cavities with a resin-based sealant. This would only provide temporary relief as woodpeckers would return to the poles and cause further damage and the estimated cost of patching was $1,000 per pole (including labor and materials), resulting in an annual cost of over $500,000. CMP now replaces wooden transmission poles with steel poles, which are more expensive but provide long term relief and additional hardening benefits against other hazards in addition to preventing future woodpecker damage.

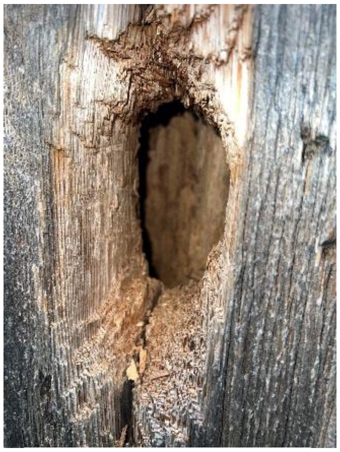


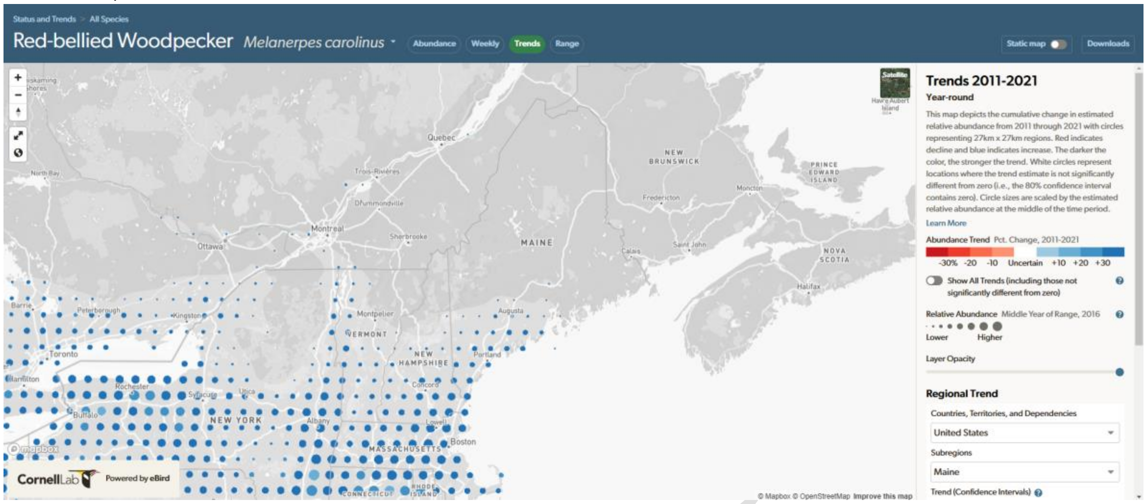
Figure 35. Cavity in a Wooden Pole Left by a Woodpecker in the CMP Service Area

Climate change is projected to lead to an increase in the woodpecker population in Maine potentially exacerbating CMP's existing challenges managing woodpecker damage. Woodpeckers are experiencing shifts in range due to climate and tree composition change. Warming temperatures have been observed to push the species further north, expanding their range, and spurring population growth in states with historically lower woodpecker populations, such as Maine. As winters become milder, these woodpeckers are more likely to establish year-round territories in areas that were previously too cold to inhabit. The Yellow-bellied Sapsucker, Pileated Woodpecker, Downy Woodpecker, Red-bellied Woodpecker are all found in Maine and have been observed to have expanding breeding ranges. [62] The Red-Bellied Woodpecker, in particular, has seen a dramatic shift into Maine. Historically concentrated primarily in the southeastern United States, now this species is on the rise in Maine and other parts of the northeast due to

[61] R.E. Harness and E.L. Walters, "Woodpeckers and Utility Pole Damage," *Rural Electric Power Conference*, June 30, 2004, B3-7, https://doi.org/10.1109/repcon.2004.1307046.

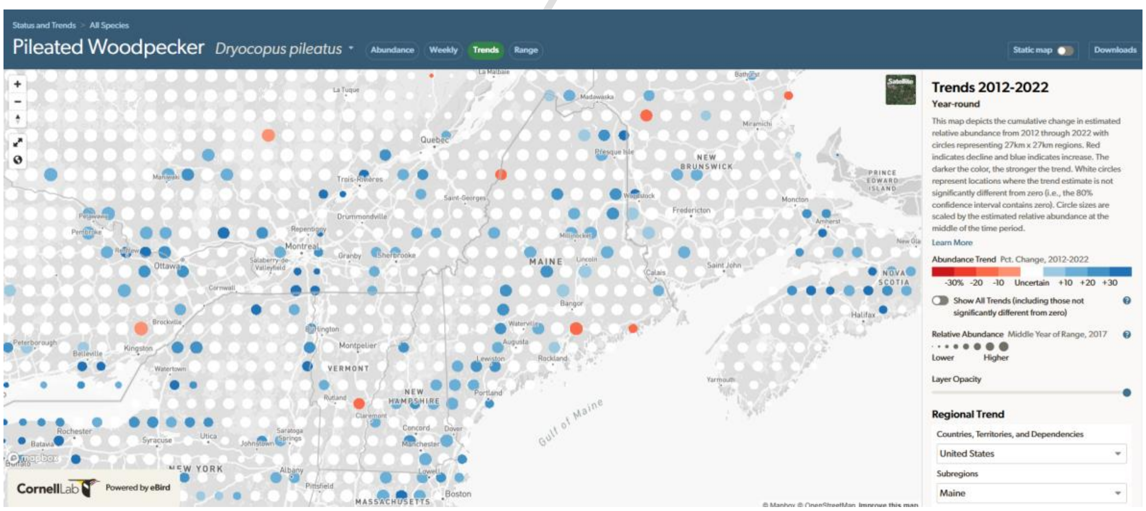
[62] Walsh et al., "Climate Change, Woodpeckers, and Forests: Current Trends and Future Modeling Needs."

changes in climate.[63, 64] While still only concentrated in the southern part of the state, some areas have seen a 100% increase in abundance between 2012-2022 (see Figure 31).[65] With continued warming in the coming years this trend is expected to increase; and as populations of these species grow the impact that they have on their environment is expected to as well.



Red-belied Woodpecker Abundance Trends 2012-2022

This trend is also notable for other species, including the Pileated Woodpecker; parts of the state have experienced over a 30% increase in Pileated Woodpecker abundance between 2012 and 2022 (see Figure 32).[66]



Pileated Woodpecker Abundance Trends 2012-2022

The climatic trends that have already accounted for these shifts are likely to continue, further increasing woodpecker migration into Maine. As woodpeckers continue to proliferate in the service territory, the risks they pose to poles and associated costs and impacts to reliability and asset health are likely to increase as well.

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[63] National Audubon Society. (2024). Red-bellied woodpecker. In *Audubon Field Guide*. Retrieved December 6, 2024, from https://www.audubon.org/field-guide/bird/red-bellied-woodpecker

[64] Stein, A. (2022, December 9). Maine bird watchers seeing more species moving north. WGME. Retrieved December 6, 2024, from https://wgme.com/news/local/maine-bird-watchers-more-species-moving-north-climate-change-red-bellied-woodpecker

[65] Cornell Lab eBird. (2023). *Red-bellied Woodpecker - Trends Map*. eBird Status and Trends, Data Version: 2022; Released: 2023. Cornell Lab of Ornithology. Retrieved from https://science.ebird.org/en/status-and-trends/species/rebwoo/trends-map.

[66] Red-Bellied Woodpecker - Trends Map - eBird Status and Trends..

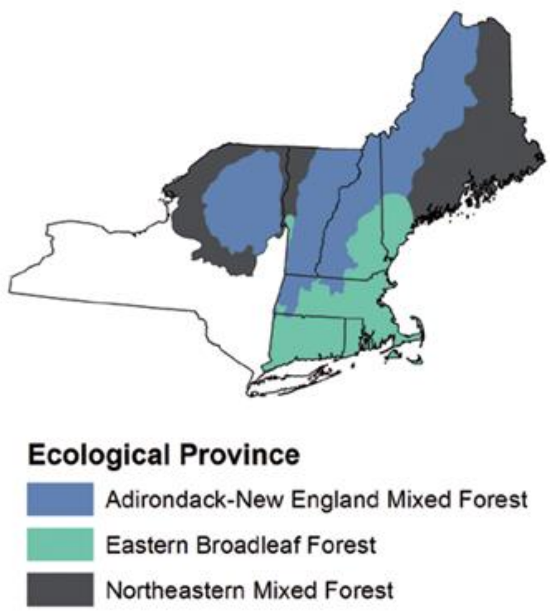
C.2. Impacts on Tree Management

Trees can damage power lines as well as disrupt repair operations by blocking roads. Though CMP has robust vegetation management, tree storm damage poses significant issues across the state. As climate changes, some tree species will be better suited to the future climate than others. This section explores how species may evolve and what that might mean for CMP.

Forest Background. Forest composition and species distribution are constantly evolving, influenced by the presence or absence of disturbances like timber management and other anthropogenic activity, climate shifts, extreme natural events, and invasive species.[67,68,69] Current tree species composition reflects historical and current environmental trends across Maine's forests, as well as the broader region.

Maine's forests are part of three ecological provinces, delineated by the U.S. Forest Service: Northeastern Mixed Forest, Adirondack – New England Mixed Forest, and Eastern Broadleaf Forest. Despite the region's overall species diversity, these three provinces share similar traits, including geology and soils. They additionally share similar geographical boundaries to Maine's distinct climate regions and are thus influenced by them.

- The **Northeastern Mixed Forest Province** has a climate moderated by proximity to the Atlantic Ocean and/or Great Lakes. Winters are generally long with continuous snow cover. Vegetation in this province reflects a transition between boreal conifer forests in colder, more northerly locations and more southerly deciduous hardwood forests.
- The **Adirondack – New England Mixed Forest Province** has a more continental climate that results in long, cold winters. This province is mountainous and has topography, geology, and soils that reflect a combination of local bedrock and glacial features.
- The **Eastern Broadleaf Forest Province** is the most southerly of the three provinces. Its topography and bedrock geology vary from broad, hilly plateaus to coastal areas along the Atlantic. This area has a warmer climate and longer growing season compared to the other identified provinces.



Ecological province distribution across New England and Maine. Source: USDA.

Forest composition across Maine is diverse. Maine is largely considered a highly forested spruce/fir State, with over 50 different tree species. This diversity benefits wildlife and ecosystem processes like drought resilience, and supports a variety of specialty forest industries.

[67] E Cleland et al., "Shifting Plant Phenology in Response to Global Change," *Trends in Ecology & Evolution* 22, no. 7 (May 3, 2007): 357–65, https://doi.org/10.1016/j.tree.2007.04.003.
[68] Davis 1983
[69] Davis 1986

Climate Impacts on Tree Species. Species distributions continually change across landscapes in response to natural and man-made pressures. Wind, fire, insects, and disease are primary natural disturbances influencing vegetation in much of Maine and New England more generally. Human activity and development are other major drivers for forest composition change. Climate change may likely influence northeastern forest migration and composition, impacting suitable habitat distribution for many common tree species, with specific tree response varying based on many factors. Temperature and precipitation are projected to change, with significant seasonal variations and associated changes in snow and ice cover, growing season length, soil moisture, lake levels, and streamflow.

In northern regions, a number of tree species are projected to decline as habits shift, including the boreal and northern species such as balsam fir.[70] The southern regions may experience fragmented habitat decline by end of century under a moderate (RCP 4.5) and high (RCP 8.5) emissions scenario. The balsam fir, red spruce, and black ash are at significant risk.[71] Conversely, there are favorable tree species with habitats projected to extend northward, some of which are also tolerant of drought and fire. Five species projected to experience suitable habitat increases in all three subregions include: black oak, white oak, black willow, silver maple, and flowering dogwood.

SPECIES HABITAT PROJECTED TO DECLINE	MINIMAL CHANGE IN HABITAT	SPECIES HABITAT PROJECTED TO INCREASE
• Balsam fir • Red Spruce • Paper Birch • White Spruce • Black Ash • Eastern White Pine • Silver Maple*	• White Ash • Scrub Oak • American Chestnut • Black Spruce • White Oak* • Chestnut Oak* • Sourwood • Green Ash • Boxelder maple	• Northern Red Oak • American Elm • Mockernut Hickory* • Post oak* • Black oak • Black willow • Flowering dogwood
Balsam fir is the most abundant tree in Maine, totaling over 8 billion in population.	*Some of these species are relatively uncommon and only present in southern Maine.*	*Most common species include Northern red oak and American elm.*

** high capacity to adapt*

[70] USDA's New England and Northern New York Forest Ecosystem Vulnerability Assessment and Synthesis (2018) See "New England and Northern New York Forest Ecosystem Vulnerability Assessment | USDA Climate Hubs," n.d., https://www.climatehubs.usda.gov/hubs/northern-forests/topic/new-england-and-northern-new-york-forest-ecosystem-vulnerability.; NCA Region Climate Change Atlas Tree Species Current and Potential Future Habitat, Capability, and Migration (2022), see Louis R. Iverson et al., "Facilitating Adaptive Forest Management Under Climate Change: A Spatially Specific Synthesis of 125 Species for Habitat Changes and Assisted Migration Over the Eastern United States," *Forests* 10, no. 11 (November 6, 2019): 989, https://doi.org/10.3390/f10110989. There are some discrepancies between these two analyses, in which case the more recent was utilized.

[71] Just over half of Maine's tree volume is softwood; the remainder is in hardwoods. Proportionally, the most softwood volume is found in Central and Northern Maine. Hardwood volume is greatest in Western and Southern Maine. Softwood is generally less dense than the wood from hardwood, and therefore more prone to damage. Hardwoods tend to be denser and more resistant to decay. There are exceptions though to this general rule of thumb, for example, balsa wood.

Climate Impacts on Tree/Vegetation Pests and Diseases. Maine's Forest Service currently identifies 13 invasive pests and diseases under four categories as potential hazards to state forests. Of these pests and diseases, seven are considered established in Maine as shown in the table.

WOOD BORERS[72]	PIERCING-SUCKING INSECTS[73]	DEFOLIATORS[74]	DISEASES
• EMERALD ASH BORER (EAB)	• ELONGATE HEMLOCK SCALE • HEMLOCK WOOLLY ADELGID • RED PINE SCALE	• BROWNTAIL MOTH • WINTER MOTH	BEECH LEAF DISEASE

Pest and disease distribution will likely shift alongside the State's climate. This may include increased ranges or quarantine areas, pest establishment, or changing disease frequency. Pests and diseases including EAB, browntail moth, and beech leaf disease have spread significantly across Maine since their initial identification in the state. The Maine Department of Agriculture, Conservation & Forestry maintains an updated resource catalogue that tracks each identified pest spread, potential quarantine areas, management strategies, and additional relevant information. It is recommended established hazards and additional forest health resources be monitored, as forest pests continue to post risk to CMP's infrastructure and service areas.

Impacts on CMP. Tree and vegetation contact with utility equipment is the leading cause of all customer outages. According to CMP staff, there are a few species particularly impactful to vegetation management, including: ash, eastern white pine, boxelder maple, silver maple, norway maple, and black willow. Shown in the table below are findings from the US Forest Service's Climate Change Atlas Tree Atlas, Version 4, based on an evaluation of how changing conditions could impact each tree species under a moderate emissions scenario (RCP 4.5) and high emissions scenario (RCP 8.5) by end of century. Though two species are at risk of declining numbers, four species are projected to increase including "cycle buster" species. A "cycle buster" species refers to a tree species that requires intermediate pruning/management within the normal trimming cycle. If these species increase, this could increase the need of vegetation management and associated expenses. Extended analysis, as well as habitat change maps per climate scenario, presented in Appendix C.

SPECIES		HABITAT CHANGE RCP4.5	HABITAT CHANGE RCP8.5	IMPACT TO CMP
Ash SPP (*Fraxinus*)	Black[75]	Decline	Decline	Ash comprises a significant portion of Northern Maine's hardwood. **It is increasingly at risk to the Emerald Ash Borer (EAB)**[76], one of the most serious invasive pest species threatening Maine's ash resources and forests. All species of *Fraxinus* ash trees that grow in Maine are susceptible to injury and death by EAB. Symptoms include dead canopy branches, excessive branching on
	Green[78]	No Change	Increase	
	White	No Change	No Change	

[72] These insects' worm-like larvae develop beneath tree bark or within wood.
[73] These insects feed on fluids of the host plant. Many spend a significant part of their lives attached to the host plant.
[74] These insects consume the foliage of host plants.
[75] NCA 2022 report identifies no change across scenarios; however more recent atlas images (Appendix C) and the USDA's 2018 report indicate habitat decreases.
[76] EAB lays its eggs in ash bark crevices. The eggs hatch and the larvae burrow into the tree where they feed, damaging and potentially killing the trees. See "Emerald Ash Borer | Animal and Plant Health Inspection Service," Animal and Plant Health Inspection Service, n.d., https://www.aphis.usda.gov/plant-pests-diseases/eab.
[78] NCA 2022 report identifies no change across scenarios; however more recent atlas figures (Appendix C) indicate increasing habitat under RCP 8.5.

SPECIES	HABITAT CHANGE RCP4.5	RCP8.5	IMPACT TO CMP
			tree trunks, vertical cracks in tree bark, and woodpecker activity.[77]
Eastern White Pine *(Pinus strobus)*	No Change	Decline	Eastern White Pine is Maine's state tree, and the predominant softwood in CMP's western service areas. They are large, growing up to around 100 feet high, and as such are subject to ground to sky initiatives. As such, their limbs pose risk to the lines below them. These trees are a known and ongoing risk managed by CMP's vegetation management team.
Boxelder Maple *(Pinus negundo)*[79]	No Change	Increase	This species was initially planted as an ornamental species but spread outside these areas. It is a short-lived, fast-growing, brittle tree, prone to wind and ice damage including uprooting. It can become invasive. It is a "cycle buster" species.
Silver Maple *(Acer saccharinum)*[80]	Increase	Increase	A common tree, found throughout the state except along the coast. It grows largely on sandy banks along streams. It is a "cycle buster" species,
Norway Maple[81] *(Acer platanoides)*	Not Available	Not Available	Most commonly found in cities and developed areas due to use as an ornamental. It is an invasive species with softer wood prone to breaking. It is a "cycle buster" species.
Black Willow[82][83] *(Salix nigra)*	Increase	Increase	Black willow occurs primarily in western and southern Maine, and is generally found along streams and ponds. It grows fast, sprouting 3 to 5 feet per year over a 20-year period. Its wood is soft and brittle. As such, it is a "cycle buster" species.

Risk Management

CMP already employs a number of vegetation management activities (see Vegetation Management Operations & Services for additional information). Given the increase in both pests/diseases and tree species that tend to be problematic for CMP vegetation management, there are a number of strategies to consider:

- Consider development of a tool or process to gauge the impact of species-specific vegetation damage and management activities by region to collect data on which regions are most costly/impacted. This data can be used over time to monitor trends and changes.
- Monitor changes in tree species and pests, drawing on the existing strong relationship between CMP and Maine Department of Agriculture, Conservation & Forestry

[77] Woodpeckers peel off the outermost layers of bark and punch their beaks through the remaining bark to eat larvae. This creates a "blonding" effect.
[79] NCA 2022 report identifies no change across scenarios; however more recent atlas figures (Appendix C) indicate increasing habitat under RCP 8.5.
[80] NCA 2022 report identifies no change across scenarios; however more recent atlas figures (Appendix C) indicate increasing habitat under both RCP scenarios.
[81] Norway Maple is a non-native species found throughout the eastern US, most commonly ornamental plantings. As a result, it was not modeled by the Forest Service Climate Change Atlas.
[82] Aside from Black Willow, most of Maine's native willows are small trees or shrubs. Black willows grow to between 45 and 65 feet on average.
[83] NCA 2022 report identifies a small decline in habitat under RCP 4.5 and no change under RCP 8.5. However, the 2018 USDA report indicates increases in suitable habitat across scenarios, and the NCA atlas figures featured in Appendix C indicate increases in suitable habitat under RCP 8.5.

Additional strategies outlined in the Vegetation Management Operations & Services One-Pager *Growing Future Resilience* section include:

- As vegetation growing cycles change and climate risk increases, increased frequency of trimming cycles and/or augmenting with condition-based trimming may help to better control growth into the ROW and prevent future outages.
- As climate risks increase, clearances may need to be adjusted to account for changes in growth cycles and increased intensity and frequency of storms.
- As the needs of vegetation management increase due to climate change, ensuring adequate staffing and funding will be critical to for maintaining adequate operations.

Habitat Projections for Top Tree Species that Impact CMP

Current range and projected change of tree habitats for tree species that are particularly impactful to vegetation management are provided below for the end of century relative to the historical baseline (1981-2010).[84] Scenarios evaluated per species include a moderate emissions scenario (RCP 4.5) and high emissions scenario (RCP 8.5). Current range maps are representative of current forest inventory and represent the abundance of the tree species which indicates how dominant a tree species is within certain area based on species frequency, density, and relative dominance.[85,86] The projections suggest the future habitat distribution, i.e., what areas of Maine are modeled to provide a suitable climate for species propagation.

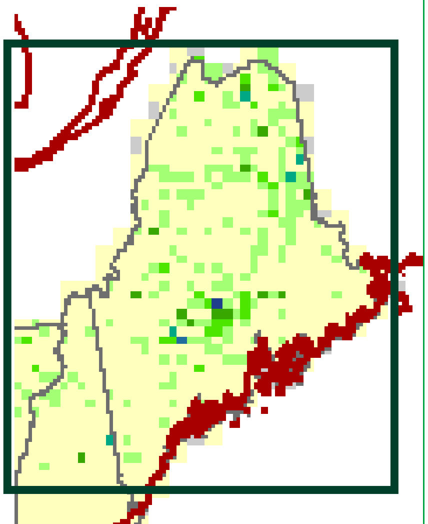
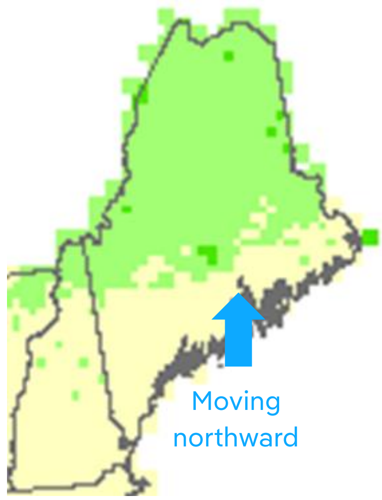
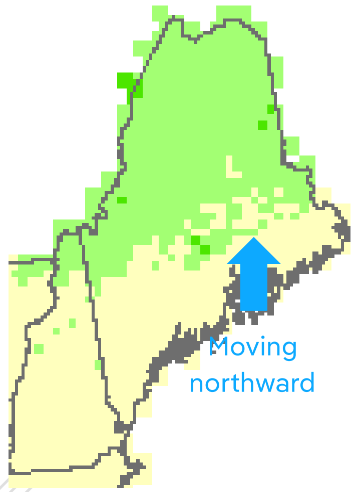
SPECIES	CURRENT RANGE[87] "TREE ABUNDANCE"	"FUTURE HABITAT DISTRIBUTION" RCP 4.5	RCP 8.5

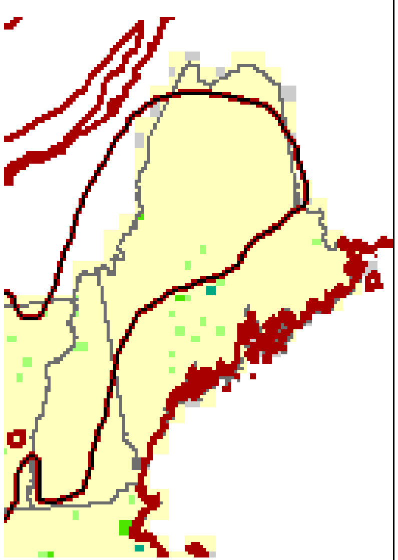
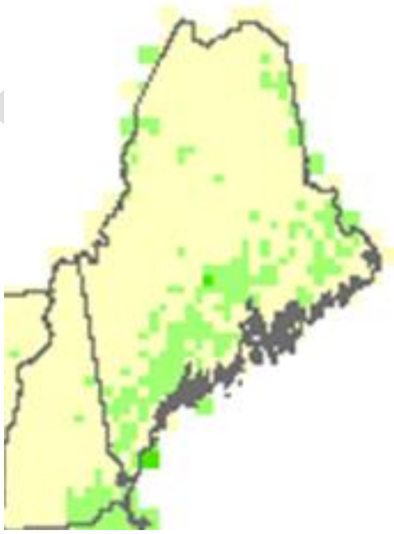
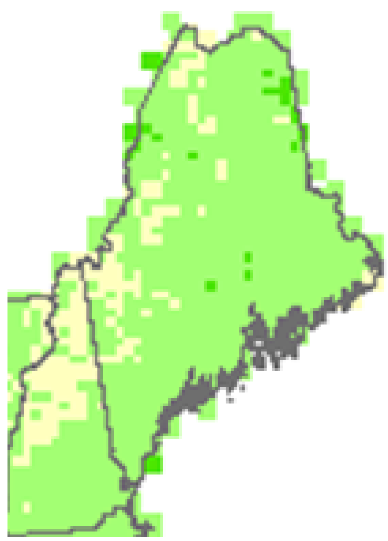
[84] Sourced from US Forest Service's Climate Change Atlas Tree Atlas Version 4. Results are from an ensemble average for three GCMs (CCSM4, GFDL CM3, and HadGEM2-ES) obtained from NASA Earth Exchange Downscaled Climate Projections. Peters, M.P., Prasad, A.M., Matthews, S.N., & Iverson, L.R. 2020. Climate change tree atlas, Version 4. U.S. Forest Service, Northern Research Station and Northern Institute of Applied Climate Science, Delaware, OH. https://www.nrs.fs.fed.us/atlas.

[85] Forest Inventory and Analysis records from >84,000 plots surveyed during 2000–2016 were used to calculate Importance Values (IVs) where Importance Values(X) = (50 * basal area(X) / basal area(all species)) + (50 * number of stems(X) / number of stems(all species)), where X is a single species (Source: US Forest Service Tree Atlas)

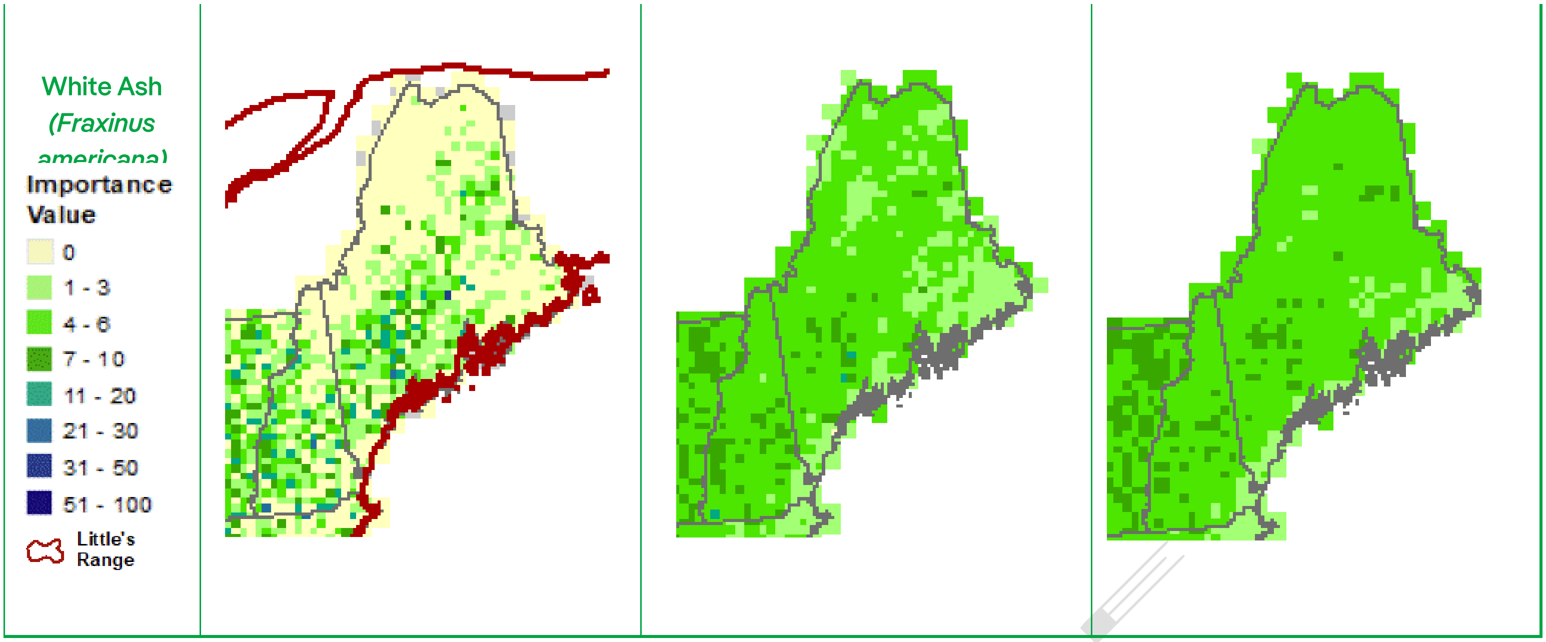
[86] Relative dominance refers to a species' basal area compared to the total basal area of all species within a specific habitat area. See Sambou et al., "Importance Value Index and Species Relative Contribution to Carbon Stocks in Savanna Ecosystems: Implications for Climate Change Mitigation and Forest Management in Patako Forest (Senegal)."

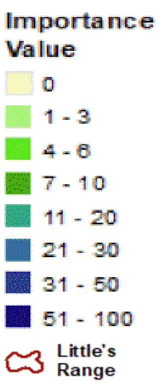
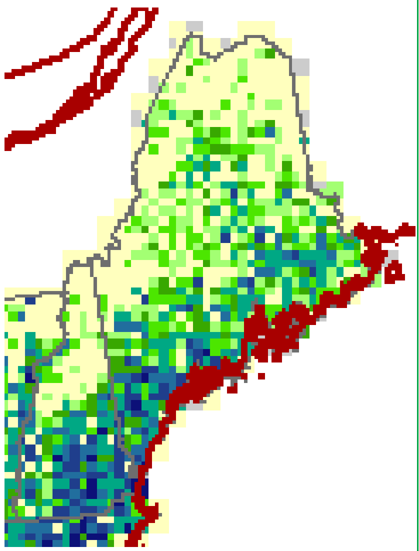
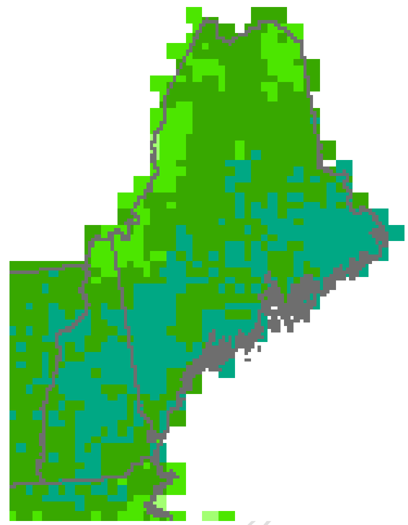
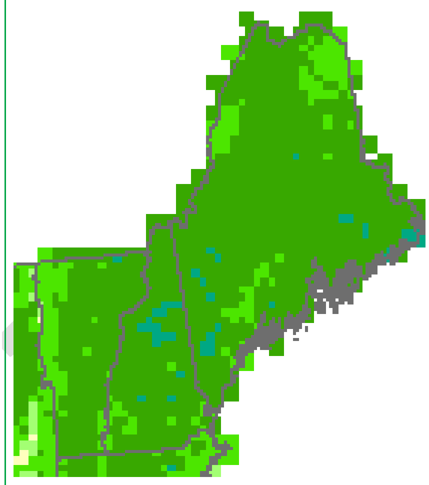
[87] Elbert L. Little developed range boundaries for many tree species across North America and published these ranges in a series of atlases during the 1970's. The ranges integrate field surveys, herbarium records, and expert knowledge to delineate boundaries to encompass tree species' natural distribution. Thus, "Little's Range" represent one estimate of the range boundary for each species. (Source: US Forest Service Tree Atlas)

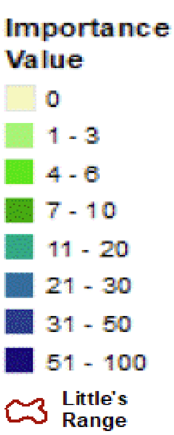
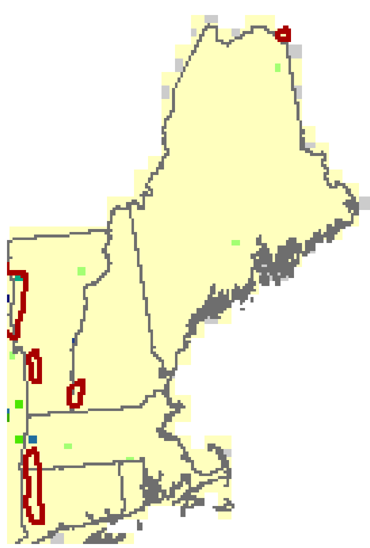
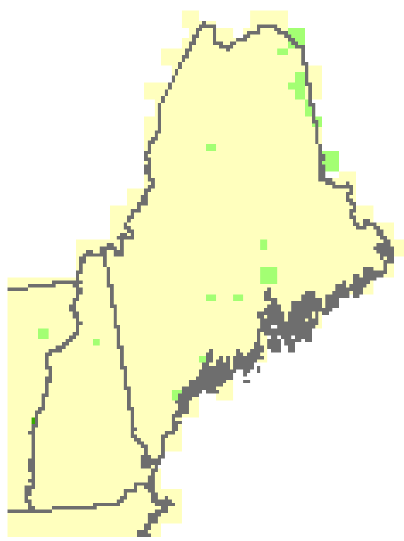
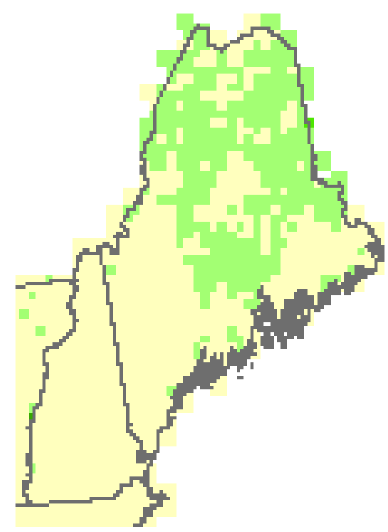
Black Ash *(Fraxinus nigra)* Importance Value 0 1 - 3 4 - 6 7 - 10 11 - 20 21 - 30 31 - 50 51 - 100 Little's Range	 Current habitat within red lines	 	

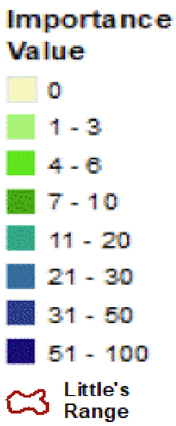
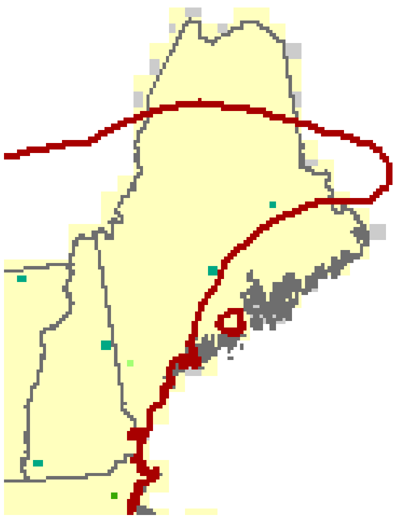
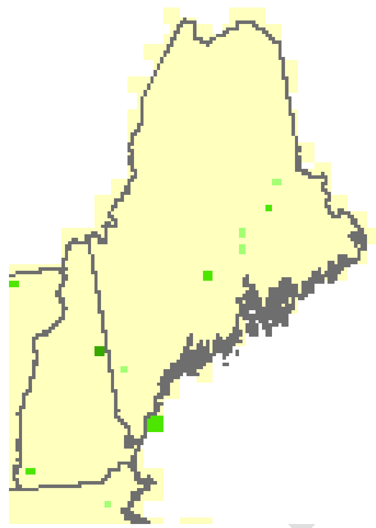
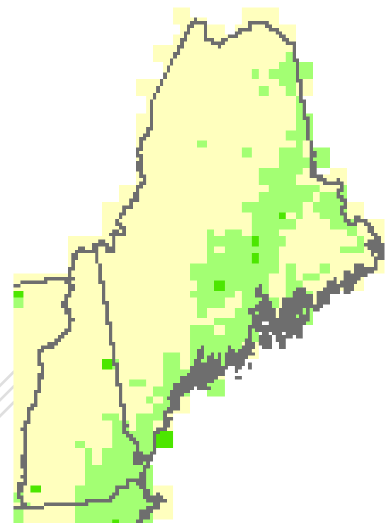
SPECIES	CURRENT RANGE "TREE ABUNDANCE"	"FUTURE HABITAT DISTRIBUTION" RCP 4.5	RCP 8.5
Green Ash *(Fraxinus pennsylvanica)* Importance Value 0 1 - 3 4 - 6 7 - 10 11 - 20 21 - 30 31 - 50 51 - 100 Little's Range			

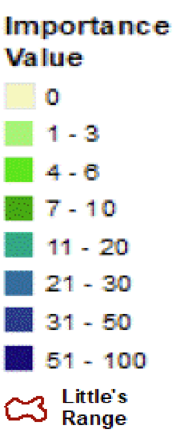
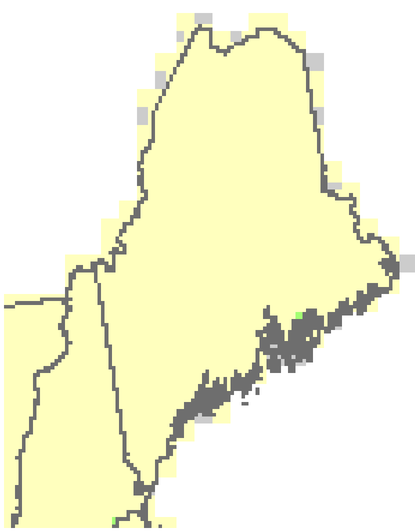
SPECIES	CURRENT RANGE "TREE ABUNDANCE"	"FUTURE HABITAT DISTRIBUTION" RCP 4.5	RCP 8.5

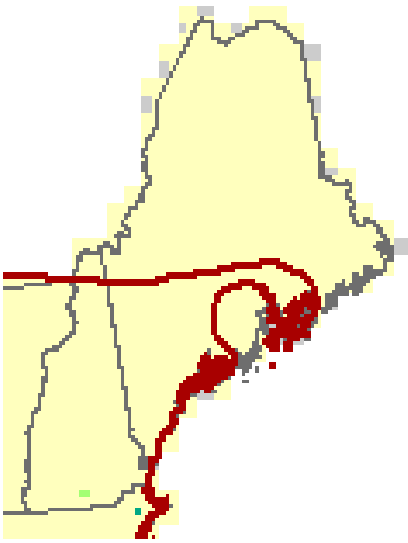
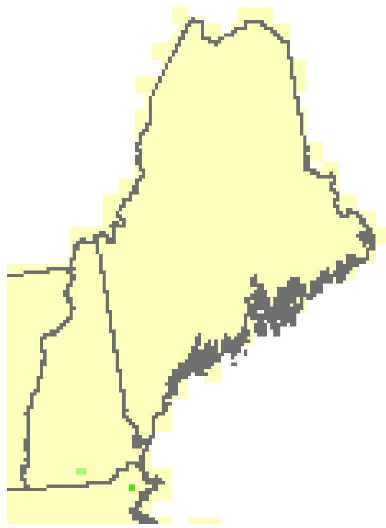
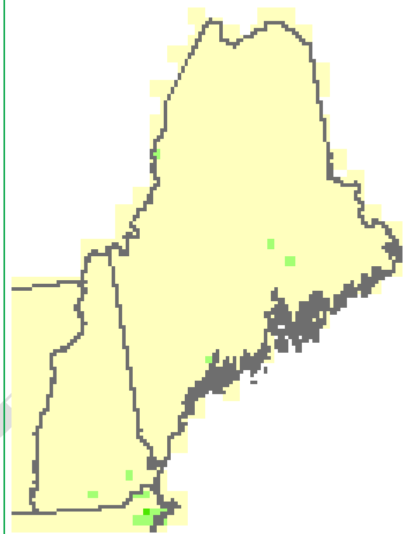

White Ash
(Fraxinus americana)
Importance Value
0
1 - 3
4 - 6
7 - 10
11 - 20
21 - 30
31 - 50
51 - 100
Little's Range

SPECIES	CURRENT RANGE “TREE ABUNDANCE”	“FUTURE HABITAT DISTRIBUTION” RCP 4.5	RCP 8.5
Eastern White Pine *(Pinus strobus)* 			

SPECIES	CURRENT RANGE “TREE ABUNDANCE”	“FUTURE HABITAT DISTRIBUTION” RCP 4.5	RCP 8.5
Boxelder Maple *(Acer negundo)* 			

SPECIES	CURRENT RANGE "TREE ABUNDANCE"	"FUTURE HABITAT DISTRIBUTION" RCP 4.5	 RCP 8.5
Silver Maple *(Acer accharinum)* 			

SPECIES	CURRENT RANGE "TREE ABUNDANCE"	"FUTURE HABITAT DISTRIBUTION" RCP 4.5	 RCP 8.5
Norway Maple *(Acer platanoides)* 		Species is non-native and narrowly distributed. Model reliability too low to project future conditions.	Species is non-native and narrowly distributed. Model reliability too low to project future conditions.

SPECIES	CURRENT RANGE “TREE ABUNDANCE”	“FUTURE HABITAT DISTRIBUTION”	
		RCP 4.5	**RCP 8.5**
Black Willow *(Salix nigra)* **Importance Value** 0 1 - 3 4 - 6 7 - 10 11 - 20 21 - 30 31 - 50 51 - 100 **Little's Range**			

Appendix F. Extended Operational Vulnerability Analysis

9.1 Asset Management

Asset Management Vulnerability Summary

The Asset Management group at CMP is responsible for tracking and evaluating health and risk of failure of substation and transmission assets. Due to the wide range of assets that the group monitors, its processes may be impacted by multiple climate hazards as detailed in table below. While some climate impacts may adversely affect some assets more than others, the wide range of potential impacts from these hazards threaten asset health and may pose issues for existing monitoring, evaluation, and repair/replacement practices.

Summary of Future Vulnerabilities for Asset Management.

Operation	Extreme Heat	Frozen Precipitation	Inland Flooding & Extreme Precipitation	Coastal Flooding	Wildfire & Drought	Extreme Cold	Wind
Asset Management	✓	✓	✓	✓	✓		✓

Climate Challenges

Based on the exposure to climate hazards and sensitivities of the group's practices and processes that were determined through interviews with SMEs, the following climate challenges have been identified :

- While transmission assets are more resilient than many other assets, maintaining the appropriate cadence of transmission line inspections to accommodate the multitude of risks brought on by climate hazards is crucial to maintaining this resilience. Increased flooding and heat risk may pose problems and wear on assets that have not previously occurred. This may include destabilization of structures caused by scouring of terrain around embedded poles caused by repeat or significant flooding events, additional stress on transmission conductors or connecting hardware caused by extreme heat events.
- Woodpeckers have caused substantial issues for wood poles throughout the service territory. The Pileated woodpecker in particular can do significant damage to wooden poles compromising their structural integrity. If left unmitigated, these damaged poles are less resilient to weather events, potentially leading to failure. CMP SMEs have reported increases in woodpecker damage in recent years. While the Pileated Woodpecker is native to Maine, climate change is expected to push populations of woodpeckers from where they currently reside south and west of the state, further north and northeast, increasing their presence in Maine, and potentially increasing the impact caused by this species in throughout the State.[88]
- The role of technology is currently somewhat limited in asset management practices. The group uses SAP to document and track asset condition and the grid is equipped with AMI and Supervisory Control

[88] Walsh, E. S., Vierling, K. T., Strand, E., Bartowitz, K., & Hudiburg, T. W. (2019). Climate change, woodpeckers, and forests: Current trends and future modeling needs. *Ecology and evolution*, *9*(4), 2305–2319. https://doi.org/10.1002/ece3.4876

and Data Acquisition (SCADA), but there are limited uses of advanced technology to model risk, failure trends, and prioritization for intervention. As impacts to asset health are expected to increase, technological insights into the system's health (such as improved testing or increased monitoring) can be an important tool to minimize losses, and prioritize resources.

- Supply chain issues, in particular for substation transformers, pad mount transformers, and distribution poles, pose a risk to the grid as immediate availability of new and replacement equipment can be challenging. As climate change may further threaten supply chains and increase the demand for replacement assets after major events, these supply chain issues may only worsen, leading to equipment shortages and longer lead time for replacements.

Existing Mitigation Measures

- Current standards have been enhanced to implement more resilient assets (e.g., steel transmission poles). As assets are replaced, they utilize the most up to date equipment and are accordingly more resilient.
- The Asset Management group, along with the Advanced Planning group, continue to explore the development of models to generate better failure prediction models and analysis. This analysis, especially when explicitly considering climate impacts, can help prioritize deployment of resources to ensure reliability in the face of increased climate risk.
- Widely deployed SCADA and AMI can provide critical insights into loading and performance of assets, providing important data in Asset Management decision making and operations.
- The design basis for substation peak load is N-1, with some planning studies calling for N-1-1, providing important contingency and resilience in substations.
- While the distribution system is operated radially, there is a concerted effort to add the ability to tie circuits and SCADA reclosers/switches to further isolate outages and improve restoration and backup capabilities.
- Important projects are under way to harden assets to major storms, including upgrading overhead conductors to increase their resilience to contact with vegetation, increasing distribution pole classes, implement steel distribution and transmission poles, and fiberglass crossarms.

Growing Future Resilience

- Increasing the use of satellite imagery, additional sensors, AI, predictive analytics, and other technologies could greatly improve the ability to model climate impacts, in-person inspections, and better allocate resources for repair and replacement.
- While risk scores are currently calculated using in-house tools, use of an asset management software platform that combines inspection data to calculate risk of failure and provide additional system insights could greatly aid the efficiency and decision-making abilities, which will becoming increasingly important as climate change impacts may lead to increased asset damage.
- Using climate projections to prioritize areas of the transmission system to conduct additional inspections based on asset vulnerability, could assist in identifying assets that may fail between existing inspection cycles.
- Reviewing and potentially increasing spare asset inventories may enhance recovery from climate impacts, especially large regional events that may further constrain the market for transformers and other high-demand assets.

9.2 Facility Ratings

Facility Ratings Vulnerability Summary

The Ratings and Modeling group at CMP determines the ratings of all CMP transmission lines, transformers, and all other devices connected in series to the transmission system. Facility ratings refer to the maximum operating limit that an electrical asset can safely handle (expressed in power units, such as voltage or current). Extreme Heat poses the largest risk to facility ratings compared to many other hazards. High temperatures can limit capacity of assets, cause wear and shorten lifespans, and in extreme circumstances lead to outages through line sag/clearance violations, load shedding, or equipment failure.

Summary of Future Vulnerabilities for Facility Ratings.

Operation	Extreme Heat	Frozen Precipitation	Inland Flooding & Extreme Precipitation	Coastal Flooding	Wildfire & Drought	Extreme Cold	Wind
Facility Ratings	✓						

Climate Challenges

Based on the exposure to climate hazards and sensitivities of the group's practices and processes that were determined through interviews with SMEs, the following climate challenges have been identified :

- Historically, CMP has calculated eight seasonal ratings, providing summer and winter ratings. Summer ratings assume 100°F (38°C) ambient temperatures and winter ratings assume 50°F (10°C) ambient temperatures for Transmission line conductors. While these ratings have historically been reflective of the temperatures in the service area, projected warming may reduce the conductor capability to handle these ratings due to strain on transmission conductors. However, much of this risk is mitigated as CMP is currently in the process of changing how they rate transmission assets to provide Ambient Adjusted Ratings as required in FERC Order 881.
- While Maine's temperature increases are projected to be somewhat limited compared to other parts of the country, warming by 2050 in the Alfred region may cause some transmission assets with lower temperature ratings to be limited in their ability to have their ratings adequately adjusted to provide the capacity to meet warming conditions, particularly during extreme heat events (e.g., intense heat waves). By 2070, additional parts of the service territory may also begin to experience problematic levels of warming, further increasing this risk.
- Much of CMP's current efforts to introduce ambient adjusted ratings focus on transmission facilities. As the potential heat impacts expand to other areas of the system it may become beneficial to include other assets in this type of program.
- Implementation of new ambient adjusted ratings requires new IT infrastructure and integration between CMP's SCADA system, weather data, CMP operations, and ISO New England. As this integration continues, it is critical that all groups involved continue to coordinate to ensure that the final product is reflective of best practices established by the transmission ratings group and that future changes can easily be implemented.

Existing Mitigation Measures

- FERC Order 881 requires utilities to implement Ambient Adjusted Ratings and encourage the adoption of Dynamic Line Ratings, which will lead to adjustments in line ratings in near real-time to reflect current temperature conditions. CMP is in the process of implementing a system to be compliant with this order and is estimated to be operational in 2025. Once complete, Ambient Adjusted Ratings will help mitigate some of the risks of extreme temperatures adversely impacting transmission conductors and other ambient adjusted rated assets. Weather data will also be highly regionalized to ensure that different parts of the system are rated to the conditions they are currently exposed to.
- In addition to using Ambient Adjusted Ratings, CMP will be calculating new ratings based on ISO-NE PP7 ambient temperatures to be utilize in the event that real-time temperature and loading information is unavailable or for use during long-term planning studies. This system moves away from the winter and summer ratings and utilizes a twelve-month rating system to provide more accurate and responsive ambient temperature assumptions.

Growing Future Resilience

- Incorporating Dynamic Line Ratings in addition to Ambient Adjusted Ratings can greatly increase resilience to extreme heat as well as extreme winds. Dynamic Line Ratings allow for greater insight into real-time conditions of an asset (e.g., line sag), potentially allowing for assets to generally be run at greater capacities and more accurately adjusted to the increasing variability of weather patterns and extreme weather events caused by climate change.
- Incorporating climate projections into long-term transmission planning can ensure that hazards continue to be mitigated in future planning as well as present day in the facility rating practices.
- Targeting older assets with lower nameplate temperature ratings for upgrading and/or increasing the capacity of highly critical lines spans can greatly improve the system's capacity and its ability to respond to heat.
- Ensuring dynamic rating practices extend to as many transmission assets as possible (e.g., transformers) can greatly increase the resilience of all transmission assets to heat and other climate impacts.

9.3 Load Forecasting

Load Forecasting Vulnerability Summary

The Load Forecasting group at CMP is responsible for projecting peak and base loading of the CMP system. While base loading may increase with electrification of heating and transportation, population growth, and emerging high-usage customers, peak loading will be also be significantly impacted by climate change. Customer demand is heavily dependent on ambient temperature and the effect on the heating and cooling of habitable spaces; extreme heat is expected to pose a vulnerability to the group's processes (see Table 8). Projected increases in high heat days, especially in the Alfred service area, will likely lead over time to increased use of energy for cooling and may challenge a lot of current assumptions and practices. If forecasting models do not account for future temperatures, incorrect forecasting can result in inefficient grid operations, unnecessary costs, and in extreme instances, outages.

Summary of Future Vulnerabilities for Load Forecasting.

Operation	Extreme Heat	Frozen Precipitation	Inland Flooding & Extreme Precipitation	Coastal Flooding	Wildfire & Drought	Extreme Cold	Wind
Load Forecasting	✓						

Climate Challenges

Based on the exposure to climate hazards and sensitivities of the group's practices and processes that were determined through interviews with SMEs, the following climate challenges have been identified :

- Increased temperatures may lead to more heating degree days and hotter summer months, leading to increased usage of air conditioning. Only 70% of Mainers currently have air conditioning (which is below the national average), and most have window air conditioning units, which are far less efficient than heat pumps.[89] Air conditioning usage is expected to rise as temperatures increase, especially in summer months, resulting in an increase in demand and an emergence of a significant summer peak in parts of the service territory. This will be further exacerbated by a shrinking diurnal temperature range, leading to higher demand in summer evenings as well.
- The current load forecasting process utilizes a weather dataset to forecast peak loads based on a rolling thirty-year sample of design weather. This rolling sample includes both present day data as well as historical trends. While the incorporation of present-day/recent data can capture recent warming and historic climatic shifts, because the dataset does not include forward-looking temperature projections, it may fail to adequately capture increases in temperature, particularly as more severe deviations from historical trends occur.
- In addition to general increases in average and maximum temperatures, climate change is projected to also increase weather variability, including increased heatwaves, sudden unexpected cold snaps (from the weakening of the polar jet stream and polar vortex)[90], and greater variability of unseasonable temperatures (sudden heating degree days in winter months). These unexpected and more variable weather events are difficult to model, especially when relying on historical data, and may result in deviations from the forecasted assumptions.
- While not directly related to the impacts of climate change, efforts to reduce GHG emissions in the heating and transportation sector through electrification are poised to have significant impacts to load forecasts, and their development.
- As load forecasting becomes more complex and data-intensive due to changes in technology and customer behavior; current staffing and skillsets will be challenged to meet the needs of the evolving nature of the group. Additional data scientists, seasoned forecasters, and staff with knowledge of climate science may be needed to adapt to changes in the practice and challenges posed to load forecasting.

[89] The Maine Monitor. (July 9, 2023). *As Maine sees more extreme heat, air conditioning is more than just a luxury*. Retrieved November 21, 2024, from https://themainemonitor.org/as-maine-sees-more-extreme-heat-air-conditioning-is-more-than-just-a-luxury/
[90] Massachusetts Institute of Technology. (May 21, 2024). *The polar jet stream and the polar vortex*. MIT Climate Portal. Retrieved November 21, 2024 from https://climate.mit.edu/explainers/polar-jet-stream-and-polar-vortex

Existing Mitigation Measures

- CMP currently uses a data-intensive and comprehensive load forecasting model that regresses weather data across different probabilities. This model incorporates present day/recent weather data on a rolling basis in addition to historical data, allowing CMP to be more reactive than some peer utilities and incorporate recent climatic shifts into their forecasting.
- The CMP load forecasting group currently can adjust their forecasting models and practices with relative ease, which allows for a nimble response and more accurate forecasts as new data, best practices, and forward-looking projections become available.
- The CMP grid has widespread AMI and SCADA. Both technologies are critical to accurately forecast load and will become increasingly important to address changes in temperature brought on by climate change.
- The load forecasting group is currently piloting a bottom-up area forecasting approach that examines customer mix, billing data, and electric vehicle usage among other inputs, that will help inform more accurate forecasting and take into account shifts in demand caused by electrification and changes in the customer base.

Growing Future Resilience

- Directly incorporating the use of future temperature projections into load forecasting model can greatly increase the group's ability to accurately forecast load amidst changes in temperature related to climate change.
- Adjusting asset ratings and equipment standards with the use of climate projections to accommodate higher loading associated with temperature increases.
- Additional staffing of experienced forecasters and other professionals with data science and climate science backgrounds can assist the load forecasting team in continuing to adjust their procedures to utilize big data, adopt best practices, and incorporate climate science into forecasting models.
- Continuing to find opportunities to integrate technology, such as additional sensors or AI, can also be useful in maintaining a dynamic and adaptive load forecasting practice that is most adaptable to the impacts of climate change.

9.4 Vegetation Management

Vegetation Management Vulnerability Summary

The Vegetation Management group at CMP is responsible for monitoring and maintaining vegetation along the CMP Right-of-Way (ROW). Vegetation coming into contact with assets and causing damage, particularly during extreme weather events, is one of the leading causes of outages for CMP and utilities nationwide. Climate change is projected to cause increases in severe storms/strong winds, flooding, and droughts, all of which may increase the likelihood or impact of vegetation coming into contact with lines and other grid assets. Climate change is also projected to change vegetation growth cycles and introduce invasive species which can lead to additional hazard trees, or in some cases, increased vegetation. A wide range of climate hazards can interact with vegetation and create challenges for the vegetation management group. As such, vegetation management is vulnerable to most climate hazards that the service territory is exposed to (see Table 9).

Summary of Future Vulnerabilities for Vegetation Management.

Operation	Extreme Heat	Frozen Precipitation	Inland Flooding & Extreme Precipitation	Coastal Flooding	Wildfire & Drought	Extreme Cold	Wind
Vegetation Management	✓ ✓ ✓		✓	✓		✓	

Climate Challenges

Based on the exposure to climate hazards and sensitivities of the group's practices and processes that were determined through interviews with SMEs, the following climate challenges have been identified :

- Extreme storms are projected to increase in frequency and magnitude due to climate change. These extreme storms have the potential to cause widespread outages from vegetation coming into contact with grid assets. Vegetation management will be an increasingly important component in mitigating the impacts of extreme weather events.
- Changes in the climate, especially in temperature, are expected to alter vegetation growth response. The vegetation management group has already observed some of these changes with faster, denser growth in recent years. These changes may result in increased encroachments of ROWs and the need for additional staffing and resources
- Projected increases in extreme precipitation may cause additional stress on ecosystems, leading to increased hazard trees. Additionally, droughts can weaken tree roots, leaving them more vulnerable to toppling over during heavy winds, floods, and storms. CMP vegetation management has already observed some of these impacts. Though extreme precipitation is projected to increase, summertime drought conditions are projected to be similar to today's conditions. However, the analysis masks the potential year-to-year variability which could increase.
- Projected increases in coastal flood risk caused by increased coastal storms and sea level rise can also pose a threat to coastal vegetation. Standing saline water can damage root systems and weaken soils; storm surge can also reach levels of force high enough to topple trees.
- More erratic winter weather (e.g., unseasonably warm days, late frosts, etc.) may also increase due to climate change and can result in stress to ecosystems, vegetation, and lead to tree damage.
- Changes in climate can create conditions where invasive pest species can thrive in areas where they previously could not have. This may result in the rise of existing invasive species or the introduction of new additional invasive species to the service territory. The vegetation management group has already observed increases in the Spongy Moth, Brown Tail Moth, and Emerald Ash Borer, all of which impact tree health and increase the amount of dead or hazard trees. In addition, insects such as the Spotted Lanternfly may also pose significant implications in the near term.
- Invasive plant species, such as the Asiatic Bittersweet Vine, have also increased in prevalence in the service territory, and can pose access issues for vegetation management crews because of their dense growth, as well as their ability to weaken and weigh-down trees, increasing their potential to topple during storms. These invasive species, as well as others, such as Kudzu (Pueraria montana), and Mile-a-minute vine (Persicaria perfoliate), which are now found as far north as New York, and Massachusetts respectively, and are projected to continue to increase and move northward with climate change.

- Much of Maine is privately owned and many trees that abut the ROW and have historically caused issues for CMP are on private property. While some of these properties have easements, many do not, and many trees that have historically caused outages are located on property where CMP does not have the legal purview to remove them without the property owner's consent. The resulting lack of access can greatly hinder vegetation management efforts and will become even more problematic as vegetation management needs are projected to grow with climate change.
- Parts of the service territory, particularly the northeast region have historically been difficult to access to perform restoration or vegetation management activities because of the area's formidable terrain. Projected increases in extreme weather due to climate change may result in increased outages, especially in this region, making the need for managing the northeast region's vegetation even more critical.

Existing Mitigation Measures

- CMP currently utilizes ground-to-sky trimming, which provides additional clearances and reduces the risk of vegetation contact with grid assets.
- CMP utilizes a database to track vegetation management activities, including planned and processed trimming work, allowing for efficient management of activities and trimming cycles.
- CMP currently uses LiDAR to assist with assessing trimming needs.
- CMP, like most electric utilities in the U.S., relies on contracted arborists to carry out most trimming work. CMP has established good relationships with several contracting companies that have performed reliably.
- CMP has both formal and informal relationships with several scientific and academic institutions in Maine that provide insights to assist in vegetation management, including the Entomology Division of the Maine Forest Service.
- While wildfires have not historically been a large issue in the area, the vegetation management group currently removes dead trees and trims brush to provide a level of mitigation to wildfire risk.

Growing Future Resilience

- As vegetation growing cycles change from increasing temperatures and potential vegetation risk grows from climate change-related increases in wind, flooding, and wildfire, increased frequency of trimming cycles and/or augmenting with condition-based trimming may help to better control growth into the ROW and prevent future outages.
- As climate risks increase, clearances may need to be adjusted to account for changes in growth cycles and increased intensity and frequency of storms.
- As the needs of vegetation management increase due to climate change, ensuring adequate staffing and funding will be critical for maintaining adequate operations and containing vegetation risks.
- The use of technology can greatly assist in vegetation management practices, especially as the practice becomes more important in the face of climate change. The use of AI and risk analysis software can greatly aid efforts in identifying and prioritizing high-risk areas for trimming.
- Directly incorporating climate projections into vegetation management planning, budgeting, and operations can ensure the group is prepared to tackle the changes associated with climate impacts and proactively address emerging risks.

9.5 Reliability Planning

Reliability Planning Vulnerability Summary

Reliability Planning spans across several disciplines at CMP, including Distribution Operations and Operational Performance. All involved staff strive to maintain and improve the system's performance and the utility's reliability metrics. Operational Performance staff analyze the data associated with the system's performance, helping CMP interpret outage trends, and providing valuable data-driven insights into how asset performance, investment, and capital projects impact reliability. Staff focused on the design and operation of the distribution system rely on this data to prioritize reliability investments. Overall, climate change is expected to greatly impact reliability as increasingly severe and frequent hazards may strain the system and are expected to increase the frequency of outages. These changes may pose a challenge to current assumptions in reliability planning and will require the creation of additional insights to inform climate-related decision making. Because of the wide range of assets that the group monitors, reliability planning is exposed to the impacts of multiple climate hazards (see Table 1 below).

Summary of Future Vulnerabilities for Reliability Planning

Operation	Extreme Heat	Frozen Precipitation	Inland Flooding & Extreme Precipitation	Coastal Flooding	Wildfire & Drought	Extreme Cold	Wind
Reliability Planning	✓	✓	✓	✓	✓		✓

Climate Challenges

Based on the exposure to climate hazards and sensitivities of the group's practices and processes that were determined through interviews with SMEs, the following climate challenges have been identified :

- Historically, storms have been the leading cause of outages at CMP. Climate change is projected to increase the frequency and severity of storms, likely resulting in an increase in the magnitude and frequency of outages and impacting the reliability of the system. Overall, climate change is projected to lead to an increase of both short-term and long duration outages, causing reliability issues for CMP, and potentially threaten the utility's ability to meet their regulatory reliability performance requirements.
- The threat of potentially emerging hazards, such as heat and flooding, may cause new impacts to reliability that have not previously been experienced, particularly by late century. Currently, reliability planning only evaluates historical hazards and outages. Not adequately modeling these potential future impacts in order to inform resilience planning and capital investment, may leave CMP unprepared to mitigate their impacts.
- Electrification will both cause challenges for reliability and increase the importance of maintaining a reliable system for CMP's customers. Increases in demand may come into conflict with decreases in capacity caused by high heat events, potentially leading to reliability issues. Increased dependence on electricity that is associated with electrification will also make maintaining reliability standards even more important.

- While CMP has taken steps to improve the resiliency and reliability of its systems through storm hardening, the impacts of climate change are projected to impact the system in a way that will require a multi-hazard holistic approach in order to maintain reliability standards.
- Much of CMP's service territory is both heavily forested and equipment often located in easements on privately owned land. At times existing easements can make performing appropriate reliability improvements or vegetation management activities challenging without permission from property owners. These conditions can often constrain the implementation of reliability improvements, limiting the potential resilience of the CMP system.

Existing Mitigation Measures

- CMP currently maintains an accurate and robust outage database. This database is highly scrutinized and routinely reviewed for accuracy. Access to accurate outage data is essential to understanding and tracking reliability trends and planning for improvements.
- CMP utilizes a robust data analytics program in the Operational Performance group. This group analyzes outage trends and produces analysis that helps to identify problematic hazards and parts of the system. As part of this program, CMP also analyzes trends between different types of weather and performance/reliability. Understanding these relationships will become even more crucial to understand how changes in extreme weather caused by climate change will impact the system.
- Reliability analysis is closely tied to the operations and decision making of other parts of the CMP system. CMP currently uses reliability data to inform capital planning, allowing the utility to target circuits that are particularly problematic, or tailoring hardening interventions to the most impactful hazards. Other operational groups, such as Asset Management, often rely on this reliability data to inform their decision making.
- The Operational Performance group continues to embrace the role of new technology to enhance their capabilities, including the use of internally developed AI capabilities. Technology will be increasingly important to confront new and growing risks associated with climate change.
- CMP was recently awarded a $30 million Department of Energy Grid Resilience and Innovation Partnerships (GRIP) grant to improve reliability in disadvantaged communities by bolstering system resilience through smart grid technologies, such as advanced grid restoration, sequential reclosing, and SCADA[91]. These investments are expected to lessen storm impacts in communities that could suffer disproportionately from outages.
- The impacts of climate change are likely to exacerbate the existing vulnerabilities of Maine's communities. Climate-related outages can further amplify these disparities. CMP currently considers customer characteristics (e.g., disadvantaged communities, Lifeline customers, etc.) as part of their reliability planning investment process.

Growing Future Resilience

- Coordinating closely with customer communications and outreach departments at CMP can help better target reliability improvements to vulnerable communities and also help customers understand how they can help prevent outages (e.g., reducing energy usage on peak demand days to avoid load shedding), which will become increasingly important as outage-risk is projected to increase from the impacts of climate change.

[91] As of the publication of this report this awarded grant is on hold due to the change in presidential administration.

- The implementation of additional resilience measures, beyond storm hardening, to address the most pressing climate hazards, including emerging ones, will be crucial to maintain and improve reliability. These measures should move beyond traditional storm hardening to include a holistic, multi-hazard approach that helps mitigate the impacts of climate change to infrastructure, operations, staff, and customers.
- Use of additional sensors to provide increased insights into system loading, weather conditions, and asset conditions can further enhance reliability planning practices. These sensors introduce additional datasets that can further inform reliability analysis and decision making.
- Implementing the use of climate projections paired with historical weather and outage data can be used to model climate impacts on reliability and assist in the planning of resilience measures.

9.6 Workforce Safety

Workforce Safety Vulnerability Summary

The workforce safety group at CMP determines and provides policies, procedures, trainings, and evaluations to ensure that CMP maintains safe working conditions for its staff. As multiple hazards intensify across the service territory, the safety of CMP's staff, especially those in the field, is expected to be challenged. If workforce safety standards and practices fail to adapt to the heightening and diversifying threat landscape, worker injury may increase. All climate hazards can pose a threat to worker safety, but not all hazards are projected to intensify; extreme heat, inland flooding and extreme precipitation, coastal flooding, and wildfire and drought are expected to be increasingly impactful to workforce safety. While not included in the quantitative analysis potion of this study, extreme storms and associated high winds, are expected to increase in the service area due to climate change and will also pose a risk to workforce safety.

Summary of Increasing Vulnerabilities for Workforce Safety

Operation	Extreme Heat	Frozen Precipitation	Inland Flooding & Extreme Precipitation	Coastal Flooding	Wildfire & Drought	Extreme Cold	Wind
Workforce Safety	✓		✓	✓	✓		✓

Climate Challenges

Based on the exposure to climate hazards and sensitivities of the group's practices and processes that were determined through interviews with SMEs, the following climate challenges have been identified :

- Climate change is projected to lead to a changing threat landscape, with the intensification of existing hazards (i.e., storms and floods), the emergence of new hazards (i.e., heat, which has historically rarely been extreme enough to cause impacts in much of the service territory), and the lessening of risk posed by other hazards that have historically caused safety issues (i.e., extreme cold and frozen precipitation). Heat poses a particularly serious risk to worker safety. The Occupational Health and Safety Administration (OSHA) considers wet bulb globe temperatures of 77°F and higher dangerous for unacclimatized workers performing outdoor strenuous work.[92] Without proper training to understand, identify, and mitigate heat stress, workers may experience heat exhaustion or heat stroke. Because of a lack of experience due to limited exposure to extreme heat in the service area, this risk may be

[92] Occupational Safety and Health Administration. (2024). *Heat Hazard Recognition*. Retrieved from https://www.osha.gov/heat-exposure/hazards.

particularly acute. If not accounted for, these shifts in hazards and associated risks may leave crews unprepared with a lack of appropriate equipment, technology, training, or PPE, or may lead to misallocations of resources and time to prepare for hazards that no longer pose a major threat.

- CMP relies on contracted labor to perform some of its field work, including power restoration and vegetation management. Although CMP currently provides contractors with safety standards/information and gives contractors the ability to determine if conditions are too unsafe to perform work, it will be increasingly critical to ensure contracted labor is informed of changing and intensifying risks and adhere to updated safety standards to reduce the risk of safety incidents and potential liability.
- While CMP gives its workers the ability to determine unsafe conditions, these judgements are made largely using low-tech devices (e.g., weather apps on smart phones). Site-specific real-time information will be increasingly critical to ensure staff are prepared to make informed decisions regarding their safety while in the field.
- As hazards intensify in frequency, duration, and severity, there may be more instances where work needs to be stopped to ensure the safety of staff. This may lead to delays in capital project work, routine maintenance and inspections, as well as increase response times and delayed restoration efforts.
- Climate change-related renewable energy targets and the associated proliferation of renewable energy (e.g., utility scale solar) that is fed directly into the distribution grid can pose safety issues to workers. CMP staff have been injured when doing work on lines fed by these renewable sites because of amperages that exceed safe working conditions.

Existing Mitigation Measures

- CMP currently trains its workers to understand and take protective action for a variety of hazards, including heat, wind/storms, and frozen precipitation and ice, among others. Workers are continuously trained and retrained and safety procedures are standardized in a Handbook that is reviewed periodically.
- Workers are currently empowered to not work in conditions they feel are unsafe and receive training to help inform these determinations. Conditions are also monitored by CMP's area command system, especially during storms. When conditions are too unsafe CMP will issue an order from the area command to withdraw workers in the field.
- CMP utilizes a variety of PPE to help mitigate the impacts from a variety of hazards to its workforce. This includes but is not limited to life preservers, light weight clothing, fire retardant clothing, hard hats, and insulated winter clothing.
- CMP currently utilizes multiple measures to mitigate heat impacts to workers, including ensuring all trucks are equipped with working air conditioners, the use of lighter weight clothing during hot weather days, supplying workers with water and electrolyte drinks, and encouraging field workers to monitor temperatures via their smart phones.
- The workforce safety division utilizes the software platform EHS360 to report, track, and monitor safety events, including near misses. The platform allows for streamlined organization of safety procedures and the implementation of lessons learned.
- Current procedure requires that all safety incidents, including near misses, must be reported within 24 hours of their occurrence. Safety managers determine which reports will receive a full analysis that includes incident details, maps, causes, corrective actions, takeaways, and lessons learned. This practice enables safety managers to continuously examine how safety can be improved.

- Safety is embedded in CMP's culture, with safety topics and reminders being brought up on daily calls and meetings, including emerging issues, such as heat.

Growing Future Resilience

- Implementing climate projections into safety planning and new standards to address emerging hazards before they become problematic would help ensure that new risks are handled proactively and not reactively. This is especially important for heat risk and increasingly severe storms and flooding.
- Ensuring the use of additional and the best available PPE, such as fire-resistant cooling vests, can help provide workers with additional protection to intensifying and emerging risks.
- The use of technology, including sensors to monitor air quality and heat, can help more accurately inform safety decision making by workers in the field.
- Continuing to ensure that contracted laborers undergo the same safety training as CMP staff and that the training also includes consideration of climate risks, can greatly increase the safety and performance of contractors.
- Incorporating emerging climate data and changing conditions into safety procedures review and planning will help ensure that as CMP continues to evolve in its understanding of climate risk, the workforce safety standards evolve with it.
- Collaborate with CMP staff unions to voluntarily or contractually implement resilience/climate-oriented best practices (e.g., increased uniformed budgets for additional PPE, heat-related mandatory breaks, use of monitors/sensors to enhance hazard safety assessment, etc.).

9.7 Emergency Management

Emergency Management Vulnerability Summary

The Emergency Management group at CMP is responsible for coordinating emergency preparedness and responses to extreme weather and other emergency events. The group has historically been most practiced in responding to winter and convective storms. As extreme weather events become more frequent and intense, emergency management may become strained to respond to a wide array of intense hazards, while simultaneously becoming more critical to ensure that the system is able to triage outage events and restore power quickly and safely. Because a wide variety of extreme events can cause outages and/or emergency conditions, the emergency management group is vulnerable to all hazards that the service territory is exposed to (see Table 1).

Summary of Vulnerabilities for Emergency Management.

Operation	Extreme Heat	Frozen Precipitation	Inland Flooding & Extreme Precipitation	Coastal Flooding	Wildfire & Drought	Extreme Cold	Wind
Emergency Management	✓	✓	✓	✓	✓		✓

Climate Challenges

Based on the exposure to climate hazards and sensitivity of the group's practices and processes that were determined through interviews with SMEs, the following climate challenges have been identified :

- Climate hazard induced emergency events are projected to increase in frequency and magnitude, increasing the operating costs of response teams on labor, private contractors, fuel, supplies, and spare parts.
- Increasing climate hazard-induced emergency events will lead to more emergency activations, which often require staff to assume storm roles and/or work extended hours. Storm-intensive winters have led to staff fatigue in the past. If emergency activations increase, particularly if they are year-round and are no longer seasonal, staff fatigue may worsen, leading to burnout, human-error/clouded decision-making ability, and retention issues. Frequent activations of storm roles may also limit staff capacity to perform their normal functions, leading to impacts on normal operations and long-term planning.
- Extreme weather events may increase CMP's reliance on mutual assistance. In severe circumstances, mutual assistance may become limited if the hazard impacts a larger region. Additionally, remote parts of CMP's service area may experience lengthened response times of mutual aid.
- Contractors are currently able to quickly meet a majority of CMP's emergency response needs, but response times are sometimes a challenge. As extreme weather events continue to increase the demand for contracted line workers, response times, and labor availability may become further strained.
- Potentially more frequent flooding, storms, and downed trees present hazardous conditions and may limit access for crews to restore power. These hazards, as well as extreme heat, can lead to safety risk for crews and could require new or additional PPE, safety procedures, and in extreme instances, may delay response/restoration times if conditions are unsafe to work in.
- Current emergency preparedness procedures are informed by past events. As climate change is projected to bring unprecedented extreme weather events, relying on historical experience may not adequately account for preparation activities necessary for future extreme weather events.
- Key lessons learned and institutional knowledge are critical to developing well-coordinated responses. The ability to develop formalized knowledge and lessons learned after major events may constrained as climate hazards become more extreme and frequent. These challenges can be compounded by staff retirement and the associated loss of institutional knowledge.
- Increasingly, extreme events have at times led to tensioned encounters between field workers and customers. CMP has already experienced these encounters, as extreme weather becomes more frequent and severe these encounters may increase.

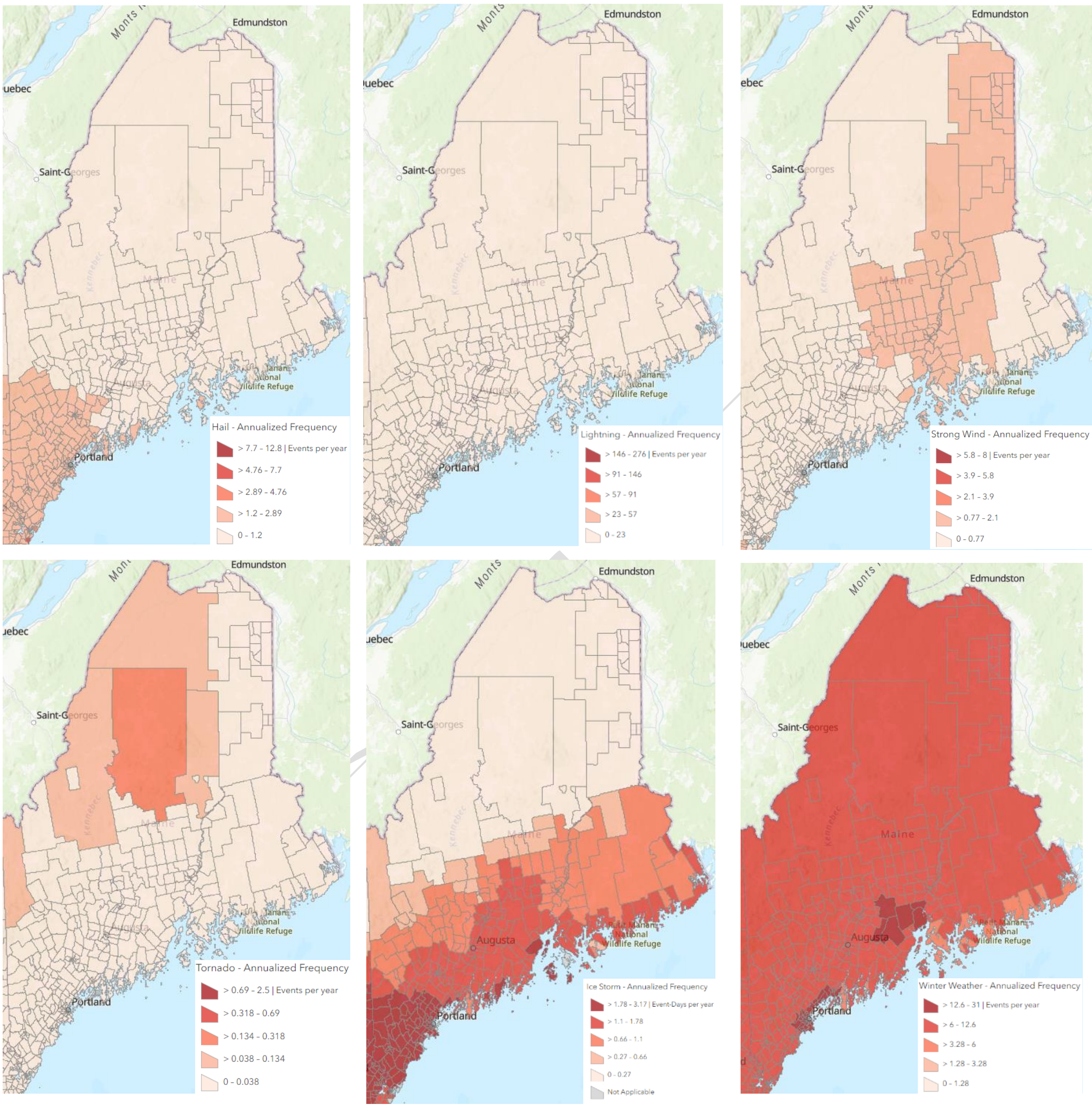
Existing Mitigation Measures

- CMP pre-stages crews (both contracted and CMP staff) and equipment, utilizing assistance from other Avangrid-owned utilities (NYSEG, RG&E, and UI) to aid in their response to storm events. If mutual aid is needed, CMP belongs to the Northeast Mutual Assistance Group (NEMAG).
- CMP identifies sensitive and critical customers for preparedness, response, and recovery activities.
- CMP currently has multiple Emergency Operation Centers (EOC) and is able to coordinate a response even if an EOC is taken offline.
- CMP is working to create an all-hazards response plan to expand their current emergency planning efforts to be inclusive and coordinated instead of focused on singular hazards scenario planning.
- CMP participates in tabletop emergency planning exercises with Maine state agencies, select municipalities, and other key stakeholders.

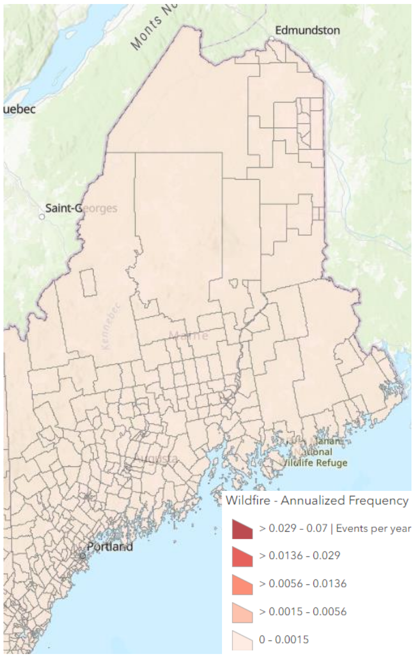
Growing Future Resilience

- Ensure adequate budgeting and staffing to avoid staff burnout, fatigue, shortages, and cost overruns due to the projected increasingly frequent and severe extreme weather events.
- Incorporate climate projections into emergency preparedness plans and tabletop exercises to ensure that scenario planning includes both historical events as well as future risks.
- Ensure that Incident Command Center (ICS) teams are 2-3 layers deep and teams have adequate training and current contact information and protocols when activations are needed to ensure sufficient levels of preparedness to confront increasingly large and frequent hazard events.
- Continue to identify and source additional contracted staff prior to extreme weather events to reduce response times, as well as identify and have Memorandums of Understanding (MOU) or contracts in place with vendors for supplies, accommodations, and other resources needed to support internal and mutual aid staff for frequent and increasingly significant incidents.
- Formalize a practice of documenting after-action reports to analyze and formalize lessons learned and best practices to inform future emergency preparedness and response procedures and continue to adapt to the growing risks of climate change.
- Continue to invest in enhanced customer outreach and communication capacity, including investing in outreach technologies and culturally knowledgeable stakeholder engagement specialists to ensure customers understand outage risks, take proactive steps to protect themselves during an outage, and that vulnerable populations and critical customers are given the necessary support to minimize adverse impacts, especially in the face of increasing outage risks that may be caused by climate change.
- Evaluate the use of technology to coordinate emergency responses, streamline internal communication, and allocate resources. This can include but is not limited to use of 5G and satellite telecommunications, mass notification software, incident reporting tools, computer-based scenario planning, and AI and predictive analytics.

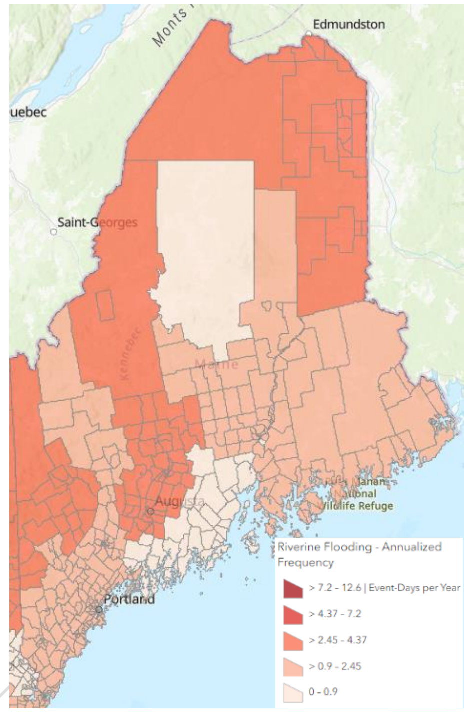
Appendix G. FEMA National Risk Index Images



Annualized frequency of impactful storm-related hazards (clockwise from top left): hail, lightning, strong winds, tornados, ice storms, and winter weather. (FEMA's National Risk Index)



Annualized Frequency of Impactful Wildfires at the census tract
Source: FEMA's National Risk Index



Frequency of impactful riverine flooding.
Source: FEMA's National Risk Index