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Climate Adaptation Approaches for Water and Electric Utilities

A compendium of existing strategies in a changing climate

January 2025

Isabel Van Dyke
Kamila Kazimierczuk
Alan Cooke
Rebecca Tapio
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U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
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Summary

Climate change is irrevocably impacting the power and water industries, straining the resources and operational capabilities of electricity and water providers, exposing critical infrastructure to more intense events, and driving events that deprive customers of electric and water services in some cases for periods extending up to several weeks. Climate drivers, such as extreme weather events, temperature increases, and sea level rise, expose electric and water systems to a variety of risks. Because the exact future state of the climate is still uncertain, utilities must be prepared to adapt to a diverse range of future climate scenarios and implement forward-thinking preventive measures. **This report explores the ways in which power and water utilities are adapting to climate change, highlights areas of opportunity to develop harmonized strategies between sectors, and touches on how existing strategies can advance equitable outcomes for climate-vulnerable communities.**

As a compendium of climate strategies, this report provides a collection of reference points for water and electric utilities seeking to increase their adaptive capacity within their respective communities. It is meant to serve as a repository of examples and resources for capacity building rather than as prescriptive guidance on how to plan for climate change.

This compendium of emerging and established practices to address climate risk to the electric utility industry is largely based on climate vulnerability assessments and associated plans to mitigate vulnerabilities, storm protection plans, and wildfire mitigation plans. For water utilities, many adaptation strategies were identified through the Environmental Protection Agency's Creating Resilient Water Utilities program. Other planning documents that take into consideration the impacts of climate change—such as water master plans, climate action plans, climate change adaptation plans, and drought management plans—were also assessed.

Water and electric systems are inextricably intertwined, and co-adaptation methods can lead to impactful, system-level outcomes for both the water and electric sectors. Research has and continues to illuminate the beneficial outcomes of water–electric utility collaboration to address climate impacts.

Several adaptation strategies found in water and electric utility adaptation plans share similarities. For example, both types of utilities are working to address sea level rises and/or storm surges. Their efforts involve either moving assets out of flood plains or, more frequently, elevating equipment a few feet so that it is above flood levels, placing vulnerable equipment in waterproof containers, or replacing existing equipment with equipment that is submersible and not vulnerable to water. Another example is adapting to extreme heat (or cold) events. Two major components of such adaptation strategies for both water and electric utilities are adjusting work practices to ensure workers are safeguarded, providing workers with appropriate training so that they understand the risks of working in extreme conditions, and providing clothing or protective equipment appropriate for the conditions.

There is no "one-size-fits-all" solution to climate change adaptation, but there is a tremendous amount that utilities and their regulators can learn from the work of other utilities and regulators with respect to tailoring their approaches. Table S.1 highlights a range of adaptive solutions that are common for both water and electric utilities.

Table S.1. Summary of Electric and Water Utility Adaptation Strategies

Climate Driver	Associated Impacts	Adaptive Solutions
Climate uncertainty	Lack of certainty regarding future climate conditions and lack of data to inform decisions	Conduct climate vulnerability and infrastructural resilience studies; develop climate resilience metrics
		Create and integrate climate risk models (e.g., scenario models or downscaled global climate models)
		Implement protocol for decision-making under deep uncertainty
	Need to adjust/improve emergency planning and response	Develop emergency response plans and practice implementation
		Implement and/or improve public advisory and emergency alert systems
Sea level rise and storm surges	Flooding of assets; equipment damage	Protect vulnerable electric and mechanical equipment (e.g., house equipment in waterproof buildings, enclose small equipment in waterproof cabinets, use submersible pump stations, or construct permanent or temporary flood barriers); institute a maintenance program to sustain waterproofing
		Replace or relocate vulnerable infrastructure or utility buildings away from flood zones
	Emergency response systems for storm surges	Install emergency alert systems for vulnerable infrastructure
		Train staff on emergency planning and response; conduct contingency planning regarding access to flooded sites, including coordination with local governments
	Longer-term design and planning	Conduct sea level rise and storm surge modeling and replace or update vulnerable infrastructure accordingly
		Implement flexible and adaptive approaches and identify signposts and thresholds for triggering additional action
Extreme temperature events (e.g., heat waves or cold snaps)	Equipment failure or damage	Weatherize equipment susceptible to freezing and failure due to freezing; develop new equipment standards for expected temperatures; install or ensure the availability of redundant equipment
		Replace aging infrastructure
		Maintain weatherization systems and subject them to testing before each winter
	Worker heat stress	Increase ventilation or active cooling in vaults, in confined spaces, and in the field
		Develop worker safety programs (including temperature thresholds and time limits for workers), communication systems for alerting workers to anticipated heat events, and protocols for workers to follow during heat events

Climate Driver	Associated Impacts	Adaptive Solutions
Droughts or changes in water quantity or the timing of water availability	Changes to precipitation timing and type	Conduct flooding studies and increase flood control measures
	Drought preparedness	Develop drought contingency plans and demand management plans (e.g., plans focused on sufficiency of potable water supply, or water for hydropower, or water for thermoelectric cooling)
	Increased risk of wildfire	Develop channels of communication between electric and water utilities and provide advance warning of any potential public safety power shutoffs
		Create or update fire models; develop fire management plans and practice their implementation (including with local fire departments and emergency response agencies)
		Increase the specificity of weather forecasting by collecting data specific to areas underserved by existing weather services, such as remote communities and unpopulated watersheds or powerline corridors
		Increase monitoring (e.g., soil moisture monitoring) in watersheds
Extreme weather and natural disasters	Equipment failure or damage, including loss	Ensure redundancy through the provision of backup power supplies and redundant equipment, including deployable portable equipment
		Retrofit or harden existing infrastructure
		Enter into mutual aid agreements
	Flooding due to heavy precipitation	Construct flood barriers and floodproof critical infrastructure; move equipment out of projected flood zones
	Power outages	Install and use on-site generators (such as solar, wind, biogas, or small hydropower generators), energy storage equipment, and demand-response or backup generators for critical loads; have dual power feeds for treatment plants and pump stations
		Coordinate in advance with power utilities to avoid inadvertent load shed during power supply shortages

Implementing comprehensive adaptation strategies can help electric and water utilities respond and react to uncertain future climate conditions while serving customers reliably and affordably. Table S.2 shows actions that water and electric utilities can take to support community resilience. The actions listed in Table S.2 have been included in water or electric utility climate mitigation plans and are actions one or more utilities have already taken or are currently taking.

Table S.2. Actions Utilities Can Take to Support Community Resilience in Climate Adaptation Strategies for Water and Electric Systems

Category	Potential Actions
Metrics and mapping	Develop maps that provide utility infrastructure system information overlaid with socioeconomic context
	Move beyond traditional system-level reliability metrics to identify areas experiencing disproportionate numbers of reliability problems
	Compare utility spending in environmental justice communities to other areas
	Develop and report on equity metrics, including those that address investment, participation, costs, reliability, accessibility, health and well-being, environmental impacts, social indicators, and economic indicators
Distribution of benefits	Identify which resilience actions benefit disadvantaged communities
	Set goals for the percentage of investments that should benefit underserved communities
Community engagement	Develop and follow community engagement plans when conducting resilience or climate vulnerability assessments
	Implement stakeholder working groups or community groups
	Provide onboarding and education for working group members
Targeted infrastructure deployment	Consider strategically placed microgrids or long-duration mobile energy storage systems to support areas facing reliability or resilience challenges
	When evaluating potential investments, develop a process to flag where investments would support environmental justice communities and use that process to identify and prioritize projects
Equity in planning	Develop engagement principles to guide the process of obtaining feedback for major projects and actions
	Incorporate community resilience into multicriteria decisional analysis
Partnering with communities	Team up with community organizations to support community resilience activities

There are abundant benefits to adopting harmonized, forward-thinking adaptation strategies to combat the effects of climate change on utility infrastructure and operation. Additionally, proactive planning and adaptation can foster capacity building between power and water industries by encouraging bidirectional exchange of information and data, which can support responsible system design and operation. Existing research has revealed that the cost of inaction in response to climate change is often greater than the capital cost of investing in adaptive strategies. As infrastructure costs rise, the implementation of adaptation measures can significantly reduce expected and unexpected system costs, with some proactive strategies halving expected annual costs under high emissions scenarios in the electric sector (Fant et al. 2020). While many aspects of climate change can be estimated, building resilience through adaptation can help to address those aspects that cannot be predicted.

Water and electric utilities across the country are engaging in this process, and the objective of this report is to identify these potential pathways to adaptation and encourage utilities to consider what may help them moving forward.

Acknowledgments

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Acronyms and Abbreviations

Con Edison	Consolidated Edison Company of New York
CRWU	Creating Resilient Water Utilities
DMDU	decision-making under deep uncertainty
EPA	U.S. Environmental Protection Agency
NYSEG	New York State Electric and Gas
PG&E	Pacific Gas & Electric Company
RCP	Representative Concentration Pathway

Contents

Figures

Tables

1.0 Introduction

The need to adapt to climate change has become increasingly apparent for utilities in recent years as changes in weather and temperature and extreme weather events have led to system-threatening conditions across the country (U.S. Environmental Protection Agency [EPA] 2024c, EPA 2024d). Climate change has strained resource availability and quality for water utilities, reduced the operational capacity of electric systems, damaged critical infrastructure, and prompted changes in the operations of both water and electric systems (EPA 2024c, EPA 2024d). Water and electric utilities suffer negative impacts that are unique to the services they provide and the equipment and personnel involved in providing those services. However, because of the interdependent nature of electric and water utility systems, they also face shared impacts. As a result, utilities have implemented a wide variety of solutions to address the impacts of climate change on their systems and resources. These solutions vary according to utility type, geographic region, and other factors (e.g., what each individual utility chooses to prioritize) and often cater to the specific needs of the respective utility. However, there are also many solutions that apply to many or most electric utilities or to many or most water utilities. Some solutions apply to a large percentage of both utility types. Responses to climate disruptions across both types of utility systems have included the diversification of resource portfolios to add more redundant supplies, redesign of infrastructure for improved operational performance under changing conditions, and strategic emergency and management planning for event-specific threats (e.g., drought or wildfire). As climate change disproportionately impacts socially vulnerable groups and populations, many utilities are designing solutions that aim to address these discrepancies to achieve more equitable service (EPA 2021). These actions align with aspects of resource planning, asset planning, and contingency planning—specifically, they aim to ensure that current energy and water supplies, related infrastructure and personnel, and internal utility operations and management are prepared for a riskier climate future (Homer et al. 2023).

As mentioned, there is overlap between the strategies of electric and water utilities for climate change adaptation due to the inherent independencies between these industries. Water is used in energy production and various energy system operations including fire suppression, and energy is used in the procurement and treatment of water. Figure 1 highlights these interdependencies and others in detail. These interdependencies mean the water and power sectors can learn from one another in crafting a responsive, forward-looking approach to an increasingly uncertain climate future. **This report ultimately explores the ways in which power and water utilities are adapting to climate change and highlights areas of opportunity to develop harmonized strategies that can help manage water–electric interdependencies and advance outcomes that benefit all customers.**

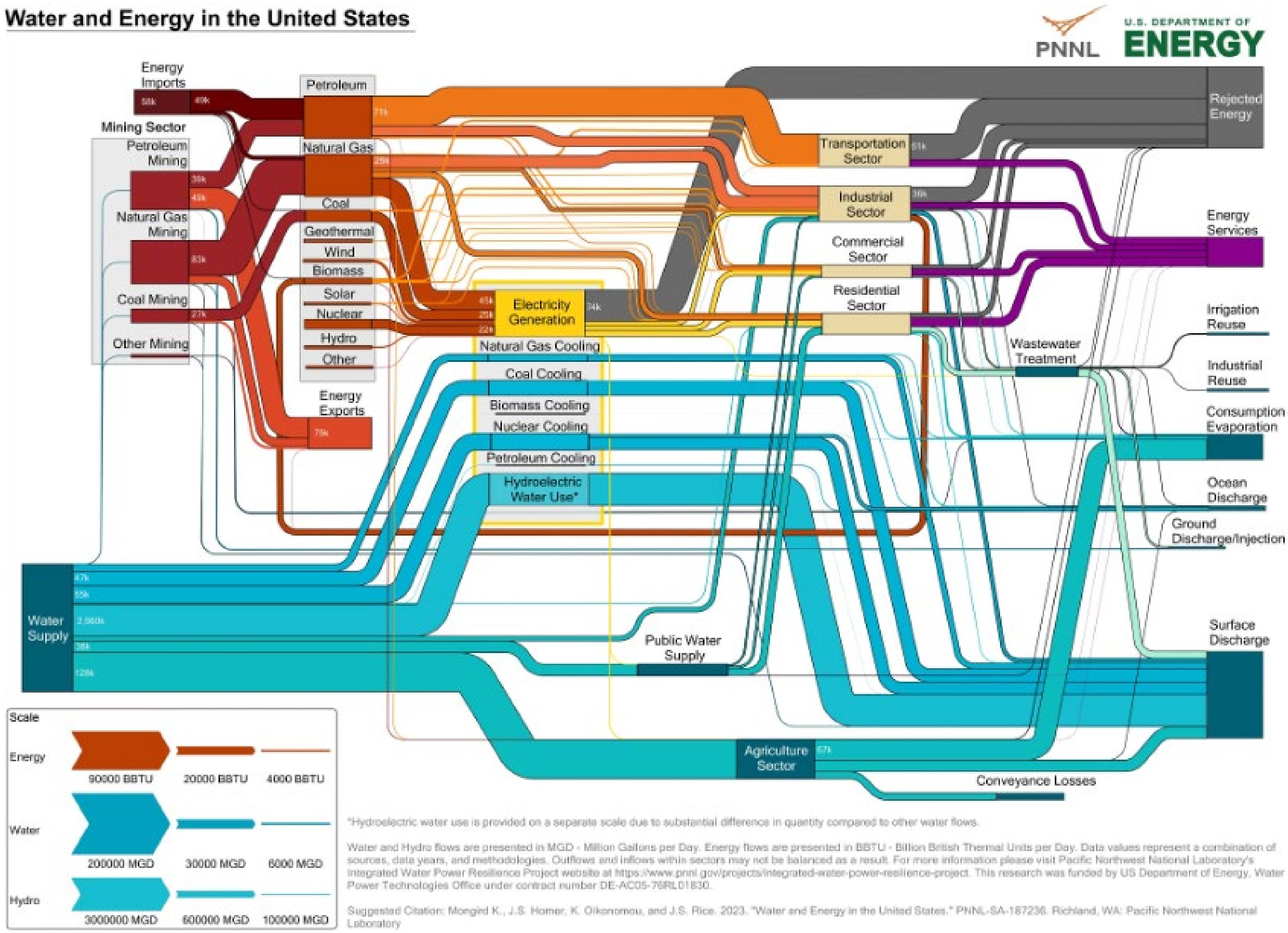

Figure 1. Sankey Diagram of Water and Energy System Linkages in the United States (Mongird et al. 2023)

This compendium of emerging and established practices addressing risks arising from climate change in the electric utility industry is based largely on climate vulnerability assessments and their paired mitigation plans, storm protection plans, and wildfire mitigation plans. For water utilities, many adaptation strategies were identified through the EPA Creating Resilient Water Utilities (CRWU) program. CRWU adaptation plans are discussed in further detail in Section 3.1 of the report. Other planning documents that consider climate change impacts, such as water plans, master plans, and climate change adaptation plans, were also assessed. This report attempts to identify climate adaptation plans that are geographically diverse, examining at least one water and electric utility plan each from the Northeast, Southeast, Midwest, Southwest, and Western regions of the United States. By explicitly seeking geographic diversity, the compendium reflects a wider range of climate issues that stress water and electric systems (ranging from glacial melt and landfalling hurricanes to extreme heat and combined ice and wind). States with requirements for public climate adaptation plans, such as California and New York, are represented heavily herein because of the availability of information and the goal to discuss as many concerns as possible. However, this compendium is not a census of effort in these states. Again, a specific intention of this summary is to add as much geographic diversity as possible in the resilience efforts documented to cover a wide range of concerns.

Across the board, electric and water utilities are at varying stages of planning for climate change—some are at an advanced planning stage, whereas others are just beginning. The urgent need for proactive and long-term planning is especially clear from the costs borne from unpreparedness and reactive remediation. Take, for example, Superstorm Sandy[1], which struck the United States in 2012. The repair and response to damages cost New York more than $32 billion, with nearly all of the cost attributable to coastal flooding and $1.5 billion attributable to sea level rise (Strauss et al. 2021). Superstorm Sandy cost over $500 million for the Consolidated Edison Company of New York (Con Edison), an electric provider to more than 3 million New York customers (Con Edison 2015). The severity of the floods forced the utility to shut down steam and electrical services to Lower Manhattan, with transmission-line damage triggering further shutdowns in Brooklyn and Staten Island (Con Edison 2013). Impacts cascaded across the power–water nexus, resulting in a loss of power to 19 water supply facilities and 13 wastewater treatment plants for the New York Department of Environmental Protection, which provides clean water to nearly 10 million New Yorkers (New York City Water Board 2012). The costly aftermath prompted the development of more climate-forward planning measures, with Con Edison implementing merged mid-to-extreme (Representative Concentration Pathways [RCPs] 4.5 and 8.5[2]) sea level rise projections in their resource forecasting, elevating vulnerable assets to 3 feet above the FEMA 100-year floodplain, and conducting climate vulnerability assessments (Con Edison 2023, Con Edison 2019, Merchant

[1] Prior to landfall, Sandy had at one point been a Category 3 hurricane with sustained winds of 115 mph. Prior to landfall near Brigantine, New Jersey, Sandy lost its convection and became a post-tropical storm. Despite having sustained 80 mph winds at landfall, Sandy was no longer a hurricane, strictly speaking. Because of the post-tropical nature of the storm at landfall, it is often referred to as Superstorm Sandy. Superstorm Sandy is the name used herein because of the familiarity of this name.

[2] RCPs are greenhouse gas emission scenarios. RCP 8.5 represents a fossil fuel–driven energy case. RCP 4.5 represents a middle-of-the-road case between RCP 8.5 and an RCP in which the world shifts away from a fossil-fueled path and onto a sustainable path emphasizing low- or no-emission energy usage. RCP is a slightly outdated term, having been replaced in the latest round of global climate modeling with Shared Socioeconomic Pathways or Shared Socioeconomic Pathways. Shared Socioeconomic Pathways is a broader measure of underlying factors like population and economic growth as well as other factors underlying greenhouse gas emission. In short, it provides a more comprehensive explanation for changes in greenhouse gas emission levels than RCPs, which are estimates of a greenhouse gas emission path without an underlying explanation for that path.

2017). Similarly, New York's Department of Environmental Protection began developing mandatory guidelines for new constructions to address design flood elevations and formulate a wastewater resilience plan to identify current and future flood-vulnerable infrastructure (Municipal Water Leader n.d.).

Proactive planning and adaptation with fine-tuned, locally responsive climate solutions can significantly reduce the expected annual average costs of climate change. One study found that proactive electric system hardening measures can halve expected costs under an end-century RCP 8.5 emissions scenario ($23.7 billion with no adaptation vs. $11.9 billion with smart adaptation, annualized total expenditures in 2017 dollars) (Fant et al. 2020). Moreover, proactive planning and adaptation can foster capacity building between power and water industries by allowing space for bidirectional information flow and data-sharing to support responsible system design and operation. There are also numerous opportunities to learn from one another, building off the inherent interdependencies in the power and water industries. **Investments made today can strategically be made to be climate-ready and integrated across water and power systems to serve multiple needs, thereby reducing the overall cost of resilience and avoiding sunk costs.**

Although climate impacts may vary by region and their risk level may differ by utility type (i.e., what is a challenge for one industry may not always be a challenge for the other), these impacts point to a fundamental need for adaptive resilience—or the process of preparing for life in a changing climate. **This report is a compendium of power and water climate adaptation strategies and is meant to serve as a repository of examples and resources for capacity building rather than as prescriptive guidance on how to plan for climate change.**

There is no "one-size-fits-all" solution to climate change adaptation, but there is a tremendous amount that utilities and their regulators can learn from the work of other utilities and other regulators with respect to tailoring their approaches. The report is structured as follows: Section 2.0 summarizes the climate adaptation strategies to various climate drivers by electric and water utilities; Section 3.0 dives deeper into each driver and its associated solution, highlighting specific examples and real-world applications; Section 4.0 discusses synergies across industries for collective climate adaptation solutions; and Section 5.0 illuminates existing practices that aim to integrate community considerations into climate adaptation planning.

2.0 Climate Adaptation Solutions Overview

This section provides an overview of the efforts made by water and electric utilities to adaptively prepare for resource changes, infrastructure impacts, and personnel hazards under a changing climate while continuing to provide reliable and sustainable service to customers under uncertain future conditions. Adaptations listed in this section were drawn from a variety of water and electric utility resilience plans and assessments. Table 1 documents strategies for water utilities to respond to various climate issues, and Table 2 lists strategies for electric utilities. These tables serve as simplified reference points for common climate drivers, associated climate impacts, and adaptive solutions for each respective utility type. Additionally, the "Examples" column in each table identifies utilities that are currently utilizing the respective adaptive solution(s). As noted in Section 1.0, this compendium represents a sample of the climate adaptation plans that have been developed across the United States. Thus, the utilities included in the "Examples" column are not a census of the plans that exist. Section 3.0 dives deeper into each driver and solution.

Table 1. Water Utility Climate Issues and Solutions[1]

Climate Driver	Associated Impacts	Adaptive Solutions	Examples
Climate uncertainty	Lack of certainty for future climate conditions and lack of data to inform decisions	Conduct climate vulnerability and infrastructural resilience studies to develop climate resilience metrics	• Southern Nevada Water Authority, NV (CRWU) • South Central Connecticut Regional Water Authority, CT (CRWU) • Greater Augusta Utility District, ME (CRWU) • Portland Water Bureau, OR (CRWU) • California Water Service, CA (CRWU)
		Create and integrate climate risk modeling (i.e., scenario modeling or downscaling global climate models)	• Tampa Bay Water 2023 • Southern Nevada Water Authority, NV (CRWU) • Portland Water Bureau, OR (CRWU) • California Water Service, CA (CRWU)
		Implement decision-making under deep uncertainty practices	• Bear Creek Watershed Association and Evergreen Metropolitan District, CO (CRWU)
	The need to adjust/improve emergency planning and response	Develop emergency response plans and practice their implementation	• City of Bend, OR (CRWU) • City of Los Angeles, CA (CRWU) • City of Fairbault, MN (CRWU) • Village of Hershey, NE (CRWU)
		Implement or improve public advisory and emergency alert systems	• Saginaw Chippewa Indian Tribe of Michigan, MI (CRWU) • Cleveland Division of Water Pollution Control, OH (CRWU) • City of San Diego, CA (CRWU)

[1] Note: Where examples contain (CRWU), the example is taken from a water utility's CRWU filing accessible at https://www.epa.gov/crwu.

Climate Driver	Associated Impacts	Adaptive Solutions	Examples
Sea level rise and storm surges	Flooding of assets, equipment damage	Protect vulnerable electric and mechanical equipment (e.g., waterproofing buildings and using submersible pump stations and permanent or temporary flood barriers)	• Tampa Bay Water 2023 • City of Anacortes, WA (CRWU) • Blue Plains Wastewater Facility, Washington, DC (CRWU) • City of Boston, MA (CRWU) • Iowa City Wastewater, IA (CRWU) • City of Miami Beach and Miami-Dade County, FL (CRWU) • South Monmouth Regional Sewerage Authority, NJ (CRWU) • Manchester-by-the-Sea, MA (CRWU)
		Replace or relocate vulnerable infrastructure or utility buildings (e.g., moving a water treatment plant away from a flood zone)	• Miami-Dade County 2021 • Tampa Bay Water 2023
	Saltwater intrusion to drinking water sources	Identify additional or alternative supplies not vulnerable to saltwater intrusion or inundation	• Tampa Bay Water 2023
		Modify groundwater pumping patterns and/or implement targeted groundwater recharge	• Tampa Bay Water 2023 • City of San Diego 2021
	The need for emergency response to storm surges	Install emergency alert systems for vulnerable infrastructure	• City of Miami Beach and Miami-Dade County, FL (CRWU) • Manchester-by-the-Sea, MA (CRWU)
		Train staff for emergency planning and response	• City of Miami Beach and Miami-Dade County, FL (CRWU), • Manchester-by-the-Sea, MA (CRWU)
	The need for longer-term design and planning	Conduct sea level rise and storm surge modeling and replace/update vulnerable infrastructure accordingly	• Manchester-by-the-Sea, MA (CRWU) • City of Miami Beach and Miami-Dade County, FL (CRWU)
Extreme temperature events (i.e., heat waves or cold snaps)	Equipment failure/damage	Weatherize equipment; develop new equipment standards for expected temperatures; install or ensure access to redundant equipment	• Swinomish Utility Authority, WA (CRWU) • City of Los Angeles Sanitation, CA (CRWU) • Saginaw Chippewa Indian Tribe of Michigan, MI (CRWU) • City of Cincinnati, OH (CRWU) • Poarch Band of Creek Indians Utilities Authority, AL (CRWU)

Climate Driver	Associated Impacts	Adaptive Solutions	Examples
	Aging pipes, pipe breaks, and water loss reductions	Replace aging infrastructure, insulate exposed pipes, and conduct regular water loss audits	• Portland Water Bureau 2020b • Seattle Public Utilities 2019 • City of Whitefish, MT 2018
	Worker heat stress	Increase ventilation or active cooling in vaults and confined spaces; develop safety programs, including temperature thresholds and time limits for workers and safety training programs	• Seattle Public Utilities 2019 • Water Utility Climate Alliance 2020 • Portland Water (Resilient Analytics)
Drought or changes in water quantity or the timing of water availability	Changes to precipitation timing and type	Reoptimize reservoirs and water storage strategies to meet flood control requirements and the needs of fish and wildlife while still meeting water supply requirements	• East Bay Municipal Utility District 2024
		Conduct flooding studies and enhance flood control measures	• City of Portsmouth, NH (CRWU) • Greater Augusta Utility District, ME (CRWU) • Seattle Public Utilities, WA (CRWU) • Water Environment Services Clackamas County, OR (CRWU)
	Freshwater availability	Diversify source portfolio and/or develop points of interconnection to partner utilities or alternative water sources	• City of Tampa Bay, FL (CRWU) • City of Fredericktown, MO (CRWU) • East Bay Municipal Utility District 2021 • Jordan Valley Water Conservancy District, UT 2021
		Implement or increase water reuse for non-potable or potable applications	• City of San Diego 2021 • Metropolitan Water District of Southern California (CRWU) • Arizona Department of Environmental Quality, n.d. • Colorado Springs, CO (See Hager 2023)
		Implement environmental-based conservation measures, such as streambank stabilization and wetland management	• City of Tampa Bay, FL (CRWU) • City of Fredericktown, MO (CRWU) • Jordan Valley Water Conservancy District, UT 2021

Climate Driver	Associated Impacts	Adaptive Solutions	Examples
		Increase the amount of usable water in reservoirs by installing floating pumping stations that enable reservoirs to be drawn down to lower levels than previously possible	• Seattle Public Utilities 2019 • Southern Nevada Water Authority, NV (CRWU)
		Conserve water by implementing measures to reduce water losses	• Swinomish Utility Authority, WA (CRWU) • City of Los Angeles Sanitation, CA (CRWU) • Saginaw Chippewa Indian Tribe of Michigan, MI (CRWU) • City of Cincinnati, OH (CRWU) • Poarch Band of Creek Indians Utilities Authority, AL (CRWU)
		Increase water storage capacity	• Swinomish Utility Authority, WA (CRWU) • City of Los Angeles Sanitation, CA (CRWU) • Saginaw Chippewa Indian Tribe of Michigan, MI (CRWU) • City of Cincinnati, OH (CRWU) • Poarch Band of Creek Indians Utilities Authority, AL (CRWU)
	Drought preparedness	Develop drought contingency plans and demand management plans	• Northern Kentucky Water District, KY (CRWU) • Poarch Band of Creek Indians Utilities Authority, AL (CRWU) • Seminole Tribe of Florida, FL (CRWU) • Jordan Valley Water Conservancy District, UT (CRWU)
		Implement strategic water preservation measures (i.e., seasonal conservation or issuing conservation credits to customers)	• Northern Kentucky Water District, KY (CRWU) • Poarch Band of Creek Indians Utilities Authority, AL (CRWU) • Seminole Tribe of Florida, FL (CRWU) • Jordan Valley Water Conservancy District, UT 2021
	Water quality degradation	Increase water quality monitoring measures for surface water and groundwater, potentially through automated quality sampling and monitoring	• Cape Fear Public Utility Authority, NC (CRWU) • The York Water Company, PA (CRWU) • SUEZ Water, NJ (CRWU) • South Central Connecticut Regional Water Authority (CRWU)

Climate Driver	Associated Impacts	Adaptive Solutions	Examples
		Install additional filtration systems to address increases in turbidity due to changes in rainfall or snowpack paradigms	• Sitka, Alaska (CRWU)
	Increased risk of wildfire	Implement preventive environmental measures such as forest health monitoring, fire management practices, and invasive species control	• City of Bremerton Utilities, WA (CRWU) • City of San Diego, CA (CRWU) • City of Bozeman, MT (CRWU) • Bear Creek Watershed Association and Evergreen Metropolitan District, CO (CRWU)
		Increase the use of monitors such as soil moisture monitors in watersheds and increase the specificity of weather forecasting by collecting watershed-specific data	• City of Seattle, WA (CRWU)
		Create or update fire models; develop fire management plans and practice their implementation	• City of Bremerton Utilities, WA (CRWU), • City of San Diego, CA (CRWU), • City of Bozeman, MT (CRWU) • Bear Creek Watershed Association and Evergreen Metropolitan District, CO (CRWU)
Extreme weather and natural disasters	Equipment failure/damage, including loss	Retrofit or harden existing infrastructure	• New York City 2013 • City of San Diego 2020
		Ensure redundancy through the use of backup power and redundant equipment	• Metropolitan Water District of Southern California 2022 • City of San Diego 2020
	Potable water contamination or other problems caused by untreated wastewater spills due to flood events or sea level rise	Ensure wastewater treatment facilities are hardened to avoid spilling untreated sewage during flood events	• Faribault, MN (CRWU) • New York City 2013 • Miami-Date (CRWU)
	Flooding due to heavy precipitation	Relocate equipment out of projected flood zones	• City of San Diego 2020 • Seattle Public Utilities (CRWU)

Climate Driver	Associated Impacts	Adaptive Solutions	Examples
		Construct flood barriers and floodproof critical infrastructure (e.g.,sealing or waterproofing equipment; using submersible pumps)	• City of Portsmouth, NH (CRWU) • Greater Augusta Utility District, ME (CRWU) • Seattle Public Utilities, WA (CRWU) • Water Environment Services Clackamas County, OR (CRWU)
Higher Water Temperature	Algal blooms	Monitor algal indicators in real time; implement watershed management to reduce algal growth; implement additional or novel water and wastewater treatment technologies; implement effluent cooling systems or retrofitted intakes to accommodate varying flow levels	• Jordan Valley Water Conservancy District, UT 2021

Table 2. Electric Utility Climate Issues and Solutions

Climate-Related Challenges	Associated Impacts	Adaptive Solutions	Examples
Climate uncertainty	Lack of data to inform decisions; lack of certainty regarding future climate conditions	Conduct various climate and infrastructural assessments and analyses	• Central Hudson Gas & Electric 2023 • Con Edison 2023a • Consumers Energy 2023 • Duke Energy 2023 • NationalGrid 2023 • New York State Electric and Gas (NYSEG) 2023 • Rochester Gas and Electric Corporation (RG&E) 2023 • Orange and Rockland Utilities (O&R) 2023 • Southern California Edison (SCE) 2022b • Seattle City Light, n.d.
		Create and integrate climate risk modeling, conduct scenario modeling analysis, and/or downscale climate projections	• Con Edison 2019 • Con Edison 2023a • Seattle City Light, n.d. • SCE 2022b
		Implement decision-making under deep uncertainty practices	• California Public Utilities Commission 2024

Climate-Related Challenges	Associated Impacts	Adaptive Solutions	Examples
Extreme cold	Freezing of portions of generating facilities or of fuel supply infrastructure	Weatherize facilities susceptible to freezing and failure due to freezing; maintain and test weatherization systems prior to each winter	• Electric Reliability Council of Texas (ERCOT) 2022
	Increase in ice and/or snow load on power lines	Harden or retrofit assets; upgrade poles, crossarms, other support hardware, and conductors	• O&R 2023 • Con Edison 2023b • Consumers Energy 2023 • Consumers Energy 2023 • NYSEG 2023 • RG&E 2023
	Increased demand on electrical distribution systems where extreme cold is rare	Upgrade capacity of existing facilities and infrastructure	• Florida Power & Light (FPL) 2022
	Increased demand on electrical transmission systems where extreme cold is rare	Replace segments of transmission conductors and associated substation equipment	• FPL 2022
	Possible loss of resources due to concurrent climate or weather events	Install and support localized energy resources (e.g., solar, wind, biogas, and small hydropower), energy storage, and demand response	• Com Edison 2022 (Argonne 2022)
	Reduced availability of import power from neighboring utilities or balancing areas	Increase transmission connectivity and access to localized distributed energy resources	• NYSEG 2023 • RG&E 2023 • FERC et al. 2021 • Con Edison 2023b
Sea level rise and storm surges	Flooding of assets and equipment damage	Harden or retrofit assets	• Seattle City Light, n.d. • Con Edison 2023 • SCE 2023c
	The need for longer-term design and planning	Establish design policies for resources in at-risk areas	• Con Edison 2023 • Entergy Louisiana 2022
		Formulate contingency plans for access to flooded sites	• Seattle City Light, n.d.

Climate-Related Challenges	Associated Impacts	Adaptive Solutions	Examples
Temperature rise	Transmission or distribution capacity derating, underground line failure, and equipment damage	Change fill materials to prevent cable damage	• Seattle City Light, n.d.
		Assess potential equipment downrating due to temperature increases	• NYSEG 2023
	The need for longer-term design and planning	Develop new equipment standards for expected temperatures	• NYSEG 2023 • RG&E 2023 • National Grid 2023 • SCE 2023b
		Implement safety measures for staff, especially field workers	• Seattle City Light, n.d. • SCE 2023d • Con Edison 2023b
Wildfire risk	Increased risk of wildfire ignition and damage to infrastructure and equipment	Increase vegetation management	• Seattle City Light, n.d. • Com Edison 2022 (See Argonne 2022)
		Implement more frequent vegetation management cycles	• Pacific Gas & Electric Company (PG&E), n.d. • PacifiCorp 2023 • Entergy Louisiana 2022
		Develop wildfire mitigation plans; identify and harden, replace, or relocate vulnerable infrastructure; use covered conductor	• PG&E, n.d. • PacifiCorp 2023 • Seattle City Light, n.d.
Extreme weather and natural events	Increased likelihood of power outages	Develop advanced forecasting tools	• SCE 2023d • FPL 2022 • Con Edison 2023b • PacifiCorp 2023
		Develop cross-ties between neighboring circuits to facilitate carrying load if a circuit is damaged	• SCE 2023e • Entergy Louisiana 2022 • National Grid 2023 • NYSEG 2023 • RG&E 2023 • Consumers Energy 2023
		Implement or enhance vegetation management	• Entergy Louisiana 2022 • Central Hudson Gas & Electric 2023 • National Grid 2023 • NYSEG 2023 • RG&E 2023
		Improve data sufficiency for outage management systems	• Consumers Energy 2023 • Seattle City Light, n.d.
	Reducing equipment damage through longer-	Floodproof equipment	• Con Edison 2023b • FPL 2022 • Entergy Louisiana 2022

Climate-Related Challenges	Associated Impacts	Adaptive Solutions	Examples
	term design and planning; planning for recovery	Use climate-forward data in equipment design criteria	• National Grid 2023 • NYSEG 2023 • RG&E 2023 • Consumers Energy 2023 • SCE 2023c
		Use of deployable, mobile equipment such as switchgear to assist in recovery efforts	• Con Edison 2023b • Con Edison 2022 (Argonne 2022)
Extreme-event-based power outages	Restoring power after outages	Enter into mutual aid agreements with neighboring utilities	• Con Edison 2023b • FPL 2022 • Consumers Energy 2023
		Coordinate emergency response with state and local governments	• FPL 2022 • SCE 2022a • PacifiCorp 2023 • Con Edison 2023b • National Grid 2023

3.0 Solutions in Practice

Solutions for enhancing adaptive capacity to climate change have considerable overlap between the electric and water sectors. Utilities are at various stages of these processes; some have led the charge of adaptation activities (especially those that have experienced the most devastating and immediate impacts), while others have just begun considering what future loads, resource conditions, and physical and human infrastructure changes might look like. While impacts to electric and water utilities may be different, parallel approaches are often taken to address various climate risks.

3.1 Water Utility Solutions in Practice

Water utilities have implemented an array of responses to adapt to climate change. From the lack of freshwater availability to flooding, the impacts of climate change on water utilities vary, particularly by region. As discussed above, several common water-related issues across the United States have emerged, including drought or water availability issues, extreme temperatures, and extreme weather or natural disasters. In addition to the hands-on solutions implemented to address these concerns, water utilities also have benefited from comprehensive planning, modeling, and analysis. The EPA's CRWU case studies (which include utility-specific issues, solutions, and forward-looking adaptation plans across 70 cases), major climate adaptation plans from utilities outside of CRWU, various water integrated resource plans, and utility master plans were analyzed to identify practices utilized by water utilities.

3.1.1 Water Modeling and Assessment

Contingency planning, or the process of developing detailed response plans for future emergencies or service disruptions, is an essential part of adapting to the changing climate. Without adapting existing management, emergency response, and contingency planning practices, water utilities run the risk of being unprepared for climate change–induced events. Comprehensive modeling, assessment, analysis, and planning can ensure water utilities meet customer demand, ensure there is reliable supply to meet critical needs (even in times of drought or other emergencies), and allow planning for future scenarios that be cannot yet predicted. Water modeling comes in many forms and is an essential part of ensuring water utilities have the information needed to successfully build resilience to climate change. From resource adequacy to asset management to vulnerability studies, various assessments and analysis tools can assist utilities in implementing solutions that are most impactful for their specific needs. Listed below are several assessment and modeling types that water utilities have identified as valuable to their adaptation planning:

- Climate vulnerability and resilience studies
- Turbidity hydrology studies
- Infrastructure resilience studies
- Extreme event modeling
- Water shortage response plan development
- Emergency response planning that incorporates considerations of climate-induced emergency conditions and relevant training for vulnerable utility staff
- Drought contingency planning

3.1.2 Drought and Lack of Water Availability

Drought is becoming increasingly frequent and severe across the United States due to rising temperatures and increased precipitation variability (Cawdrey 2023). Drier areas, such as the Southwest United States, are particularly vulnerable to the growing risk of drought, but utilities across the United States are adapting to accommodate for longer or more severe stretches (C2ES n.d.). In order to build resilience for periods of drought, water utilities are recognizing the importance of preparing early and comprehensively through contingency planning and other management practices from source portfolio diversification to inter-utility partnerships. Water utilities, local governments, and state governments have developed drought response plans that outline the steps to be taken in the event that drought conditions arise or water supplies are insufficient to meet the normal water demands of customers (City of Tucson n.d., CWCB n.d., Jordan Valley Water Conservancy District 2021).

The subsections below outline different approaches for dealing with a lack of water availability.

3.1.2.1 Diversification of Source Portfolio

Several utilities have identified a need to diversify or broaden their resource portfolio to include a wider variety of water sources to ensure redundancy in periods of drought (as opposed to pulling from a single source or several unreliable sources). Such portfolios often include water savings achieved from offering incentives to consumers for the installation of water-efficient fixtures such as low-flow toilets or efficient irrigation systems. For example, Jordan Valley Water Conservancy District, which serves the state of Utah, designed a plan to diversify its supply source portfolio in its 2021 Drought Contingency Plan. Groundwater and surface water supplies dwindled during previous periods of drought, and the utility decided that it was necessary to develop a broadened portfolio that anticipated drought impacts to surface supplies (Jordan Valley Water Conservation District 2021). With a diversified portfolio, water utilities can better adapt to an especially dry season or an unexpected drop in water availability from one watershed by turning to an alternative watershed. In particular, utilities in the Southwest United States have been adopting this adaptation strategy in combination with others.

3.1.2.2 Inter-Utility Partnerships

As an additional method of ensuring redundancy and adapting to limited water supply, several utilities have paired up with other local utilities within or outside of their watershed to facilitate interconnections or other partnership opportunities. The Metropolitan Water District of Southern California has made mutually beneficial relationships with neighboring water utilities including water transfers between utilities (EPA 2015). Several other utilities are adapting similarly and maintaining important relationships with other utilities in their watershed. This has also taken the shape of regional water planning, which involves entities beyond just utilities in water supply and demand management, such as state and local governments.

3.1.2.3 Voluntary and Prescribed Demand Management Practices

Several water utilities are adapting to longer and more frequent periods of drought by preemptively implementing both voluntary and mandatory demand management efforts. Some utilities have opted to take a discretional approach in which their customers are incentivized through bill credits to use less water or reduce their water usage at peak use times. For example, the City of Spokane, WA, created a wastewater bill credit for residential customers in the lowest 20 percent bracket for water usage, issuing a credit of $5 per monthly bill on an annual basis (City of Spokane n.d.).

Additionally, stricter prescribed restrictions during peak hours and comprehensive water use ordinances have also been used to conserve water during drought periods. Typically, this route is taken more often during crisis periods in which immediate conservation is necessary and voluntary reductions cannot be relied upon. Adapting planning methods to incorporate seasonal conservation practices tends to be more impactful for utilities in regions where there is more abundant water during colder and rainier seasons and less during hotter and drier summer months.

3.1.2.4 Loss Management

Water utilities are no stranger to minor system-level water loss. Reducing water loss is an aspect of resource planning that can be adapted to and mitigated with utility-implemented measures. Not only does reducing water loss save money; adapting systems to minimize loss also helps utilities save water in times when it is most needed. Several utilities have implemented updated monitoring practices to ensure no leaks go undetected. Additionally, many utilities are continuously replacing or upgrading critical infrastructure that is aging or becoming weakened due to climate impacts (e.g., extreme temperatures, floods, or wildfires).

3.1.2.5 Wastewater Reclamation

An emerging practice among wastewater utilities is wastewater reclamation, which involves recycling well-treated domestic sewage water for alternative purposes. While reclaimed water is not typically used for drinking water in the United States, it can be safely utilized for a variety of other purposes, including irrigation, the replenishing of groundwater resources, construction activities, and recreational activities. An increasing number of utilities are using reclaimed water in conditions where drinking water is unnecessary. In Washington State, reclaimed wastewater is used to replenish Olympia's East Bay Plaza stream, which sits across from the Hand's On Children's Museum and creates a safe and sustainable stream to the local community (Washington State Department of Ecology n.d.). Additionally,

Wastewater Reclamation

In recognition of water scarcity and cost, western water utilities and large users have investigated the use of treated wastewater for years. In 2010, the Arizona Public Service signed a new 50-year agreement for reclaimed wastewater for use in cooling the Palo Verde nuclear plant. The new agreement replaced an agreement signed in 1973—a time when wastewater was truly considered a waste product (Water Technology 2010). Across the Southwest United States, wastewater has been used in situations such as landscape irrigation (City of Scottsdale 2018), in industrial processes that require water but not necessarily potable water, and for the replenishing of groundwater basins (Metropolitan Water District of Southern California n.d.).

Arizona, southern Nevada, and Southern California rely at least in part on water imported from the Colorado River. However, the Colorado River has experienced a historic, extended drought (USGS n.d.) since 2000. This, alongside water shortages or potential shortages in other water sources, has caused western water utilities to seek alternative water supplies, both by applying traditional, tried-and-true methods like buying out the water rights from others—such as large farming or ranching operations—and by investigating new supplies, such as treating wastewater to levels considered clean and safe to drink. The City of San Diego, California, is pursuing the Pure Water San Diego Program (City of San Diego n.d.) to develop a wastewater treatment project that will treat wastewater to drinking water standards. The Pure Water Program, when completed, will contribute by making the city more drought resilient and diverting water out of an existing wastewater facility, which will enable the overall system to meet water quality requirements (City of Sand Diego 2014). In Colorado, interest in wastewater reuse led to legislation that sets standards for water quality for direct potable reuse and that requires public outreach related to projects (Hager 2023). Arizona, Texas, Florida, and California have published guidelines for potable water reuse technology, but Colorado is the first state with such legislation. In Arizona, cities in the Phoenix area are considering or designing treatment facilities for direct potable reuse (Hager 2024). In California, the Metropolitan Water District in California and the Los Angeles County Sanitation Districts are teaming up on a regional water recycling program called Pure Water Southern California (Metropolitan Water District of Southern California n.d., Hager 2022).

the Arizona Department of Environmental Quality is now considering new laws that would permit the direct potable reuse of treated wastewater for pilot, demonstration, or educational facilities (Arizona Department of Environmental Quality n.d.). In a limited number of cases, direct potable use is happening in the United States (McFarland 2024). The information box labeled "Wastewater Reclamation" highlights several additional examples of wastewater reclamation in practice at water utilities through the country.

3.1.2.6 Adapting Water Storage

In order to ensure that water is available year-round and under any climatological circumstances, many utilities are taking the initiative to adapt their existing storage facilities to accommodate a greater amount. Aligning with seasonal conservation practices mentioned previously, utilities are frequently deciding to store more water during more abundant periods of supply to be available for use when supply is limited. Utilities have increased their storage capacity in several ways. The City of Traverse City, MI, has stated an intent to increase its existing wet well storage capacity, while the City of Atlanta, GA, plans to build a new pump station and associated storage tank (CRWU Traverse City, Michigan, CWRU Atlanta, GA). Some utilities, like the City of Durham, NC, plan to build new intakes to their existing storage reservoirs, while SUEZ Water—a private company serving customers in three New Jersey counties—will be removing silt from its existing reservoir to increase its capacity (CRWU Durham, NC; CRWU SUEZ Water, NJ). Along with adapting the capacity of existing storage facilities and building new storage sites, some utilities are opting to intentionally facilitate the recharge of local aquifers, a practice known as aquifer recharge or storage (Escriva-Bou et al. 2021). This process involves filling recharge basins or unlined canals or riverbeds by allowing water to sink into the ground or injecting water into the ground through wells. In some cases, reclaimed water can be used in this context.

3.1.3 Extreme Temperatures

Extreme weather patterns, including both hot and cold temperature extremes, are becoming more frequent and intense (NASA, n.d.). Heat waves and cold snaps alike can have extremely detrimental impacts on water utility infrastructure. Unusually high temperature days are increasingly common, particularly in major cities, due to the concurrent impact of the heat island effect (EPA 2024e). Extreme heat events often coincide with drought because heat waves can impact water availability and quality. The causal relationship between climate change and cold snaps is an ongoing area of study, but initial findings have indicated that extreme cold events are correlated with global warming patterns (Hsu et al. 2022). While extreme temperatures tend to have a more visceral effect on electric utilities, water utilities still must adapt to a variety of temperature-related impacts, including equipment failure, water loss, and water quality degradation from algal blooms. Worker safety issues are also important when it comes to extreme temperatures. Additional safety measures—such as active cooling and temperature thresholds, working time limits, and exposure thresholds—have been implemented by several utilities.

3.1.4 Equipment Failure

Some equipment, such as electric motors (pumping), motor control centers, roofing materials, and parking lot pavement, will be susceptible to more extreme maximum temperatures (WUCA 2020). To address the associated risks, some utilities are looking to motors with higher insulation temperature ratings as well as roofing systems and asphalt grades that are more resistant to high temperatures. Of major concern for water utilities is the availability of electricity for pumping and water treatment. If extreme heat damages power equipment that serves water utilities or if the power supply is interrupted by the electric utility (e.g., to reduce the risk of wildfires), earthquakes, or other natural disasters, operations cannot continue without backup power. For this reason, water (and wastewater) utilities have implemented redundant power systems—such as installing a backup generator or having dual electric feeds to pump stations and treatment plants—at facilities that meet critical customer needs. Solar or wind, especially in combination with battery storage, have been used (Metropolitan Water District of Southern California 2022). It should be noted that, depending on the severity of events, some facilities might be forced to operate on backup generation for long periods of time; as such, several utilities have integrated backup power (New York City 2013). Many utilities are adapting to extremes by retrofitting or hardening existing infrastructure to ensure resilience against extreme temperatures.

3.1.5 Water Quality

Changes in water quality can occur as a result of extreme temperature events, such as algal blooms, and other toxicity issues that result in a deterioration of quality. This is especially important for drinking water utilities because there are federal drinking water quality standards that must be upheld regardless of the changing climate. Utilities have adapted to these changes in several ways, including improving toxicity and quality monitoring systems for both groundwater and surface water systems. Many utilities have opted to automate water quality sampling systems to improve reliability and ensure nothing is missed. The City of Portsmouth, VA, increased monitoring during periods of drought (when the quality was most unreliable) to safeguard the condition of its surface water sources (City of Portsmouth CRWU). Additionally, filtration has been employed by utilities in response to water quality issues such as increased turbidity caused by the quicker melting of glaciers that feed into water systems (AWWA 2023).

3.1.6 Wildfires

Modeling performed in recent studies has estimated that the frequency of extreme wildfire events has more than doubled in the last two decades and will continue to increase as climate change progresses (Cunningham, Williamson, and Bowman 2024). Many wildfire adaptation methods overlap with those attributed to drought because the two often occur hand in hand. A significant secondary impact of wildfires on water utilities is on clean drinking water: many public water systems located in wildfire-prone or wildfire-damaged areas are at an increased risk of being contaminated by fire byproducts like ash and damage-induced mudslides. Several utilities and state agencies have identified a need for utilities to adapt to the increasing risk of wildfire through comprehensive response planning, asset protection, and resource diversification (Jordan Valley Water Conservancy District CRWU). Utilities have adapted to wildfires by updating fire models and training staff on fire management plans. Several have also included the assessment of wildfire risk when siting critical infrastructure or hardening existing critical infrastructure to be more resilient in the event of a wildfire. Several previously discussed adaptation practices are also pertinent to wildfire planning, including the diversification of source portfolios. As is the case with drought response, water utilities may benefit from having redundant sources of water in case of a wildfire-induced emergency. Several utilities have specifically identified wildfires as a foundational reason for either partnering with other local utilities or obtaining access to secondary or tertiary water sources in case primary sources become unsuitable for obtaining drinking water (City of Bozeman CRWU, Evergreen Metropolitan District CRWU). Water utilities may also decide to identify critical facilities and priority customers (e.g., hospitals, schools, or assisted living facilities) to install redundancy measures such as generators or storage systems for emergencies.

Many utilities have identified the benefits of adapting their existing environmental management practices to include practices that reduce the risk of wildfire, especially near critical water infrastructure. Their efforts have included increasing forest monitoring and forest health tracking, increasing soil moisture monitoring, increasing the number and dispersion of weather monitoring stations, and installing and maintaining utility-owned weather monitoring equipment if commercial sources of data are unavailable. These practices are more common for electric utilities but are still occasionally used by water utilities in relevant scenarios.

3.1.7 Flooding

In the reports and resources reviewed for this report, floods were among the most commonly identified forces driving water utilities to implement climate adaptation measures. Flooding has impacted drinking water, stormwater, and wastewater utilities by damaging infrastructure, contaminating clean water supplies, overwhelming stormwater systems, damaging wastewater systems, and more. Both the distribution system as well as the standing facilities (such as pump stations and treatment plants) are at risk of damage from floods.

One adaptation method commonly identified by utilities is to floodproof existing and new infrastructure. Approaches include retrofitting critical infrastructure (particularly electrical infrastructure within utility facilities in flood-prone areas) by either raising the equipment above common flood levels or waterproofing it in other ways, such as enclosing the equipment in waterproof cases. Some utilities have also opted to floodproof the foundation or critical structural barriers of utility facilities and install submersible equipment. Clackamas Water Environment Services (Clackamas Country, Oregon) has identified an intention to build new deep and shallow submersible pump stations (CRWU, Clackamas River Water Providers). More uncommonly, some utilities have decided to construct temporary or permanent flood barriers around their critical infrastructure or facility, such as the Poarch Band of Creek Indians Utilities Authority in Alabama (CRWU, Poarch Band of Indians, AL). Rarer yet, but still applicable, is the complete relocation of critical facilities or infrastructure. Several utilities, including the City of Los Angeles Sanitation in California, have stated interest in fully uprooting certain facilities that are located in floodplains or are frequently affected by flood damage and moving to an alternative location outside common flood areas (CRWU, City of Los Angeles Sanitation).

3.1.8 Sea Level Rises and Storm Surges

Sea level rise is an increasing regional concern for coastal water utilities. The east and southeast coasts of the United States are especially impacted by sea level rise in its current patterns (EPA 2024f). The primary concerns that utilities must adapt to related to sea level rise are the risk of flooding due to storm surges or exceptionally high tides (so-called king tides) and the salination of critical water resources due to rising sea levels or storm surges. In practice, solutions have mirrored the flood-related adaptation methods discussed above, such as relocating facilities or infrastructure away from areas expected to be inundated by sea level rise. One example of sea level rise adaptation is the sea level rise guidance developed by the Seattle Public Utilities' Drainage & Wastewater Line of Business. This guidance specifies that all new projects must be designed to accommodate the sea level rise expected to occur within the lifetimes of the projects (SPU 2019). In Miami-Dade County, FL, the Water and Sewer Department recently constructed a new chlorine building at the Central District Wastewater Treatment Plant. The new building was located at a higher elevation to withstand future storm surges. Additionally, the floor of the building was elevated to a height essentially the same as the roof of the old facility (Miami-Dade County 2021).

3.2 Electric Utility Solutions in Practice

From more extreme cold conditions to higher temperatures and increased wildfire risk, the impacts of climate change on electric utilities vary, particularly by geographic region. As discussed previously, several common climate-related electric system issues across the United States have emerged, including inland flooding or sea level rise, causing equipment damage; increasing wildfire ignition risk, leading to the development of utility programs intended to reduce or eliminate the risk of utility facilities causing wildfires; increased compound events such as high winds and ice, leading to damaged transmission and distribution facilities and customer outages; and extreme temperatures (both cold and hot), driving increased demand on distribution and transmission systems while simultaneously stressing system components with temperatures beyond component ratings. In addition to implementing hands-on solutions to address these concerns, electric utilities have advanced comprehensive planning, modeling, and analysis solutions. The solutions presented below were derived from a diverse geographic representation of U.S. electric utility resource plans, climate vulnerability assessments and their paired mitigation plans, event-specific storm protection plans and wildfire mitigation plans, and more broad-sweeping climate action and energy plans.

3.2.1 Assessments and Resiliency Planning

Electric utilities in several states are performing risk assessments and resiliency planning under various names—including climate change resilience plans (California, New York, Maine, Michigan, and Louisiana), wildfire mitigation plans (California, Nevada, Oregon, Utah, Washington, and Utah), and storm protection plans (Florida)—or implementing them as part of broader resilience plans or distribution system plans (e.g., Colorado, Connecticut, and Hawaii). All of these plans attempt to identify extreme weather or climate change risks facing the utility and strategies to mitigate these risks so as to increase the resilience of the system. At the outset, electric utility climate adaptation processes arose mainly as reactions to major events; in some cases, however, they have led to prescriptive and methodical processes, including both legislative and regulatory requirements (Schellenberg and Schwartz 2024). Similar to water utilities, electric utilities often conduct an array of analyses and assessments to inform contingency planning efforts, including but not limited to climate vulnerability studies, resilience studies, climate risk modeling, extreme event modeling, and infrastructure resilience analysis.

3.2.2 Flooding, Sea Level Rises, and Storm Surges

The growing risk of major flooding is a concern identified by many electric utilities. Flooding can damage electric infrastructure such as power lines and substation facilities and lead to outages. Electric utilities have identified several methods to address flooding concerns. Several have opted to harden existing assets by undergrounding cables, replacing vulnerable transmission and distribution infrastructure, installing flood barriers, raising equipment, relocating equipment, or when possible identifying higher elevation sites to elevate equipment above FEMA flood plains during the initial installation stage. Additionally, critical facilities like substations are often structurally waterproofed with pump systems installed to prevent significant damage.

Sea level rise and storm surges can significantly impact electric systems by flooding important assets and damaging critical infrastructure. Storm surge incidents have historically caused major power outages in vulnerable coastal areas of the United States and can be extremely dangerous for staff working to restore power. Coastal regions, especially those in the southern U.S., can expect the coastline to rise 10–12 inches over the next 30 years (Florida Climate Center n.d.). Rising sea levels exacerbate storm surges and put pressure on utilities to consider the integration of sea level rise projections into their long-term planning efforts. Sea level rise and storm surge adaptation methods mirror flood-related adaptation methods, including hardening existing assets, installing flood barriers, and installing pump systems in critical facilities. Con Edison has implemented several strategies to deal with flooding and sea level rise to make their infrastructure resilient to a 100-year storm and 1 foot of sea level rise (Con Edison 2023b). This solution takes into account both existing and future projections of climate change–related impacts and addresses multiple interconnected climate drivers at once.

Extreme events can also include inland flooding from precipitation. The climate resilience plans adopted by NYSEG and Rochester Gas & Electric both include proposals to move substations out of floodplains that are inland and thus subject to flooding from inland precipitation and not storm surges (NYSEG 2023; RG&E 2023).

3.2.3 Wildfires

As mentioned, wildfires are becoming increasingly common and harmful in the United States as a result of climate change. Wildfires are a two-sided issue in the context of electric utilities. Wildfires have caused significant damage to electrical infrastructure that has resulted in major outages (consider the California wildfires of 2020, which collectively caused millions of customers to lose power). The second side of the wildfire issue is the potential financial liability to utilities that cause wildfire ignitions. Settlements in three recent cases have topped $1 billion. In Hawaii, the Maui wildfire global settlement called for Hawaiian Electric to pay $4 billion to victims (Yamachika 2024). The California Camp Fire in 2018 caused 85 deaths and was attributed to PG&E mechanical failures and a failure to maintain adequate tree strike clearances (Physicians 2021). PG&E's total settlement agreements totaled over $25.5 billion (CA PUC 2019). In Oregon, PacifiCorp has paid over $1 billion in settlements related to the 2020 Labor Day weekend fires, and additional claims are yet outstanding (Stempel 2024).

Utilities have implemented solutions that address both sides of the issue, such as environmental management practices to prevent the ignition of wildfires as well as efforts to harden infrastructure so as to improve resiliency in the event of a fire. Many utilities are expanding their vegetation management practices to be more robust or cover a larger geographic area. For example, PG&E has taken several steps to adapt to wildfires, including vegetation management, which involves the removal of trees or other plant material surrounding electrical infrastructure such as power lines. Additionally, PG&E has undergrounded over 10,000 miles of power lines and has hardened existing infrastructure with stronger poles (PG&E n.d.). Several utilities are also enhancing safety settings on targeted powerlines to accelerate emergency power shutoffs to prevent fire ignition during high-risk wildfire weather conditions (PSE n.d.; PacifiCorp 2023; PG&E 2022). The enhanced settings enable the utility to deenergize a line faster when it comes in contact with vegetation, animals, or flying debris and keep the line in a deenergized state until a line crew can verify it is safe to reenergize.

3.2.4 Extreme Cold Events, Winds, and Icing

Extreme events and natural disasters, such as hurricanes, tsunamis, landslides, and blizzards, are the primary cause of major power outages in the United States (Climate Central 2024). Wind and ice loads are a primary concern for electric utilities facing natural disasters like hurricanes and blizzards because these loads can create situations where lines contact foliage or structures. Trees or tree branches brought down by wind or ice can fall onto lines or poles, breaking poles or crossarms and bringing power lines down. For the purpose of designing systems to meet wind and ice loading, utilities follow the National Electrical Safety Code rule for extreme ice conditions, which varies by region. Several utilities, including NYSEG, RG&E, and Consumers Energy in Michigan, have conducted climate-forward asset planning in accordance with their regional classifications and designed facilities and lines to withstand greater loads of ice and wind. Similarly, Entergy Louisiana employed equations within the National Electrical Safety Code wind-loading rule to determine a 150-mph design criterion for distribution facilities in areas closest to the Gulf of Mexico, which frequently experiences hurricane-force winds (Entergy Louisiana 2022). Beyond revising design parameters and updating equipment to follow industry standards, utilities are also performing a myriad of asset-hardening and vegetation management activities to prepare for wind and ice impacts to infrastructure. The use of “tree wire”—which has a relatively low risk of causing an outage in the event of contact between vegetation and wire—and removal of danger trees are common ways of dealing with both wind and ice risks. Some utilities are also proposing to completely remove vegetation around and encroaching upon power lines (ground-to-sky programs) by using herbicides beneath power lines to prevent undergrowth, deploying special sensing equipment such as light detection and ranging (i.e., LIDAR) to identify vegetation encroaching on power lines, and removing trees known to fare poorly in specific conditions or prematurely die, which would in turn pose an outage hazard (Entergy Louisiana 2022; Central Hudson 2022; FPL 2022).

Recent events such as Winter Storm Uri have highlighted the need for utilities to be prepared to deal with extended periods of extreme cold. Cold snaps have impacted electric utilities by freezing fuel supply infrastructure and increasing the demand on the distribution system from customers requiring more heat. Utilities have implemented several adaptation solutions to address these impacts related to asset hardening and backup power distribution planning. Several utilities are weatherizing facilities susceptible to freezing, such as substations and power lines, and conducting routine testing of these facilities to ensure reliability. Undergrounding portions of vulnerable circuits and replacing transmission and distribution line segments that cannot meet existing needs have also been solutions adopted by many utilities.

Furthermore, utilities are recognizing the importance of localized and distributed energy resources, such as solar, wind, and small hydropower, in supporting consumers while the bulk system is down as a result of an extreme event (San Miguel Power Association n.d.). Figure 2 highlights Winter Storm Uri, a cold snap in Texas that caused a loss of power for millions and hundreds of deaths in 2021.

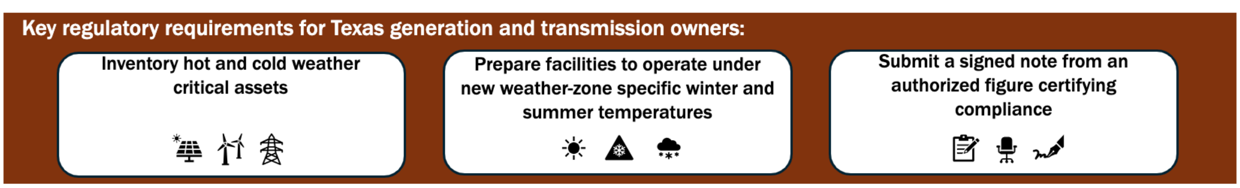

Figure 2. Texas Model for Adapting to Extreme Cold

3.2.5 Temperature Rises and Extreme Heat Events

Similar to extreme cold events, extreme heat events and consistent average temperature rises have incited utilities to adapt existing infrastructure and practices. Extreme heat has caused damage to electric systems through equipment failure, which can result in outages. Electric equipment is designed for use within a specified temperature range. At temperatures above design levels, equipment capacity can be derated or equipment damage or failure can occur. In the case of transformers, issues arise when temperatures exceed either the maximum outdoor ambient temperature for which the transformer is designed or when average temperatures over some period (e.g., 24 hours) do not fall low enough to allow the equipment to cool down. To reduce loading, utilities can call for voluntary demand reductions and implement all demand management programs or implement voltage reduction methods. If this is insufficient, utilities are forced to choose between rotating outages to protect the equipment or operating at temperatures above the design threshold. Moving forward through climate adaptation plans, utilities can plan for future conditions that are hotter than those of the past. For example, New York State Electric & Gas previously used design criteria for substations with average temperatures not above 86°F over any 24-hour period but later changed this threshold to 95°F after reviewing downscaled temperature projections (NYSEG 2023). Other adaptation methods have included similar weatherization and hardening techniques related to the cold weather events discussed above as well as incorporated the implementation of new equipment standards rated for higher temperatures and the changing fill material of cables to prevent damage. Utilities in regions where extreme heat is a primary concern (such as the American Southwest) have made a concerted effort to protect staff members from injury as a result of heat exposure by increasing protective gear and conducting safety planning for facilities with high risk.

Texas Winter Climate Adaptation: Lessons from ERCOT for Extreme Cold Weather Conditions

In 2021, Winter Storm Uri poured record amounts of snow over Texas, resulting in over 4 million customers losing power and over 240 deaths (Plautz 2024). Overreliance on natural gas for power restoration, lack of resource diversity to jump-start the grid, and inadequate weatherization of generators were key contributors to the prolonged, deadly outages (FERC et al. 2021). Since then, critical resilience measures have been issued to improve electric system performance, allowing the state to navigate two major winter storms in 2022 and 2024 without any blackouts (Plautz 2024). Following the aftermath of Uri, the Public Utility Commission of Texas adopted new and expanded rules for weather emergency preparedness of power generators and utilities (PUCT 2022b). These rules were issued in two phases—in 2021 and 2022, respectively—and contain several provisions utilities must begin adhering to as of 2023 (ERCOT 2022). These include requirements for market participants to inventory hot and cold weather critical components; fix any critical issues caused or exacerbated by Winter Storm Uri; prepare generation and transmission facilities to operate under new weather-zone specific summer and winter temperature standards (e.g., ensuring sustained operation at the ninety-fifth percentile minimum average 72-hour wind chill temperature for applicable zones); and issue a notarized attestation from a CEO or similar authority certifying weather readiness compliance (PUCT 2021, PUCT 2022b, ERCOT 2022). Per these new rules, the ERCOT, which operates Texas's electrical power system, is also required to update its historical weather study every 5 years to account for weather variability and climate change uncertainties (PUCT 2022b). To coordinate the implementation of these climate adaptation measures, ERCOT must also inspect generation facilities (each resource/3 years) and transmission facilities (10 percent of facilities/3 years) on a regular basis to determine compliance, as well as provide inspection reports and grace periods to address deficiencies (PUCT n.d.).

3.3 Planning and Decision-Making Under Uncertainty

As climate change progresses, it becomes increasingly challenging to predict exactly how weather and climatological patterns will manifest and change in the future. Utilities and others can no longer solely utilize past conditions to inform future predictions, and downscaling global climate models has proven to be a difficult task. For this reason, several utilities have identified the importance of planning with a degree of uncertainty. The practice of decision-making and planning under conditions of uncertainty is a growing area of research known as decision-making under deep uncertainty (DMDU). DMDU refers to a set of practices and methodologies used to make informed decisions in situations where the future is highly unpredictable and traditional prediction-based approaches are inadequate. Deep uncertainty exists when decision-makers do not know or the parties to a decision cannot agree upon a solution to a problem, the value of outcomes to differing stakeholders, or the methods required to come to the right decision. Because of the complex, long-term, and uncertain nature of climate change adaptation planning, DMDU practices can assist utilities in developing solutions that are forward-thinking and efficient.

Table 3 highlights an array of DMDU approaches that water and electric utilities can integrate into existing planning processes.

Table 3. DMDU Approaches (Homer et al. 2023)

DMDU Approach	Methodology	Application	Benefits
Robust Decision-Making (RDM)	Proposed strategies are evaluated over a range of plausible futures, using stress testing to evaluate the performance of the strategy over combinations of uncertainties (Lempert 2018). Model runs are plotted to reveal vulnerabilities–where strategies succeed or fail over broad futures–in order to create a robust portfolio of options (Toolkit 2021). Includes robust stakeholder engagement.	Useful when parties may not agree on model accuracy of climate impacts, when probability distributions of impacts are deeply uncertain, or when there are stakeholder disagreements about the value of certain outcomes (e.g., increasing water supply vs. decreasing demand).	Describes strengths and weaknesses of strategies, not characteristics of future, allowing stakeholders to analyze tradeoffs and make informed decisions (RAND Corporation).
Dynamic Adaptive Pathways	“Tipping points” of the current system (or unacceptable outcome thresholds) are identified, policy actions are proposed, and pathways are visualized in a decision tree or score card, allowing for selection of initial and long-term actions based on tradeoffs between strategies.	Effective in decision-making spaces subject to inaction and gridlock or when “tipping point” conditions have already been reached.	Useful when decisions are needed during changing conditions; allows for comparison of alternative strategies (Haasnoot, Warren, and Kwakkel 2019).
Decision Scaling	Stress testing is conducted on the climate change factors of a strategy in order to understand the performance of the strategy and generate new options if needed.	Useful for understanding key climate change impacts simply and quickly.	Scalable to data inputs; can be used with statistically downscaled datasets, perturbed historical climate record, or recently observed data that has been statically modified to generate alternative conditions (Toolkit 2021), (Lempert 2018).

DMDU Approach	Methodology	Application	Benefits
Scenario Planning	A limited set of scenarios are developed that span the range of future uncertainties, based on identified driving forces.	Effective when uncertainty is minimized.	Cost-effective; does not require technical resources or involved stakeholder engagement processes. Can be repurposed for stress tests (Heiligtag, Maurenbrecher, and Niemann 2017).

4.0 Integrated Water–Electric Adaptation

Adapting and building resilience to climate change is a multifaceted, complex challenge that both electric and water utilities face. Synergies exist across the electric and water industries that can spark co-developed solutions for proactive climate change adaptation. Cascading climate-induced conditions require symbiotic solutions between electric and water utilities. Cascading climate impacts occur when one climate-related event sets off a series of interconnected effects that spread through different sectors and systems, magnifying the overall impact. These cascading effects can be complex and can influence natural and human systems in unforeseen ways. In many cases, electric and water utilities in a region share the same climate risks, such as wildfire and sea level rise, serve the same communities and critical infrastructure points simultaneously, and face similar challenges in the face of planning under conditions of uncertainty. Water utilities need power to operate, and water utilities represent large loads and revenue sources for electric utilities. Water is a critical infrastructure point for electric utilities as well, in terms of daily operation and fire protection. In some cases, like Con Edison, the electric utility is associated with a steam system that requires water as a critical input. Working together can not only bring about new, diversified perspectives and create avenues of redundancy and resilience but also potentially reduce costs (e.g., if an electric utility is already digging to underground wires and water utility pipes nearby also need hardening or replacement, the utilities may be able to complete these efforts concurrently and avoid additional construction). Additionally, many electric and water utilities share the same overarching goal of decarbonization, which can also be achieved through collaborative efforts. For example, a water utility intending to decarbonize may work with its electric utility to interconnect on-site generation or storage. For this reason, it can be highly impactful for electric and water utilities to build partnerships in which they can work in tandem to create synergistic solutions and co-adapt to climate change together.

Many of the water utilities surveyed for this report are driven by state-level requirements to minimize their greenhouse gas footprint. Others are driven by local ordinances or mandates. In response to these types of requirements, many water utilities are either installing solar or solar plus storage, investigating doing so, or investigating other means of renewable energy generation. In many cases, responding to state or local requirements dovetails with a need to ensure that the water utility has access to electricity, even when their electricity supplier is experiencing outages. As noted below, some water utilities see self-generation as a hedge against electricity price increases. In the review of water utility plans, renewable resource and related plans included the following:

a. Solar photovoltaics and energy storage
b. Generators installed on water supply pipes or inline hydropower turbines
c. Wind turbines
d. Cogeneration using biogas from wastewater treatment plant digesters, including the incorporation and processing of food waste in addition to the incoming sewerage
e. The electrification of fleet vehicles to enable the utility to meet greenhouse gas goals and more fully utilize distributed energy resources installed at the utility's facilities

Part of the impetus for implementing renewable generation can be to provide a hedge against electric utility price escalation. The supply and price protection provided by installing energy generation capabilities at water utilities is important because their electric bill is one of their largest operating costs. From the other perspective, water and wastewater facilities represent large loads for electric utilities. In an era when electric utilities are seeing a resurgence of growth in electricity demand (DOE 2024), collaborating on renewables at water and wastewater facilities is a significant area where electric and water utilities can mutually benefit.

Table 4 below provides a summary of adaptation solutions for climate resilience for both water and power utilities. Water and power utilities can coordinate on these actions.

Table 4. Integrated Water–Electric Adaptation Solutions

Climate Driver	Associated Impacts	Adaptive Solutions
Climate uncertainty	Lack of certainty for future climate conditions and lack of data to inform decisions	Conduct climate vulnerability and infrastructural resilience studies; develop climate resilience metrics
		Create and integrate climate risk modeling (i.e., scenario modeling or downscaling global climate models)
		Implement DMDU practices
	Need to adjust/improve emergency planning and response	Develop emergency response plans and practice implementation
		Implement or improve public advisory and emergency alert systems
Sea level rise and storm surges	Flooding of assets, equipment damage	Protect vulnerable electric and mechanical equipment (e.g., waterproof buildings, use submersible pump stations and construct permanent or temporary flood barriers)
		Replace or relocate vulnerable infrastructure or utility buildings away from flood zones
	Emergency response for storm surges	Install emergency alert systems for vulnerable infrastructure
		Train staff for emergency planning and response; conduct contingency planning regarding access to flooded sites including coordination with local government
	The need for longer-term design and planning	Conduct sea level rise and storm surge modeling and replace or update vulnerable infrastructure accordingly
		Implement flexible and adaptive approaches and identify signposts and thresholds to trigger additional action

Climate Driver	Associated Impacts	Adaptive Solutions
Extreme temperature events (i.e., heat waves or cold snaps)	Equipment failure/damage	Weatherize equipment and develop new equipment standards for expected temperatures; install or have redundant equipment on-hand
		Replace aging infrastructure, weatherize facilities susceptible to freezing and failure due to freezing; maintain and test weatherization systems prior to each winter
	Worker heat stress	Increase ventilation or active cooling in vaults, confined spaces, and in the field
		Develop worker safety programs, including temperature and time thresholds for workers
Drought or changes in water quantity or the timing of water availability	Changes to precipitation timing and type	Conduct flooding studies and increase flood control measures
	Drought preparedness	Develop drought contingency plans and demand management plans (i.e., focused on water supply or water for hydropower and thermoelectric cooling)
	Increased risk of wildfire	Increase use of monitoring such as soil moisture monitors in the watershed and increase the specificity of weather forecasting by collecting watershed-specific data; create or update fire models and practice fire management plans
Extreme weather and natural disasters	Equipment failure/damage including loss	Ensure redundancy through backup power and redundant equipment; retrofit or harden existing infrastructure; enter into mutual aid agreements
	Flooding due to heavy precipitation	Construct flood barriers and floodproof critical infrastructure; move equipment out of projected flood zones
	Extreme-event-based power outages	Install and exercise on-site generation (such as solar, wind, biogas, and small hydropower), energy storage, and demand-response or backup generators for critical loads; have dual power feeds for treatment plants and pump stations
		Coordinate in advance with power utility to avoid inadvertent load shed during power supply shortages

5.0 Extending Climate Adaptation to All Communities

Communities experience different levels of climate risk due to a variety of factors. Depending purely on where they are physically located, some communities can experience greater than average exposure to extreme heat, flooding, outages (in terms of duration or frequency), and water quality issues. Communities situated at the end of radial transmission or distribution lines have tended to experience longer than average outage times during major events simply due to the way restoration work rolls outward from the main, central facilities toward the ends of radial facilities. Where these communities with higher outage vulnerability overlap with historically disadvantaged communities, utility customers may have a lower capacity to adapt to power and water outages. They may also struggle to recover after extreme events, including covering the costs of repair and food replacement. Another customer group that can be vulnerable is people who rely on power for medical devices. People needing electricity for medical devices such as supplemental oxygen have been particularly at risk in the event of a power outage. Thus, in some states, regulatory commissions have focused on ensuring that the benefits of climate adaptation work extend to all communities and that nobody gets left behind (see California Public Utilities Commission 2020 for an example of such regulatory commission focus).

Different geographic communities and vulnerable populations experience risk in unique ways, including indigenous populations, rural populations, and older adults (EPA 2024b). Rural populations face the same risks as those in urban area (i.e., the same heat, flooding, and wildfire risks), but with additional compounding factors—for example access limited to one road into an area that, if washed out by a major rain event, poses extreme challenges to recovery and rebuilding efforts. Identifying vulnerable communities and populations and their specific vulnerabilities can help utilities understand where risks are greater than average across their service territory and help address these differential risks. Targeting actions specifically in such communities or incorporating considerations into existing decision-making processes and frameworks can help achieve this goal.

Targeting resources based on level of vulnerability can limit costs and reduce the risk of loss of life in areas that would be at the greatest risk. Actively seeking to incorporate stakeholder input from communities identified as vulnerable can both improve outcomes for all communities and potentially improve buy-in for projects and reduce opposition that can delay capital projects.

Failure to address at-risk communities in resilience and adaptation planning may deepen the divide between people who can independently afford to weather storms and those who cannot. Those who cannot afford to adapt or to simply leave the area often suffer repeated impacts, all while having limited financial resources to recover from extreme events.

Water and electrical utilities are incorporating community considerations into their climate adaptation plans and actions in different ways. Public utility and service commissions in Illinois, New York, California, and Michigan have been tackling the dual challenges of climate adaptation and community concerns in recent rules in order to make the outlaying of investment in physical resources and infrastructure serviceable for future generations. Table 5 describes some actions that utilities can take to incorporate community concerns into their climate resilience planning. The actions identified in the table are drawn from climate adaptation and resilience plans analyzed throughout this report; the specific utilities that have taken these actions can be seen in further detail in Table 6.

Table 5. Actions Utilities Can Take to Support Community Concerns in Climate Resilience for Water and Electric Systems

Category	Potential actions
Metrics and mapping	Develop maps that provide utility infrastructure system information overlaid with socioeconomic context
	Move beyond traditional system-level reliability metrics to identify areas experiencing disproportionate reliability problems
	Compare utility spending in underserved communities to spending other geographic areas
	Develop and report on metrics, including those that address investment, participation, costs, reliability, accessibility, health and well-being, environmental impacts, social indicators, and economic indicators
Distribution of benefits	Identify which resilience measures benefit disadvantaged communities
	Set goals for the percentage of investments that should benefit underserved communities
Community engagement	Develop and follow community engagement plans when conducting resilience or climate vulnerability assessments
	Implement stakeholder working groups or community groups
	Provide onboarding and education for working group members
Targeted infrastructure deployment	Consider strategically placed microgrids or long-duration mobile energy storage to support areas with reliability or resilience challenges
	When weighing potential investments, develop a process to flag where investments would support community resilience and use that to help identify and prioritize projects
Equity in planning	Develop engagement principles to guide getting feedback on major projects and actions
	Incorporate community resilience in multi-criteria decisional analysis
Partnering with communities	Team up with community organizations to support community resilience activities

The methods that utilities use to incorporate community resilience into utility planning include leveraging existing community organizations and networks within their service territory, incorporating stakeholder input into existing processes, distributing benefits to disadvantaged communities to correct for historic underinvestment, deploying infrastructure to target communities with higher risk, and incorporating equity as a parameter in decision-making. Table 6 includes several community resilience actions taken by water and power utilities to date. This table is intended as a varied cross section of utility actions and is not exhaustive.

Table 6. Community Resilience Actions Taken by Water and Power Utilities

Category	Utility	State	Issue/Solution—Community Resilience Actions
Use of mapping and equity metrics	Consumers Energy Company	Michigan	**Issue:** Provide information on environmental justice and related data in the Electric Distribution Infrastructure Investment Plans, including maps that overlay system information with socioeconomic context (Consumers Energy 2023). **Solution:**

Category	Utility	State	Issue/Solution—Community Resilience Actions
			"Grid Archetypes" approach to consider circuit characteristics beyond reliability metrics to ensure all customers benefit equitably from investments and no section of the grid is left behind. By overlaying data on maps of environmental justice communities, they have been able to compare the distribution of spending in environmental justice communities and outcomes within their service territory.
	Southern California Edison	California	**Issue:** SCE needed equity metrics to incorporate into its adaptation work. **Solution:** SCE asked the RAND Corporation to develop metrics. In the resulting metrics Rand used the California Energy Commission's clean energy equity indicators, which include objectives around access to clean energy, investment in low-income and disadvantaged communities, and local energy resilience and services. The final list of metrics focused on public investment inputs and activities, participation, customer costs, service reliability and accessibility, and health and well-being (Kalra et al. 2022).
	San Diego Municipal Water District	California	**Issue:** Create a climate equity index to measure opportunity across the City of San Diego and the degree of potential impact from climate change to these areas. **Solution:** Equity indicator categories include environmental, socioeconomic, housing, mobility, and health metrics (City of San Diego n.d.-c). This index was used to implement the city's Climate Action Plan (City of San Diego 2022), which shares the actions taken thus far in a dedicated dashboard.

Category	Utility	State	Issue/Solution—Community Resilience Actions
	PG&E	California	**Issue:** For its Climate Adaptation and Vulnerability Assessment, PG&E needed tools to assess the adaptive capacity of communities and to align with feedback acquired during the community engagement process (Gazda 2024). **Solution:** PG&E developed measures using the Baseline Resilience Indicators for Communities index. This index measures six categories of community disaster resilience: social, economic, community capital, institutional, infrastructural, and environmental. The Baseline Resilience Indicators for Communities scores were used to create composite scores for regions and to help in designing and targeting policy (Bengtsson 2024)
Distribution of benefits	NYSEG	New York	**Issue:** The Climate Leadership and Community Protection Act (New York) mandates that no less than 35 percent, with a goal of 40 percent, of the state's climate action benefits go toward disadvantaged communities (NYSEG 2023). **Solution:** NYSEG is actively identifying which resilience measures included in its Climate Change Resilience Plan benefit disadvantaged communities.
Use of stakeholder working groups/community engagement	California Public Utility Commission	California	**Issue:** Ensure utilities engage with vulnerable and disadvantaged communities to ensure they are not left behind as utilities develop Climate Adaptation and Vulnerability Assessments. **Solution:** Utilities are required to file community engagement plans every 4 years, and 1 year before the filing of the vulnerability assessment. Utilities must meet with community-based organizations and disadvantaged vulnerable communities in developing their plans. (California Public Utilities Commission 2020)

Category	Utility	State	Issue/Solution—Community Resilience Actions
	Austin Water	Texas	**Issue:** In developing Water Forward, Austin's adaptive 100-year integrated water resource plan, Austin Water sought to develop tools for transparent decision-making and equitable distribution of benefits and burdens. **Solution:** Austin Water created a Community Ambassador's Group with members from across the city selected as ambassadors. The Community Ambassadors Group guided the development of the Equity and Affordability tool used to assess the impacts of the integrated water resource plan strategies. The tool includes themes viewed through an equity lens, including water supply reliability, public health, accountability, and affordability (Austin Water 2024).
Targeted infrastructure deployment	San Diego Gas & Electric	California	**Issue:** Borrego Springs had a history of outages due to environmental conditions (high winds and monsoonal storms). Extreme conditions and location at the end of a single transmission line made it very vulnerable to long-duration outages (Katmale et al. 2019). **Solution:** Develop a renewables-based microgrid to enable the islanding of the entire Borrego Springs community to independently provide power to the community. San Diego Gas & Electric built a renewable energy-based microgrid (26 MW photovoltaic system; 3 MW of rooftop solar; two 1.8 MW distributed generation resources; two substation batteries and three community energy storage batteries) that can provide power to the entire community during the day and that has the ability to drop to serve only critical loads at night (Katmale et al. 2019).

Category	Utility	State	Issue/Solution—Community Resilience Actions
	Green Mountain Power	Vermont	**Issue:** Green Mountain Power (GMP) proposed establishing resilience zones in areas with a history of challenging reliability statistics, with no distribution feeder backup and taking into account whether the subtransmission is looped or radial, and where the community is underserved or unserved with broadband and has poor or no cellular service (GMP 2020). **Solution:** GMP partnered with NOMAD Transportable Power Systems to establish resilience zones using long-duration mobile energy storage (GMP 2023, GMP 2022). GMP plans to add three more resilience zones to its service territory per year to provide backup battery power and local renewable power generation to keep communities connected during severe weather (DOE 2023, Vermont Biz 2024).
Incorporating equity into existing planning frameworks or software and tools	Consumers Energy Company	Michigan	**Issue:** In response to regulatory commission expectations, Consumers Energy Company needed to develop distribution planning tools to prioritize circuits where environmental justice considerations intersected underperforming circuits. **Solution:** Consumers Energy integrated environmental justice considerations into its Grid Archetype planning methodology. The process includes certain “flags” that help prioritize circuits. Consumers Energy added a new flag in 2023—whether a circuit intersects with an environmental justice census tract. If a circuit triggers two or more reliability flags, it is prioritized. Consumers Energy will also be using environmental justice status as a tiebreaker moving forward when comparing two otherwise equal circuits while prioritizing them for forestry work when comparing traditional reliability performance (Consumers Energy 2023).

Category	Utility	State	Issue/Solution—Community Resilience Actions
	Con Edison	New York	**Issue:** Con Edison has prioritized working with a Climate Resilience Working Group for years to improve its community outreach and distribution of resources. The working group recommended additional focus on environmental justice and prioritization, including equity. **Solution:** The Con Edison Environmental Justice Working Group (Con Edison 2023b) was formed to apply an equity lens to its operations and programs. Con Edison also reports the dollar amount of investments in disadvantaged communities and tracking outages that occur there. It identifies disadvantaged communities as part of the Project Prioritization Selection Criteria in the Climate Change Resilience Plan in order to consider equity in the plan's implementation.
	Eversource	Massachusetts	**Issue:** Eversource needed an approach to guide its Electric Sector Modernization Plan process to enable equitable outcomes for all communities and customers. **Solution:** Eversource developed an Equity Framework to deliberately increase engagement and communication with communities that have historically been marginalized. The Equity Framework includes: engagement principles to guide the company's solicitation of feedback on major projects and actions going forward proactively soliciting stakeholder input ensuring stakeholders and communities feel respected and that the work supports their dignity mitigating negative community outcomes from company activities operationalizing equity into daily business practices, decisions, and processes (Eversource 2024).

Category	Utility	State	Issue/Solution—Community Resilience Actions
	National Grid	New York	**Issue:** National Grid needed a mechanism to solicit stakeholder input and to engage communities, customers and advocates at the front end of decision-making. **Solution:** National Grid created the Climate Resilience Working Group to participate in creating the Climate Change Resilience Plan (NationalGrid 2023). National Grid incorporated state disadvantaged community metrics and identification in its planning and community resilience into its business justification framework, which compares its historic reliability to others in the service territory. National Grid is also working to incorporate resilience benefits as part of the value models for resilience projects. The tool it developed provides visibility on whether a project serves a disadvantaged community or not.
	Central Hudson Gas & Electric	New York	**Issue:** Central Hudson needed a mechanism to incorporate community resilience into the development of its climate change resilience plan (Central Hudson 2023). **Solution:** Central Hudson developed a multi-criteria decisional analysis to select and prioritize resilience measures. The criteria for community resilience include the extent a project will reduce impacts to customers that need life support equipment, how it provides benefits to the community beyond Central Hudson infrastructure, and whether it provides benefits to customers from disadvantaged communities.
Partnering with community organizations	Entergy New Orleans	Louisiana	**Issue:** Following extreme weather events, including hurricanes, flooding, and heat waves, community leaders and citizens collaborated to identify mechanisms to strengthen community resilience. **Solution:** The Feed the Second Line's "Get Lit, Stay Lit" initiative works to transform local restaurants into community hubs by helping them install microgrids. Entergy New Orleans has partnered with "Get Lit, Stay Lit." Entergy New Orleans contributed $250,000 to fuel the Feed the Second Line mission of prioritizing resilience, renewable energy and community empowerment (Henry 2024).

Category	Utility	State	Issue/Solution—Community Resilience Actions
	Camden County Municipal Utilities Authority	New Jersey	**Issue:** Camden faced numerous complex environmental issues and desired proactive, holistic, and innovative solutions to help Camden become a vibrant, sustainable city. **Solution:** The Camden County Municipal Utilities Authority partnered with the City of Camden, Camden Community Partnership, the NJ DEP, and the U.S. EPA to create the Camden Collaborative Initiative (Camden County n.d.). The initiative collaborates to address topics of water resources, air quality, waste management and land. Separate working groups focus on each of the four main topics. In the water resources topic area, the working group is tackling issues related to water quality, stormwater management, sustainability, water equity, and other quality of life and environment issues for the residents of Camden, NJ (Camden County n.d., Camden Collaborative Initiative 2023, US Water Alliance 2019).

6.0 Conclusion and Next Steps

Climate change is irrevocably impacting the power and water industries. Severe and extreme weather events strain the resources of electric and water providers, exposing critical infrastructure to more intense events and driving events that deprive electric and water services for periods extending up to several weeks. There is a need to identify risks related to climate change and proactively plan for upgrading and operating utility systems to handle such risks. Several states have required utilities to identify and address their service territory's major climatic vulnerabilities and develop plans to address those vulnerabilities. Some utilities have proactively developed climate vulnerability assessments and mitigation plans without state requirements.

While the impacts of climate change have been extremely costly for utilities, in many instances, there are positive examples of resilience through adaptation that have prevented extensive infrastructural damage, avoided costs, prevented wildfires, and averted major outages. **This compendium of climate strategies provides a collection of reference points for water and electric utilities seeking to increase or improve adaptive capacity within their respective communities**.

The solutions listed in this compendium are currently being used. Examples presented are based on a survey of utility climate vulnerability assessments and mitigation plans, water industry master water plans and drought management plans, wildfire mitigation plans, and storm protection plans. This compendium draws upon plans developed from all regions of the country in a deliberate effort to discuss as many climate risks as possible and present proposed adaptive measures. Because it is a survey and not a census, this report is not exhaustive. However, it captures a range of solutions that address major climate vulnerabilities that utilities have identified. There are likely more solutions in practice within utilities that do not currently have a public document or that were not available when this compilation was assembled and that were therefore not included in this report. It is equally likely that as water and electric utilities gain more experience in making their systems more resilient, additional solutions will be developed. **It is in the best interest of water and electric utilities alike to stay up-to-date on evolving adaptation methods and coordinate and collaborate with other utilities and entities.**

The electric and water sectors are inseparable. In understanding the array of solutions that have already been implemented, **water and electric utilities can learn from each other** and potentially identify areas of overlap. Power costs are one of the largest operating costs for water utilities, and for many electric utilities, the total amount of electricity required by the water utility is a significant load. During extreme weather events, issues with electric power can significantly impact the water utility, and vice versa. Thus, the systems are inextricably intertwined, and **co-adaptation methods can lead to impactful, system-level outcomes for both the water and electric sectors**. This report explores how power and water utilities adapt to climate change, highlighting areas of opportunity to develop harmonized strategies between sectors. It also highlights ways electric and water utilities have advanced resilience outcomes for climate-vulnerable communities. Addressing impacts across water and electric sectors can lead to more comprehensive, holistic approaches to climate change adaptation and to partnerships that strengthen resilience and provide economic benefits to both sectors.

While the purpose of this paper is to document and organize existing adaptation strategies, there is more work to be done moving forward. It is hoped that as utilities continue to gain experience with climate resilience adaptation, they will share the results of their efforts with the greater utility community—in the form of publications, conference papers, or both. To further the work of sharing information and discovering ways that utility sectors can collaborate, workshops and conferences that invite experts from both water and electric utility sectors could go a long way toward breaking down silos and finding mutually beneficial ways to coordinate to improve resilience overall.

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