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Paying for Climate Disasters on the Water Bill









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AUTHORS
Morgan Shimabuku
Shannon M. McNeeley
Rebecca Anderson

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ABOUT THE AUTHORS

Morgan Shimabuku

Morgan Shimabuku is a program manager at the Pacific Institute. She conducts research on a wide range of water management issues, including solutions to water equity and access challenges, benefits and tradeoffs of water management strategies, and a universal approach for measuring water resilience at the basin scale. Prior to joining the Pacific Institute, Morgan was a senior program manager at an environmental nonprofit in Colorado where she ran residential and commercial water conservation program operations in partnership with municipal water providers. Previously, she worked as a scientist at a water resource consulting firm and supported the PacFish/InFish Biological Opinion Effectiveness Monitoring Program (PIBO) of the US Forest Service as a stream technician. Morgan received a bachelor's degree in environmental studies and geology from Whitman College and a master's degree from the Department of Geography at the University of Colorado Boulder, where she studied climate change, hydrochemical cycling, and snow hydrology at the Institute of Arctic and Alpine Research.

Shannon M. McNeeley

Dr. Shannon McNeeley is an associate director at the Pacific Institute and the Water and Climate Equity Program lead. Her work focuses on water and climate equity and justice for frontline communities. This engages an interdisciplinary and cross-cultural co-production approach, incorporating the social and natural sciences along with different ways of knowing to understand human-environment relationships and how people are impacted by and respond to environmental change. Her research has focused on climate change science and policy, water resources and drought preparedness, and climate planning and action, all with a strong focus on supporting those who are overburdened and underresourced through just and equitable solutions. Dr. McNeeley has worked closely for decades with a multitude of different partners, organizations, decision makers, Tribes and Indigenous peoples, and frontline communities, bridging technical research with applied decision-support information and tools. Prior to joining the Pacific Institute, she was at the North Central Climate Adaptation Science Center at Colorado State University and before that at the National Center for Atmospheric Research. Dr. McNeeley holds a master's degree in international environmental policy from the Middlebury Institute of International Studies at Monterey and a doctoral degree in environmental change and sustainability science, which integrated anthropology, ecology, and climatology, from the University of Alaska Fairbanks.

Rebecca Anderson

Rebecca “Becky” Anderson is a funding navigator manager with Environmental Policy Innovation Center (EPIC). She provides technical assistance that connects small, underresourced communities with capacity and resources to access funding and financing for critical water and wastewater infrastructure. Previously, she worked as a researcher in water and climate equity at the Pacific Institute, where she focused on interdisciplinary and collaborative research to advance climate-resilient water and sanitation for frontline communities. Becky has also worked as a program manager at a national environmental nonprofit where she supported underresourced communities in developing locally driven, climate-resilient water projects. Her earlier work includes research on agricultural perspectives on water and climate change in the Colorado River Basin, as well as contributions to the review of Groundwater Sustainability Plans in California. Becky holds a bachelor’s degree in earth sciences from Ohio State University and a master’s degree in geography from Portland State University, where her thesis explored the equity implications of water efficiency tradeoffs.

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Dedication

To future generations who will inherit the earth.

Water is life.



Table of Contents

Acronyms and Abbreviations 8

Glossary 9

Summary 11

1. Introduction 12

2. The Water Affordability-Climate Disaster Feedback Loop 14

3. Causal Pathways from Climate Disaster to Water Unaffordability 16

3.1 Drought and Declining Water Supply 17

3.2 Wildfire 20

3.3 Flooding and Extreme Precipitation 21

3.4 Extreme Temperatures 23

3.5 Increased Energy Demand 23

3.6 Climate Migration 24

4. Strategies and Approaches: How to Disrupt the Water Affordability-Climate Disaster Feedback Loop 25

4.1 Disaster Preparedness 25

4.2 Climate-Informed Management and Planning 27

4.3 Funding, Financing, and Water Rate Design 29

4.4 Legal and Regulatory Protections 32

5. Priority Research Gaps at the Intersection of Water Affordability, Climate Change, and Equity 35

5.1 Utility Finance and Affordability 35

5.2 Geographies and Populations at Most Risk 36

5.3 Equitable, Climate-Resilient Strategies and Other Approaches 37

5.4 Water Affordability in Decentralized Systems 38

6. Conclusion 39

References 41

Figures and Charts

Figure 1. The Water Affordability-Climate Disaster Feedback Loop 15

Figure 2. The Causal Pathway Between a Climate Disaster and Water Affordability Challenges . . . 17

Acronyms and Abbreviations

AMWA	Association of Metropolitan Water Agencies
AWIA	America's Water Infrastructure Act
CAPs	Customer assistance programs
CREAT	Climate Resilience Evaluation and Awareness Tool
EPA	US Environmental Protection Agency
EPIC	Environmental Policy Innovation Center
GAO	US Government Accountability Office
gpcd	Gallons per capita per day
HABs	Harmful algal blooms
IBR	Increasing block rate
LADWP	Los Angeles Department of Water and Power
NACWA	National Association of Clean Water Agencies
NCEI	National Centers for Environmental Information
NOAA	National Oceanic and Atmospheric Administration
O&M	Operations and maintenance
PIEVC	Public Infrastructure Engineering Vulnerability Committee
PVC	Polyvinyl chloride
RCP	Representative Concentration Pathways
SDWA	Safe Drinking Water Act
S&P	S&P Global Ratings
SRFs	State Revolving Funds
TAP	Tiered Assistance Program
US	United States
WARN	Water/Wastewater Agency Response Network

Glossary

Affordable: In general, water service is affordable when a household can pay for the cost of essential water and sanitation, including operating and maintaining their own systems, without forgoing other essential goods and services, such as housing, healthcare, food, and other utilities (Feinstein 2018; Teodoro 2019).

Asset management: The practice of managing capital assets to the appropriate budget for operation, maintenance, and replacement of these assets while delivering optimum service levels (Vedachalam et al. 2020).

Centralized wastewater system: A system in which a network of sewer pipes collects wastewater from homes, businesses, and industries and conveys it to a central wastewater treatment plant. Centralized systems differ from decentralized systems, such as septic systems, which treat wastewater at or near where it is generated, typically for individual properties or small clusters of homes.

Climate adaptation: In human systems, the process of adjustment to actual or expected climate and its effects to moderate harm or exploit beneficial opportunities. Human intervention may facilitate adjustment to expected climate and its effects. Equitable adaptation intentionally incorporates recognitional, procedural, and distributional principles of equity in design, planning, and execution (Grade et al. 2023).

Climate change: A change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere, and which is, in addition to natural climate variability, observed over comparable time periods (United Nations Framework Convention on Climate Change 1994).

Climate migration: The movement of a person or a group of persons, either across an international border or within a nation (Grade et al. 2023), as a result of a climate-related disaster. This migration can result in a significant change in a water utility's customer base.

Community water system: A public water system that supplies water to the same population year-round (US Environmental Protection Agency 2015b).

Disadvantaged communities (DACs): The White House Climate and Economic Justice Screening Tool identified census tracts that were overburdened and underserved. This also included federally recognized Tribes, including Alaska Native villages. Under the Safe Drinking Water Act, a disadvantaged community is the service area of a public water system that meets affordability criteria set by the state in which it is located. The Clean Water Act does not define "disadvantaged community," but it requires states to establish affordability criteria to determine which municipalities are eligible for additional subsidization from the Clean Water State Revolving Fund.

Frontline communities: Communities that are overburdened and underresourced who face disproportionate, "first and worst" impacts of climate change on their water and sanitation systems or access.

Green infrastructure (GI): Interconnected, built urban ecosystems and infrastructure that function together to provide a variety of benefits for water equity, quantity, biodiversity, air quality, urban heat, recreation, and beautification (Grabowski et al. 2023).

Indigenous peoples: Self-determining societies whose political and cultural foundations pre-exist the formation of the United States, regardless of their recognition status by the US government. Indigenous peoples in the United States include the 575 federally recognized Tribes (as of 2026), Native Hawaiians, Pacific and Caribbean Islanders, state-recognized Tribes, and unrecognized Tribes and peoples. More specific terms will be used where the particular government, legal, cultural, or diplomatic situation is being referenced. Indigenous peoples' self-determination can be best respected by using terminology that acknowledges Indigenous governance systems and sovereignty (Status of Tribes and Climate Change Working Group 2021).

Public water system: A water system that provides drinking water through pipes or other conveyance to at least 15 service connections or an average of 25 people for at least 60 days per year. A public water system may be publicly or privately owned. There are three types of public water systems: community water systems, non-transient non-community water systems, and transient non-community water systems.

Safe: Drinking water that meets or exceeds standards set forth by the federal Safe Drinking Water Act, and by any additional standards established by individual states where geographically applicable. Safe sanitation means that the waste is separated from humans, and transported, treated, and discharged to the environment where it is not a liability or hazard to human, wildlife, or environmental health.

Sanitation: The conveyance, storage, treatment, and disposal of human waste. This includes toilets, pipes that remove wastewater from the home, and treatment measures (Roller et al. 2019).

Small water systems: Defined under the Safe Drinking Water Act as community water systems serving 10,000 or fewer people.

Source water: Source water includes natural bodies of water, such as rivers, streams, lakes, reservoirs, springs, and groundwater, that supply water to both public drinking water systems and private wells (US EPA 2015a).

Sufficient: The World Health Organization considers 50–100 liters (approximately 13–26 gallons) per person per day to be the minimum necessary to ensure most basic needs are met. However, this amount may not be sufficient for broader uses of water that are necessary for healthy, resilient households and communities; this represents the bare minimum for health purposes (Feinstein 2018; Gleick 1996).

Wastewater: Water that has been used and disposed of, which often contains contaminants such as untreated human waste, sewage, or sludge.

Summary

Climate disasters alter water supply, quality, and availability and can damage or disrupt water and wastewater systems (i.e., water systems or utilities). As such, water utilities often face immediate recovery costs, longer-term adaptation costs, and in some cases reduced revenue following a climate disaster. These pressures can lead water systems to increase rates, fees, or debt burdens that affect household water and wastewater affordability (i.e., water affordability) because most water system costs are ultimately recovered from ratepayers. When households cannot keep up with rising bills, they may be shut off from water service and their water systems may experience revenue shortfalls that lead to deferred maintenance, workforce cuts, or postponed improvements, leaving systems more vulnerable to future climate shocks.

Here we present a conceptual framework, the Water Affordability-Climate Disaster Feedback Loop, to explain how household water affordability is affected by climate shocks and stresses that damage infrastructure and disrupt a water system's services, thereby triggering a vicious cycle, or feedback loop. Case examples and emerging literature addressing drought, utility responses, and household affordability impacts illustrate how climate disasters reach household bills, creating this loop.

Yet the vicious cycle is not inevitable; there are strategies and tools that water systems, government agencies, technical assistance providers, and communities can use to better prepare for and respond to climate disasters that raise water bills to unaffordable levels. These include actions and measures to increase disaster preparedness, improve climate-informed management and planning, create equitable funding and financing, support intentional rate design paired with customer assistance, and enact legal and regulatory protections. These actions and measures can interrupt the feedback loop at different points. However, significant knowledge gaps remain with a need for research and innovation on how utilities are managing climate-related financial pressures, which geographies and populations face the greatest overlapping exposure to climate stress and unaffordability, and which actions most effectively protect frontline communities. The Water Affordability-Climate Disaster Feedback Loop framework is intended as a foundation to support researchers, utilities, policymakers, and advocates working to ensure that everyone, regardless of income or zip code, has access to safe, reliable, and affordable water and sanitation.

1. Introduction

Water and wastewater services are unaffordable for an estimated 12.1 million to 19.2 million US households (9.2%–14.6%) (US EPA 2024).[1] When faced with an unaffordable bill, households must make difficult decisions between paying their bill or paying for other necessities, such as food, medicine, transportation, or energy. Households unable to pay are at risk of late fees, liens on their homes, or having their water shut off. Because water is essential for day-to-day tasks like cooking, bathing, and using a toilet, this loss can have devastating consequences for a household. For instance, some states consider lack of running water as grounds for removing parental custody (Amirhadji et al. 2013; Levine et al. 2022). At the community level, unaffordable water can undermine public health, economic stability, and social equality, and contribute to psychological and psychosocial stress (US EPA 2024).

Water and wastewater costs are rising, and this is exacerbated by climate disasters, both acute and chronic. We focus on climate disasters that disrupt access to water and sanitation due to hazardous weather events such as floods, droughts, extreme temperatures, wildfires, and hurricanes. These disasters are becoming more frequent and severe due to human activity that alters the composition of the global atmosphere, above and beyond the natural climate variability observed over comparable time periods (United Nations Framework Convention on Climate Change 1994). Climate disasters are placing increasing financial and operational pressure on water and wastewater systems (here referred to collectively as water systems or utilities) across the United States, with the most severe impacts falling on frontline communities that are already overburdened and underresourced (Pacific Institute and DigDeep 2024). These impacts can result in loss of drinking water and sanitation access either temporarily or permanently.

When faced with an unaffordable bill, households must make difficult decisions between paying their bill or paying for other necessities, such as food, medicine, transportation, or energy.

Water systems were designed for historical climate conditions and are ill-equipped to withstand more frequent and intense floods, droughts, heatwaves, hurricanes, wildfires, and sea level rise. Utilities nationwide are being forced to adjust their planning, infrastructure investments, and day-to-day operations to contend with climate impacts affecting water reliability, water quality, operations and

1 Affordability definitions and thresholds can vary widely (Meehan et al. 2020; Pierce et al. 2021). These estimates reflect two affordability thresholds used by the US EPA: combined drinking water and wastewater bills exceeding 4.5% (12.1 million households) or 3% (19.2 million households) of household income.

maintenance (O&M), business functions, and physical infrastructure (Lyle et al. 2023). Retrofitting, repairing, and adapting these systems to climate change requires substantial new investments (Mastracchio et al. 2026; National Association of Clean Water Agencies and Association of Metropolitan Water Agencies 2009; Value of Water Campaign et al. 2024).

Climate-driven costs compound with the need to replace and upgrade aging infrastructure, insufficient and inaccessible low-interest financing, changing regulations, inflationary pressures, and new industrial demands such as those associated with the data center boom (Black & Veatch 2025; Kane 2016; Value of Water Campaign et al. 2024). To address infrastructure renewal, evolving regulatory requirements, alternative water supply development, and climate resilience strategies, the American Water Works Association estimates that a $2.1–$2.4 trillion investment in drinking water systems will be required between 2026 and 2050 (Mastracchio et al. 2026). Because utilities recover most of their costs through rates, these rising expenses are ultimately passed on to customers through water bills (River Network 2021).

Research is emerging on how climate disasters are exacerbating water affordability for frontline communities (Feinstein et al. 2017; Heyman et al. 2022; Nayak et al. 2023; Rachunok and Fletcher 2023; Skerker 2025; Skerker et al. 2026). Some research, focused primarily on drought, has demonstrated the mechanisms by which climate change and water utility responses translate to worse household-level affordability outcomes (here referred to as "water affordability"). However, to date, there has been little research exploring how flooding, wildfires, and extreme temperatures affect water and wastewater affordability. There is also a lack of decision-support information or tools for water system managers, government agencies, technical assistance providers, or communities to address the specific affordability challenges exacerbated by climate change in equitable ways.

To fill these gaps, this report will:

- present a conceptual framework for how climate disasters create a self-reinforcing water affordability feedback loop (Section 2);
- explore the ways that climate change is worsening water affordability (Section 3);
- discuss several key strategies and approaches for breaking the feedback loop (Section 4); and
- identify data gaps and research limitations on the interconnections between climate change and water affordability (Section 5).

We focus on water affordability for households served by community water systems[2] and centralized wastewater systems.[3] In the next section, we present the underlying framework explaining how climate impacts on water systems translate to household water affordability challenges.

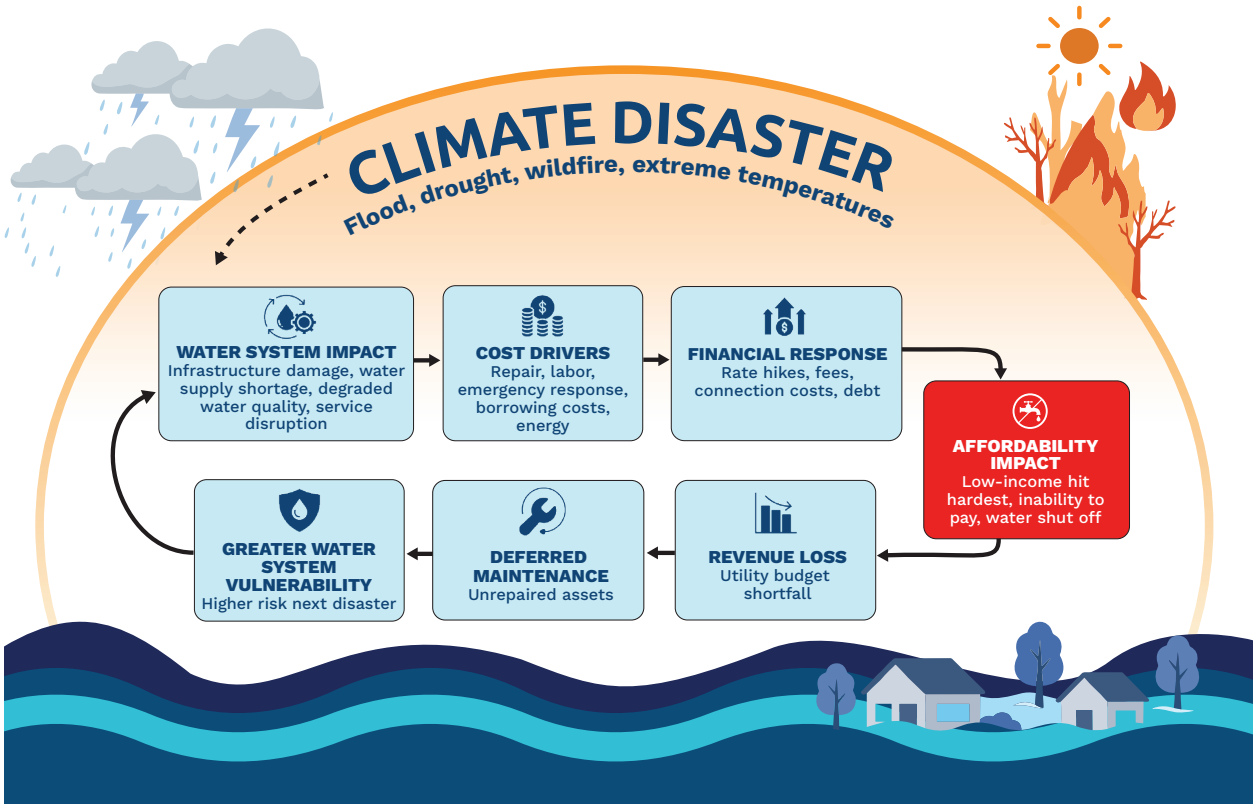
2 A community water system is defined as a public water system that serves water to the same population year-round (US EPA 2015b).

3 Although critically important, it is beyond the scope of this report to address the water affordability challenges faced by people with decentralized, onsite water and sanitation systems like private wells or septic tanks.

2. The Water Affordability-Climate Disaster Feedback Loop

Climate disasters can trigger a self-reinforcing water affordability feedback loop. This feedback loop, depicted as a conceptual framework (Figure 1), contains eight stages, emphasized in italics as they appear in the figure. The loop begins when a *climate disaster* such as a flood, drought, wildfire, or extreme heat produces a *water system impact* by damaging infrastructure, disrupting operations, reducing water availability, or degrading water supplies. Responding to the impact generates new *cost drivers*: utilities may then need to repair facilities, change treatment processes, secure alternative water sources, absorb higher energy and labor costs, or make other costly changes. Because the utility must recover these costs, they prompt a *financial response* in the form of rate increases, new fees, property tax charges, or additional debt. For households already struggling to afford water services, that response can translate into an *affordability impact*, with low-income households hit hardest. When those households cannot pay all or part of their bills, they may have their water shut off, receive extra late fees, or have liens placed on their homes. At the same time, the utility experiences *revenue loss*. Budget shortfalls in turn force *deferred maintenance*, leaving assets unrepaired and capital projects postponed. The result is *greater water system vulnerability*, which raises the likelihood and severity of the next disruption and continues the loop.

FIGURE 1. The Water Affordability-Climate Disaster Feedback Loop



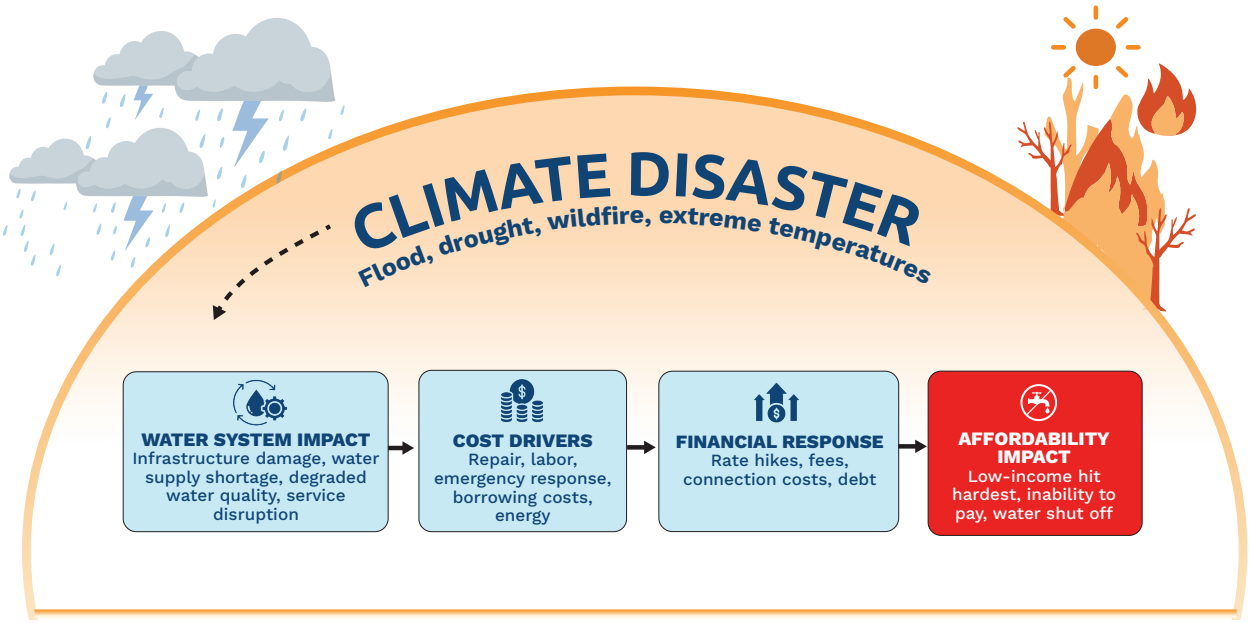
This report examines the evidence base for the mechanisms that create, sustain, and can ultimately disrupt this loop. We focus on climate disasters because they are increasingly frequent and severe, exposing and intensifying preexisting water system vulnerabilities and cost drivers such as aging infrastructure and security breaches, especially in frontline communities. Climate disasters are risk multipliers, adding acute damage, service disruption, water supply and water quality impacts, revenue instability, and new adaptation costs to systems that already struggle to maintain safe, reliable, and affordable service. Climate change also creates distinct planning, funding, and equity challenges for water systems and communities. Although water unaffordability is shaped by many factors, this report focuses specifically on the pathways through which climate-related shocks and stresses affect household water bills. Likewise, we do not suggest that water bill impacts are the only, or even the most severe, consequences of climate disasters. Our focus is limited to affordability outcomes, even though climate disasters can also disrupt employment and income, damage property, displace residents, and cause loss of life.

Climate disasters are risk multipliers, adding acute damage, service disruption, water supply and water quality impacts, revenue instability, and new adaptation costs to systems that already struggle to maintain safe, reliable, and affordable service.

3. Causal Pathways from Climate Disaster to Water Unaffordability

This section explores the first five stages of the Water Affordability-Climate Disaster Feedback Loop: the causal pathways from climate disasters, impacts on water systems, utility cost drivers, and financial responses that can affect low-income households' water affordability (Figure 2). It does this by examining how different types of climate disasters — drought, wildfire, flooding, extreme precipitation, and extreme temperatures — uniquely impact water systems. First, Section 3.1 summarizes emerging research on the linkages between extreme drought, water utility responses, and water affordability. Case examples from climate disasters that have resulted in infrastructure damage, operational changes, utility insurance increases, or bond rating downgrades provide evidence from which household affordability impacts can be reasonably inferred. The next three subsections (3.2–3.4) broaden the analysis beyond drought, showing how wildfire, flooding and extreme precipitation, and temperature extremes can each trigger infrastructure, operational, and water quality costs that may ultimately reach households through rates or fees. Lastly, Sections 3.5 and 3.6 focus on increased energy demand and climate migration, which cut across disaster types rather than stemming from any one type of event. These subsections are therefore organized by impact rather than by event. Even so, they follow the same pathway described above: climate impacts increase utility costs, utilities respond financially, and those responses can place added pressure on household water bills. This distinction matters because event-linked disasters produce repair and recovery costs that are comparatively visible and readily attributed to a single event, while the pressures in the last two subsections accumulate gradually through operations, financing, planning, and demographic change. Those diffuse costs are harder to trace back to climate change and therefore easier to overlook in utility planning and affordability policy, but they reach household bills through the same loop.

FIGURE 2. The Causal Pathway Between a Climate Disaster and Water Affordability Challenges



3.1 DROUGHT AND DECLINING WATER SUPPLY

Drought serves as a starting point for this discussion because the evidence for causal pathways is the most developed. Severe droughts can increase costs for water systems by reducing water supply and forcing utilities to rely on more expensive or less reliable sources. During prolonged drought conditions, utilities may need to purchase supplemental water, increase groundwater pumping, or treat lower-quality supplies, raising supply and O&M costs (Feinstein et al. 2017; Heyman et al. 2022; Porse et al. 2023). Persistent droughts and long-term shifts in water availability may also lead utilities to evaluate or invest in new supply infrastructure, including water transfers, aquifer storage and recovery, direct potable reuse, and desalination, although the feasibility and necessity of these options are context-specific (Jordan 2026; Skerker 2025; Skerker et al. 2026). Drought can also degrade groundwater quality in some settings and alter the quality of rivers, lakes, and reservoirs, although these effects vary by hydrologic system and pollutant (Levy et al. 2021; Mosley 2015). Such degradation may increase treatment or other water-supply costs, but the evidence linking drought-induced quality changes specifically to higher drinking-water treatment costs is more limited (Feinstein et al. 2017). At the same time, mandatory or voluntary conservation can reduce volumetric sales revenue while leaving utilities with substantial fixed costs, leading some utilities to impose temporary drought surcharges or raise rates (Feinstein et al. 2017; Rachunok and Fletcher 2023). These increases can disproportionately burden low-income households, particularly when rates or surcharges are used to finance drought-resilience measures or recover supply-related costs (Feinstein et al. 2017; Rachunok and Fletcher 2023).

The literature on drought-related impacts on water affordability shows how drought expenses differ from those of more acute climate disasters. Because droughts can develop slowly, act as chronic stresses, and can persist for months to decades (Wehner et al. 2017), the resulting system impacts, cost drivers, and financial responses are similarly drawn out. Droughts can still trigger costly emergency responses, however, particularly where a system has not prepared adequately (Klasic et al. 2022; Rachunok and Fletcher 2023).



Heyman and co-authors (2022) provided one of the first analyses tracing climate-driven changes in water supply through to household-level affordability outcomes. Focusing on El Paso Water, the authors coupled a regional water balance model with the utility's 50-year supply plan to construct scenarios in which reduced river flows and constrained aquifer pumping had to be replaced by costlier alternatives such as desalination or imported groundwater. Across these scenarios, total water supply costs rose three to eight times in real terms by 2070. The authors translated those costs into household bills, finding that households in every scenario in the lowest income quintile paid 6% or more of their income for basic water service by 2070.[4] Because the model excluded wastewater charges, which typically account for roughly half of a household's bill (Teodoro and Thiele 2024), these estimates were conservative. The authors also reported associations between burdened census tracts and indicators of vulnerability such as age and disability, though they cautioned that these relationships were suggestive rather than causal.

Rachunok and Fletcher (2023) linked household-level water affordability impacts to local water stress. In this study that focused on Santa Cruz, California, the researchers used a socio-hydrological model linking drought scenarios to utility rate decisions, household water use and bills, and back to utility revenue. They found that household water affordability and total utility costs decoupled during drought. Drought surcharges prompted all households to cut use, but households with higher discretionary water use could reduce more during the drought, thereby mitigating water rate and fee increases on their water bills. Lower-income households tended to have less ability to reduce water use and therefore incurred a relatively greater cost burden from the utility's financial response. The authors emphasized that reporting aggregate or median bill changes would conceal this divergence entirely. They also found that decisions made years before a drought shaped who bore its costs, through infrastructure lock-in, a phenomenon created by debt service for infrastructure constructed in anticipation of increasing water demands that are not realized. Under-building was also costly, since emergency measures were expensive, underscoring the need for long-term planning that accounts for socio-hydrologic considerations and household-level responses to utility financial decisions.

4 A quintile is one of five equal-sized groups formed by ranking a population from lowest to highest on some measure, such as income. Households in the lowest income quintile are the 20 percent of households with the lowest incomes.

Skerker and co-authors (2026) developed a city-scale modeling framework to estimate how climate-driven water supply stress and utility adaptation decisions could affect household water affordability in Santa Cruz, California. This framework linked a water-resources and supply model with models of infrastructure financing and rate design and an econometric model of household water demand. It used climate projections, water-supply planning scenarios, utility financial and rate data, historical customer billing records, and demographic and property-tax data to translate changes in water availability and utility costs into household-level bill and affordability outcomes. The authors found that, across the modeled climate and infrastructure-adaptation scenarios, climate change could leave an additional 7%–16% of Santa Cruz households paying more than the affordability benchmark of 2.5% of household income (a threshold chosen by the authors) for water by mid-century, compared with current conditions.

Porse and co-authors surveyed and interviewed wastewater system managers in California to help understand the climate adaptations the sector has made to operations, maintenance, and asset management in response to decades of drought and declining water demand (Porse et al. 2023). They found that wastewater system managers had adapted operations to lower wastewater flows. For example, in collection systems, managers inspected pipes more frequently, performed more preventative cleanouts and flushings, and expanded staff time to address blockages, odors, and solids accumulation. In treatment plants, they adjusted biological treatment and aeration-basin operation and increased chemical use or introduced new chemicals. They also documented the sector's increased attention to maintenance of pipes, valves, sensors, manholes, and pumping equipment that had been exposed to increased and highly corrosive hydrogen sulfide, another result of lower flows. Interviewees, however, were often uncertain as to whether these changes were permanent or whether some responses, like increased chemical use, were only needed temporarily. Whether temporary or permanent, these changes can all contribute to increases in operational costs.

A case example further demonstrates how drought-related cost pressures can translate into higher utility borrowing costs and potential affordability challenges for households. In Corpus Christi, Texas, worsening drought conditions have contributed to a credit-rating downgrade for the city's water utility (Tempest 2026). Utilities typically carry large amounts of debt from bonds issued to finance capital projects, and credit agencies assign letter grades reflecting default probability (with AAA the strongest rating and BBB- the lowest investment-grade rating). Higher ratings help secure lower interest rates, and because capital projects often cost millions of dollars, even a small interest-rate reduction carries long-term affordability benefits. Due to ongoing drought in the region, aging infrastructure, and rapid demand growth (Coastal Bend Regional Water Planning Group 2025), Corpus Christi faces substantial long-term investment needs, such as a proposed $978.8 million desalination project (City of Corpus Christi 2026). Although a city council vote in September 2026 created uncertainty for this project, a need for investment in water supply remains (Crow 2026). With about 17.1% of the community living under the poverty line (US Census Bureau 2025a), large capital costs and the possibility of increased borrowing rates can pose affordability risks for residents, especially those with low incomes (Cardoso and Wichman 2022).



Land scorched by fire/ ©Shutterstock

3.2 WILDFIRE

Wildfires can substantially increase costs for water systems by degrading source water quality and damaging or contaminating treatment and distribution infrastructure. Post-fire erosion and run-off can increase sediment, nutrients, and dissolved organic matter in surface waters, complicating treatment and increasing operational demands, including monitoring, treatment adjustments, and, in some cases, additional infrastructure. These effects are highly variable but can persist for years or, for some water-quality and sediment processes, decades after a fire (Bladon et al. 2014; Chow et al. 2019). Wildfire-related contamination of distribution systems can also require extensive testing, flushing, pipe and meter replacement, and long-term monitoring. Volatile organic compounds from melted PVC pipes can contaminate water in distribution networks and households for months (Proctor et al. 2020). Over the longer term, wildfire risk may necessitate that water utilities expend resources on wildfire mitigation, such as vegetation management, structure hardening (i.e., reducing ignition risk of buildings), or other strategies (Pierce, Porse, et al. 2026).

The experience of Las Vegas, New Mexico, illustrates how wildfire combined with subsequent flooding can generate substantial capital costs. In spring 2022, the Calf Canyon/Hermits Peak Fire burned land above the community, and heavy monsoon rains later carried ash and sediment into the town's main water supply, degrading water quality and overwhelming the treatment system with sludge (Romero 2022). The mayor estimated that replacing the town's entire water-filtration system would cost approximately $100 million. This cost would create a particularly serious burden for a small community in which 32% of the population lives below the poverty line (Romero 2022).

Wildfire impacts in Los Angeles County provide another example of how a utility's financial response can pass recovery costs directly to customers. Following the January 2025 Eaton Fire, which destroyed Las Flores Water Company's two reservoirs and impacted 88% of its service area, the utility required households to pay a $3,000 charge through $50 monthly installments over 60 months; customers who could pay up front were offered a $2,600 alternative (Walton 2026). The payments were intended to help the utility repair its reservoirs and maintain operations while avoiding bankruptcy.

In areas impacted by the Palisades Fire, also in January 2025 in Los Angeles, S&P Global Ratings lowered its ratings on the Los Angeles Department of Water and Power's (LADWP's) revenue bonds. The rating agency explained that "the increasing frequency and severity of highly destructive wildfires within LADWP's service territory and recent spread into more urban areas highlights the utility's potential vulnerability to financial liability claims that could eclipse its liquidity and insurance coverage" (Dyson and Bodek 2025). The financial sector's actions reflect both real and perceived infrastructure vulnerability, insurance exposure, and gaps in water system assets and emergency preparedness. These actions can lead to upward pressure on rates and fees that utilities require to maintain financial stability.

Rising water system insurance costs are another pathway leading to long-term rate increases. Although homeowners insurance premiums are rising nationwide, they are rising most rapidly in regions exposed to wildfire and hurricane hazards (Belsie 2024; US Government Accountability Office 2026). Anecdotal evidence indicates that water systems and their customers may face similar increases (Lukins 2025). The co-owner and general manager of Lukins Brothers Water Company in South Lake Tahoe reported that her system's insurance costs rose after the Caldor Fire from $56,000 in 2021 to $299,000 in 2023, despite never filing an insurance claim (Lukins 2025). Lukins further stated that insurance costs rose from 6% to 20% of the water system's expenses in this same time frame. This claim links wildfire risk to expenses borne by the water system; however, the supporting evidence remains anecdotal, and it is unclear if the costs were passed on to customers.

3.3 FLOODING AND EXTREME PRECIPITATION

Flooding can increase water system costs by damaging infrastructure, disrupting operations, reducing treatment capacity during peak wet-weather flows, and increasing the need for sewer investments. Extreme precipitation and flooding can inundate treatment facilities, pumping stations, water-distribution pipes, and wastewater-collection systems. They can also mobilize pollutants into source waters, cause treatment disruptions and sewage discharges, and increase vulnerability to wet-weather flows, sewer overflows, and infiltration into collection systems (Austin et al. 2024; Moussavi et al. 2024; Pacific Institute and DigDeep 2024). Utilities and local governments may therefore face simultaneous pressure to repair or replace flood-damaged water and sewer assets while upgrading aging systems and investing in new gray and green stormwater infrastructure to reduce future risk. These demands are particularly difficult for systems with aging infrastructure, limited technical capacity, or constrained financial resources (Moussavi et al. 2024; National Governors Association 2022).

> The flood compounded a water system already degraded by decades of inadequate maintenance, concentrating the resulting cost burden on a remaining population that is majority Black or African American with a poverty rate of over 27%.

The water crisis in Jackson, Mississippi, in August 2022 illustrates how extreme rainfall can compound long-standing infrastructure weaknesses and accelerate the need for costly system investment and repair. A record-wet August (National Weather Service 2026) caused the Pearl River and Ross Barnett Reservoir to flood, overwhelming Jackson's primary drinking water treatment plant. Flooding contributed to treatment plant and pump failures, and in some cases raw reservoir water entered the distribution system (Bruggers 2022; National Oceanic and Atmospheric Administration

National Centers for Environmental Information 2022; Trotta 2022). The crisis followed decades of deteriorating infrastructure, including aging and undersized pipes, frequent main breaks, and repeated boil-water notices (Southern Poverty Law Center 2023; Trotta 2022).

The flood exposed the extent of the system's noncompliance with federal drinking water standards, and the US Justice Department, on behalf of the US Environmental Protection Agency (US EPA), filed suit against the City of Jackson under the Safe Drinking Water Act (42 USC § 300f et seq.) (*United States v. City of Jackson*, No. 3:22-cv-00686 (S.D. Miss. filed Nov. 29, 2022)). The resulting court order placed the system under the supervision of a court-appointed interim third-party manager (*United States v. City of Jackson*, No. 3:22-cv-00686 (S.D. Miss. Nov. 29, 2022) (interim stipulated order)). Despite nearly $800 million in federal investment since the flood, ongoing operations and debt service still required rate increases (Rozier 2023, 2025). Court supervision also transferred rate-setting authority from the city council to the court, requiring the supervising judge to approve the proposed rate increases. In February 2026, the judge approved an approximately 12% increase in water rates, raising the average residential bill from about $76 to $85 per month, to address a $20.4 million financial shortfall (Dankins 2026). The flood compounded a water system already degraded by decades of inadequate maintenance, concentrating the resulting cost burden on a remaining population that is majority Black or African American with a poverty rate of over 27% (Bruggers 2022; US Census Bureau 2025b).



Pearl River/ ©iStock

3.4 EXTREME TEMPERATURES

Extreme heat refers to temperatures that are hotter — or, in some definitions, hotter and more humid — than average conditions. Since the 1950s, heatwave frequency has increased significantly across almost all parts of the world (Grade et al. 2023; Perkins-Kirkpatrick and Lewis 2020). Cumulative heat has also increased in most regions, primarily because of more heatwave days, while heatwave duration has increased substantially in some regions (Perkins-Kirkpatrick and Lewis 2020). Higher temperatures can increase water demand and evaporation, reducing water availability, which can exacerbate drought conditions and lead to financial responses equivalent to those described above for droughts. Extreme heat events also enhance conditions for harmful algal blooms (HABs) from cyanobacteria[5] in nutrient-rich surface-water bodies, potentially making water unusable for days to over a week (Jöhnk et al. 2008; N. Li et al. 2023).

No direct evidence yet supports linkages between extreme heat-driven HABs and household affordability. However, where HABs are an issue, research supports the costliness of managing these events, particularly when they recur. When a HAB occurs in a water source used for drinking water, water systems may need to either use alternative sources or, if none are available, provide bottled water to affected customers. This was the case in 2018 in Salem, Oregon, when samples indicated that the city's drinking water supplies, sourced partly from Detroit Lake, were contaminated with toxins from cyanobacteria. The state and the city responded by providing bottled and potable water at designated sites for Salem residents (Weiser 2018). Other cities and towns with recurring HABs have responded by installing new drinking water treatment equipment, extending water intakes farther into lakes, and developing in-house testing capacity for quicker results (Hazen & Sawyer, n.d.; VanderHart 2018; Walton 2021). These activities are costly and contribute to raising water bills both in the short and longer term.

Arctic climate change may alter atmospheric circulation in ways that bring extreme cold to parts of the Northern Hemisphere's mid-latitudes (Cohen et al. 2021). These events can damage water infrastructure directly, rupturing water mains and service lines and causing pressure loss that exposes distribution systems to contamination. Winter Storm Uri, which struck Texas in February 2021 alongside widespread grid failure and power shortages, was among the costliest disasters in the state's history (Payton Scally et al. 2021; NOAA NCEI 2025). Water systems sustained extensive damage to pipes and pumping stations as well as water loss (Freese and Nichols, Inc. 2021; Payton Scally et al. 2021). Since the event, utilities have invested in disaster preparedness. San Antonio's water system, for example, winterized pump stations and insulated other above-ground features, and purchased roughly $300 million in new generators (Ebertowski and Gamez 2026). These costs, incurred well after the disaster itself, are likely to ultimately reach households through rates.

3.5 INCREASED ENERGY DEMAND

Water and wastewater treatment plants account for 30%–40% of total energy consumed at the municipal level, making them among the largest consumers of electricity within municipal governments (US EPA 2016b). Climate change can increase energy costs for water systems by raising water demand and intensifying the energy required to deliver and treat water. Higher temperatures can increase water demand for residential, irrigation, and some commercial and industrial uses, like data centers (Han et al. 2026; Hemati et al. 2016; Wang et al. 2016), which in turn can require greater pumping. These demands will fall primarily on the local water systems already managing increased

5 Cyanobacteria live in surface water around the world and multiply quickly in warm, nutrient-rich waters, forming harmful algal blooms (HABs). HABs can produce cyanotoxins, which, if ingested, are toxic for humans, animals, and aquatic life.

demands from climate change. All of these additional water demands drive up electricity consumption costs for utilities (Truettner and Barkdoll 2022).

Research across multiple water distribution systems suggests that energy use tends to increase alongside climate-driven demand — i.e., higher water use during hotter, drier conditions — and in some cases, utilities may need to upgrade pumps or increase pipe sizes to maintain service (Truettner and Barkdoll 2022). At the same time, climate change can increase the overall energy intensity of water treatment. As freshwater availability declines and conventional water sources become less reliable, utilities may increasingly rely on energy-intensive processes such as advanced treatment and desalination (Rosińska et al. 2024; Skerker et al. 2026). Because energy is required across nearly every stage of water treatment and distribution, increases in energy demand can substantially raise operating costs. These cost drivers can then prompt financial responses such as higher rates and fees for customers.

3.6 CLIMATE MIGRATION

Climate change can also increase costs for water systems by destabilizing the customer base that supports utility revenues. Climate-related disasters and long-term environmental change can lead to population loss in some regions and growth in others (Hurdle 2022). These demographic changes create financial and operational challenges for utilities that must adjust infrastructure and service levels to shifting demand patterns (Lyle et al. 2023; US EPA 2024). Population loss can be especially destabilizing because water systems carry substantial fixed costs for utilities, which must then be recovered from a decreased number of ratepayers (Bash et al. 2020; Boles 2019; US EPA 2024). As a result, utilities may struggle to maintain infrastructure and financial stability while placing greater cost burdens on remaining customers, who are often the least able to relocate (Bash et al. 2020; Chrobak 2025; River Network 2021).

The recovery of New Orleans following Hurricane Katrina in 2005 demonstrates how large-scale displacement can reduce the ratepayer base and undermine utility finances. The city's population remained significantly below pre-storm levels for years after the hurricane (Gutmann and Field 2010). In 2011, the Sewerage and Water Board of New Orleans was delivering 14% more water than during the pre-Katrina period, even though its customer base was 18% smaller. Circle of Blue attributed the higher required supply to worsening system leakage, with water losses rising from 35% to 50% of water entering the system (Circle of Blue 2011). A 2015 local news article reported that New Orleans water bills were set to more than double from pre-Katrina levels by 2020, as infrastructure repair costs were spread across a smaller ratepayer base (Biz New Orleans 2015). This case demonstrates how disaster-driven displacement can weaken utility finances, contribute to rising system costs, and ultimately deepen water affordability challenges for the households that remain (Figure 2).

Although the interconnected dynamics of the Water Affordability-Climate Disaster Feedback Loop are still emerging areas of research, the literature and examples summarized here demonstrate a wide range of mechanisms by which climate disasters translate, through water system impacts, cost drivers, and financial responses, into household water affordability impacts (Figure 2).

4. Strategies and Approaches: How to Disrupt the Water Affordability-Climate Disaster Feedback Loop

The Water Affordability-Climate Disaster Feedback Loop is not a foregone conclusion. Water systems, government agencies, technical assistance providers, and communities can pursue a range of strategies to protect household water affordability, access, safety, and reliability, even as climate disasters intensify. These approaches span disaster preparedness, long-term management and planning efforts, funding and financing mechanisms, rate design, and legal and policy reforms to strengthen governance of water systems under climate stress. This section reviews approaches that governments and utilities are already adopting, each offering short- or long-term benefits for household water affordability. They are presented in the order in which they intervene in the feedback loop: before a disaster occurs, as costs accumulate and are financed, and at the point where those costs reach household bills.

4.1 DISASTER PREPAREDNESS

Preparedness is foundational for protecting water affordability and access, particularly as climate change increases the frequency and severity of disruptive events (Pacific Institute and DigDeep 2024). Disaster preparation is not only a technical or operational concern but also an affordability strategy. By reducing the likelihood and severity of service disruptions, improving interagency coordination, and avoiding unfunded or poorly allocated emergency costs, proactive planning frameworks can help stabilize utility finances while protecting vulnerable households from the cascading impacts of climate-driven water crises. At their best, preparedness activities keep a disaster from setting the feedback loop in motion. At a minimum, they limit the system damage and emergency spending that would otherwise reach households through rates or fees.

Legal and planning frameworks play a critical role in determining whether water and wastewater systems can maintain service continuity and avoid costly emergency responses that ultimately translate into higher household bills (Campbell-Ferrari et al. 2025, 2024). Historically, many water systems have relied on reactive approaches to disasters, but a growing body of research emphasizes the importance of proactive planning, risk assessment, and system redundancy to reduce both financial and social vulnerability (McNeeley et al. 2025).

At the federal level, laws such as the America's Water Infrastructure Act (AWIA) require community water systems serving more than 3,300 people to conduct risk and resilience assessments and develop emergency response plans that evaluate threats from natural hazards, including floods, droughts, and extreme events (America's Water Infrastructure Act of 2018, Pub. L. N. 115-270, 132 Stat. 3765 (2018)). These assessments are intended to identify vulnerabilities across physical infrastructure, operations, and financial systems, and to guide investments that can reduce system disruptions and associated economic shocks. However, these requirements remain uneven, excluding many small systems that are often the most vulnerable to climate disasters and least able to absorb disaster-related costs, and AWIA does not explicitly require consideration of climate change hazards or projections (Lyle et al. 2023; Taylor et al. 2024).

State and local laws also play a role in embedding disaster preparedness into water system governance (Campbell-Ferrari et al. 2025). Hazard mitigation planning requirements under the Stafford Act (42 USC § 5165; 44 CFR § 201.6) and related policies provide funding incentives for local governments to assess risks and develop resilience strategies, although these plans have historically not fully incorporated climate change projections (Campbell-Ferrari et al. 2025; Neumann et al. 2021). More recent policy innovations demonstrate the potential for stronger integration, such as state laws requiring climate risk and vulnerability assessments, emergency preparedness plans, and the incorporation of climate considerations into long-term water planning processes (e.g., Cal. Water Code §§ 10631, 10632, 10635; Cal. Water Code §§ 10609.50-10609.80; Massachusetts Executive Order 569 (2016)) (Campbell-Ferrari et al. 2024; Craig 2020; Dyckman 2023; US GAO 2020). These approaches link disaster preparation directly to infrastructure investment decisions, helping to avoid costly retrofits or service failures that disproportionately burden low-income households.

A key component of disaster preparation is ensuring system redundancy and backup capacity that provide greater assurance that water supplies are accessible even as climate change threatens infrastructure and historically secure supplies (Anderson et al. 2023). Evidence from past climate-related disasters shows that systems lacking backup capacity are more likely to experience



prolonged outages, requiring expensive emergency measures such as water hauling or bottled water distribution (Feinstein et al. 2017; Pacific Institute and DigDeep 2024). Legal and regulatory frameworks can require utilities to maintain emergency water supplies, develop interconnections with neighboring systems, or diversify supply portfolios to reduce the risk of service disruption during extreme events (Campbell-Ferrari et al. 2025).

Emerging risks such as large-scale wildfires expose a mismatch between existing system design and current demands, as water infrastructure has historically been built to provide drinking water and support localized structural firefighting rather than prolonged, high-intensity wildfire response (Pierce, Gorman, et al. 2026). However, expanding system capacity to meet these demands can introduce significant tradeoffs with water quality, system reliability, and affordability, particularly when capital upgrades are financed through rates. Small water systems, in particular, face significant challenges in wildfire preparedness (Sun et al. 2025). These systems may be best able to enhance resilience through activities such as engaging in mutual aid networks, like the Water/Wastewater Agency Response Network (WARN), which allows them to support and be supported by other water systems in their region or state when disasters occur. Other resilience strategies for small water systems can include improvements to fire-flow capacity, maintenance of backup water storage, interties with neighboring systems, and regionalization that enhances technical, managerial, and financial capacity (Sun et al. 2025).

Disaster preparedness can be critical for reducing water systems' risk from climate impacts, thereby saving them and their ratepayers money on responses and repairs over the long term. Along with disaster preparedness, management and planning that take climate change into account help expand a utility's planning from singular threats to longer-term trends that may be changing or accelerating due to climate change.

4.2 CLIMATE-INFORMED MANAGEMENT AND PLANNING

Management and planning shape whether water affordability and climate resilience are addressed proactively or allowed to worsen over time. Whereas disaster preparation focuses on acute shocks, management and planning govern the routine and long-term decisions that determine infrastructure conditions, financial stability, and the distribution of costs across households. This includes asset management, capital improvement planning, long-range supply and demand management and planning, performance monitoring, and interagency coordination. Where preparedness works to keep a climate disaster from setting the loop in motion, management and planning shape how the loop unfolds, determining whether climate-driven costs are managed gradually and deliberately or passed on as abrupt rate shocks to households.

> Management and planning are not simply administrative functions but core affordability strategies that help utilities anticipate risk, align investments with long-term resilience goals, and institutionalize more equitable decision-making under climate change.

Research increasingly emphasizes that these functions must be adapted to climate uncertainty rather than based on historical hydrologic conditions alone, using scenario-based and adaptive planning approaches that allow utilities to revise investments and operations as conditions change (Dyckman 2023; Lempert and Groves 2010; Milly et al. 2008; Porse

et al. 2026; Waage and Kaatz 2011). When utilities rely on deferred maintenance, outdated demand forecasts, or rigid capital plans, the result is often more frequent infrastructure failure, more expensive emergency spending, and larger future rate increases (Abraham et al. 2020; Bipartisan Policy Center 2016; Dyckman 2023; Skerker 2025; Stratton et al. 2017; Walton 2026). By contrast, stronger management and planning frameworks can sequence investments more efficiently, improve transparency about tradeoffs, and reduce the need for abrupt cost recovery measures that disproportionately burden low-income households (Dyckman 2023; Nayak et al. 2023; Skerker 2025; Stratton et al. 2017; Teodoro 2018; US Water Alliance and Stantec Consulting Services, Inc. 2023).

Water utilities have developed systematic frameworks to integrate climate risk into infrastructure investment cycles. These include formal protocols such as the Public Infrastructure Engineering Vulnerability Committee (PIEVC) vulnerability assessment process, digital tools like AdaptWater™ and the Climate Resilience Evaluation and Awareness Tool (CREAT) 3.0 for quantifying asset-level risks, and governance mechanisms such as Seattle Public Utilities' "Stage Gates" process that required climate sensitivity assessments for all capital projects (Heyn and Winsor 2015). The New York City Department of Environmental Protection's 9-step Adaptation Assessment procedure demonstrated how government-university collaborations can embed climate considerations into strategic and capital planning over long time horizons (Rosenzweig et al. 2007). One of the objectives of these efforts is to increase the likelihood of long-term reliability and resilience of new capital assets, thereby reducing exposure of the system to climate risks and associated costs.

Another approach to reducing climate risks, particularly those that alter water supply availability, is demand management, which does not require building new, large infrastructure. Managing water demands through water efficiency and conservation can be less expensive than developing new water supply and treatment infrastructure for both utilities and customers. It also supports climate resilience by helping to stretch water supplies longer before emergency measures are required (Elgendy et al. 2024; Gleick and Cooley 2021).

Evidence of the affordability benefits of demand management is borne out in avoided cost analyses in four communities in the western US (Chesnutt et al. 2018; Feinglas et al. 2013; Mayer 2017a, 2017b). Although each community experienced population growth over the study period, they also experienced per capita water-use reductions, helping to avoid significant capital and O&M costs. For example, in the City of Westminster — a community in the Denver metro region of Colorado — water efficiency and conservation reduced water use from 180 gallons per capita per day (gpcd) in 1980 to 149 gpcd in 2010, helping the city to avoid more than $590 million in capital costs and $1.2 million in O&M costs per year (Feinglas et al. 2013). The researchers estimated that without efficiency and conservation, customer bills would have been 91% higher than they were, and connection fees would have needed to be 80% higher.

Utility-led demand management can provide significant capital and O&M cost savings, but only if utilities effectively integrate water efficiency and conservation into their long-range planning and avoid unnecessary investments in expensive new capital projects (Abraham et al. 2020; Diringer et al. 2018). Analysis may help identify the distributional impacts of different demand management approaches, helping to ensure affordability impacts are not inequitable (Rachunok and Fletcher 2023).

Embedding equity into these processes is also critical (Dyckman 2023; Nayak et al. 2023; Skerker 2025; US Water Alliance and Stantec Consulting Services, Inc. 2023). Decisions about which assets to replace, which neighborhoods to prioritize, how to evaluate service levels, and who participates in planning processes all influence whether historically underserved communities continue to face higher risks of service disruption and unaffordable bills (Grabowski et al. 2023; Heaps and NEJAC Water Infrastructure Financing Working Group 2018; Hoover et al. 2021; Solis 2018). In this sense,

management and planning are not simply administrative functions but core affordability strategies that help utilities anticipate risk, align investments with long-term resilience goals, and institutionalize more equitable decision-making under climate change.

A major barrier to management and planning is water system capacity. Evidence from the Safe Drinking Water Act (SDWA) compliance records shows that small water systems serving less than approximately 20,000 customer connections are unlikely to have the technical, managerial, and financial capacity to effectively maintain adequate water quality, even without climate change (Teodoro 2026).[6] Furthermore, small- and medium-sized utilities often lack skilled staff, necessary tools, technical expertise, and reliable information required to manage emerging climate risks effectively (McNeeley et al. 2025). Teodoro (2026) argued that consolidation of small water systems (full organizational consolidation, with or without physical connection) is an insufficient but necessary condition to achieve the goals set out in the SDWA. This level of consolidation may also bolster water system capacity for climate management and planning (Dobbin et al. 2023; Landes et al. 2021). However, Dobbin and co-authors (2023) found that the potential for economies of scale through consolidation may be limited, and that communities of color and low-income communities are underrepresented among consolidated systems, calling into question the potential for it to advance equity.

Ultimately, how well utilities manage infrastructure over time and plan for changing and unpredictable future conditions determines not only system resilience but also the financial burdens placed on households. When planning frameworks are weak, deferred, or inequitable, the costs do not disappear; rather, they accumulate and are eventually recovered through rates, often in ways that hit low-income households hardest. The following section examines the funding, financing, and rate design mechanisms that shape how those costs are distributed and how they can be structured to advance both resilience and affordability.

How well utilities manage infrastructure over time and plan for changing and unpredictable future conditions determines not only system resilience but also the financial burdens placed on households.

4.3 FUNDING, FINANCING, AND WATER RATE DESIGN

The costs that eventually flow through rate structures are shaped upstream by how utilities access capital, what taxes they are required to pay, and whether external funding is available to offset investment needs (Hansen et al. 2021; D. Li et al. 2024; Teodoro 2021). Most water and wastewater infrastructure is financed through a combination of debt — primarily tax-exempt municipal bonds (D. Li et al. 2024) — and state and federal funding programs, including the Drinking Water and Clean Water State Revolving Funds (SRFs), which provide low-interest loans and, for disadvantaged communities, principal forgiveness (Fox 2022; Hansen et al. 2021; Rosser et al. 2024). The Infrastructure Investment and Jobs Act (Pub. L. No. 117-58, 135 Stat. 429 (2021)) significantly expanded these resources, directing billions toward water infrastructure with explicit equity provisions, though access has been uneven and many smaller or financially weaker utilities lack the institutional capacity to successfully pursue competitive grants (Nagpal et al. 2024; Scanlan and Husain 2022). When external funding is unavailable or insufficient, utilities must finance capital

6 Although broader than this report's definition (see Glossary), Teodoro's (2026) definition includes all systems covered here, so the study's findings remain relevant.

projects through debt service recovered via rates or defer investment entirely, both of which carry long-term affordability consequences. High debt burdens reduce financial flexibility, limit a utility's ability to absorb revenue shortfalls during droughts or demand shifts, and can trigger credit rating downgrades that raise future borrowing costs. In this way, access to external funding and the structure of capital finance are not separate from rate design but directly determine how much cost pressure utilities must pass on to households and how equitably those costs can be managed. As discussed above, drought and wildfires have already led to credit rating downgrades at some utilities. Funding, financing, and rate design therefore determine where climate-driven costs ultimately land. Where external funding is available and rates are deliberately structured, these mechanisms can absorb and spread those costs; where they are not, the costs pass through to household bills and the loop continues.

Where external funding is available and rates are deliberately structured, these mechanisms can absorb and spread those costs; where they are not, the costs pass through to household bills and the loop continues.

Water rate design is a central mechanism through which utilities recover the costs of providing service and, critically, translate infrastructure investment needs into household affordability outcomes. Most US utilities follow cost-of-service principles, in which total revenue requirements are allocated across customer classes and recovered through a mix of fixed charges and volumetric rates (Woodcock et al. 2017). Utilities may also be subject to complex, restrictive, and ambiguous state regulations, which can place barriers and restrictions on rate design approaches, especially when utilities try to use them to support customer assistance programs (Environmental Finance Center at UNC Chapel Hill et al. 2017). Increasing block rate (IBR) structures, where marginal prices rise with higher consumption, are widely used to support conservation while maintaining revenue sufficiency and equity objectives (Olmstead et al. 2007; Whittington and Nauges 2020).



Paying for Climate Disasters on the Water Bill

However, the structure of rates has significant distributional implications. A growing reliance on fixed base charges to stabilize utility revenue can create a regressive structure that shifts costs onto low-income households, since these households tend to use less water and therefore have less ability to reduce bills through conservation (Levine et al. 2022; Teodoro and Thiele 2024). Beecher (2020) made a similar point by arguing that high fixed utility charges are particularly regressive because they are disproportionately burdensome and largely uncontrollable by the consumer, while a more equitable approach combines an essential-use allowance with cost-based volumetric rates for discretionary use. In this view, volumetric rate structures and IBRs can better align costs with discretionary consumption, but they still depend on sufficient high-volume demand to cross-subsidize essential use.

Decisions about the balance between fixed and volumetric charges, the structure of increasing blocks, and the integration of assistance programs fundamentally shape how the costs of climate adaptation are distributed.

Climate change intensifies these challenges by increasing the need for costly supply and resilience investments, such as desalination, reuse, or infrastructure hardening, which are typically financed through rate increases rather than external funding (Patterson et al. 2020). Because residential water demand is relatively price inelastic, particularly for essential indoor uses, these increases tend to raise household bills without proportionate reductions in consumption (Dalhuisen et al. 2003; Olmstead et al. 2007). As a result, even modest rate adjustments can push low-income households above commonly cited affordability thresholds of 2–2.5% of income for water, or 4–4.5% for combined water and wastewater (Mack and Wrase 2017; Teodoro 2018).

To address these inequities, utilities increasingly pair rate design with customer assistance programs (CAPs) embedded within or layered onto billing structures. Common approaches include fixed bill discounts, percentage-based reductions, lifeline rates for essential use, and income-based rate structures (Shimabuku et al. 2025; US EPA 2016a; Vedachalam and Dobkin 2021). Each approach interacts differently with underlying rate structures: volumetric discounts scale with rising prices but



KY water tank construction © Delilah Griswold

may not sufficiently protect essential use, while fixed discounts provide stability but can erode over time as rates increase. Evidence suggests that while existing CAPs often offer substantial median bill reductions of around 40%, they remain severely undersubscribed with typical participation rates of only 10–25% of eligible households (Mack et al. 2020; Vedachalam and Dobkin 2021). Overall, CAPs fall short of ensuring systemwide affordability for the most vulnerable populations (Hasan 2025; Mack et al. 2020; NACWA and Moonshot Missions 2021; Pierce et al. 2020, 2021). New approaches to improve enrollment in existing programs and more comprehensive affordability models that better address affordability for the lowest-income customers may therefore be needed. One example is Philadelphia's Tiered Assistance Program (TAP), which enrolls prequalified households automatically and structures utility bills as a percentage of household income rather than relying solely on post hoc discounts (Mack et al. 2020; Pierce et al. 2020). Because this approach is administratively complex, it may be infeasible for small or capacity-limited utilities.

Overall, water rate design is not merely a financial instrument but a key equity lever. Decisions about the balance between fixed and volumetric charges, the structure of increasing blocks, and the integration of assistance programs fundamentally shape how the costs of climate adaptation are distributed. Without intentional design, rate structures that ensure utility solvency and promote conservation may simultaneously exacerbate affordability challenges, particularly under climate scenarios requiring substantial new investment.

Legal and regulatory protections generally operate at the last stage of the feedback loop, where utility financial responses reach households. They do not prevent climate-driven costs from arising, but they shape whether those costs become unaffordable bills, arrears, or shutoffs.

4.4 LEGAL AND REGULATORY PROTECTIONS

Legal and regulatory protections play a critical role in protecting vulnerable households from water insecurity from climate disasters, yet in the United States these protections remain fragmented and often insufficient (Campbell-Ferrari et al. 2025, 2024). A central tension arises from cost-of-service requirements embedded in many state constitutions and statutes, which can limit the ability of water and wastewater utilities to implement redistributive or income-based rate structures (NACWA and Moonshot Missions 2021; Nayak et al. 2023; Pierce et al. 2021). Setting rates to ensure cost-of-service requirements are met helps maintain utility financial sustainability and is considered transparent; however, it can affect affordability (Beecher 2020). At the same time, water governance systems were largely designed for more predictable climatic conditions and rigid allocation regimes, making them ill-suited to protect household water access under increasing climate variability and uncertainty (Craig 2020; Payton et al. 2023). Meaningful legal and policy protections also depend on how affordability is defined and measured; scholars have argued that metrics must account for essential household water needs and income disparities to support the design of effective programs (Teodoro 2018). Legal and regulatory protections generally operate at the last stage of the feedback loop, where utility financial responses reach households. They do not prevent climate-driven costs from arising, but they shape whether those costs become unaffordable bills, arrears, or shutoffs.

Additional legal tools aim to prevent loss of service and reduce acute hardship. Anti-shutoff protections, arrearage management policies, and payment assistance programs can reduce immediate risks

to household water insecurity, particularly during periods of climate-related disruption (Pierce et al. 2021). Washington State provides a notable climate-specific example: a state law, enacted in 2023, requires water and energy utilities to delay utility shutoffs during extreme heat events, including to tenants of metered apartment buildings and residents of mobile homes (2023 Wash. Sess. Laws ch. 105). The law is intended to protect households struggling to pay their bills when extreme temperatures increase risks to human health and illustrates how legal protections can treat continued water access as a component of climate adaptation rather than solely as a matter of utility debt collection (Campbell-Ferrari et al. 2024). These protections nevertheless remain limited in scope. For example, Washington's law requires utilities to delay (not permanently prohibit) shutoffs during extreme heat and therefore functions primarily as a crisis-response measure rather than a structural affordability policy. It illustrates both the potential and the limits of climate-responsive legal protections: such measures can prevent immediate loss of service during dangerous conditions, but they must be paired with income-based assistance, arrearage relief, and equitable rate design to address persistent unaffordability.

Water affordability under climate change is not simply a matter of household ability to pay but a function of how institutions anticipate risk, allocate costs, and protect access.

Anti-shutoff protections and payment assistance policies are increasingly used to reduce immediate risks to public health, though they often do not address the underlying drivers of unaffordability (Pierce et al. 2021; Vedachalam and Dobkin 2021; Zhang et al. 2022). Crisis relief measures, including flexible payment plans that redistribute debt based on household income, promote continued water service while allowing for revenue collection, though they are administratively expensive and often require beneficiaries to invest substantial time demonstrating need (Jones and Carpenter 2024; Pierce et al. 2021). Scholars noted that such methods are most effective when paired with structural affordability strategies, including rate design reforms and income-based assistance (Mack et al. 2020; Pierce et al. 2021).

Finally, legal frameworks governing planning, implementation, and enforcement can indirectly strengthen protections for vulnerable households. Laws requiring climate-adaptation planning, risk assessments, public notice, and meaningful community participation can help utilities anticipate service disruptions and incorporate the needs of disadvantaged communities into infrastructure and emergency planning (Campbell-Ferrari et al. 2025). However, complex implementation requirements and inconsistent definitions of "disadvantaged communities" can limit equitable access to these protections (Scanlan and Husain 2022; Smith et al. 2023; Vedachalam et al. 2020).

In sum, while a range of legal tools exists to protect vulnerable households, they operate in a fragmented and often reactive manner. Strengthening water affordability and access under climate change will require more integrated legal frameworks that explicitly link rate setting, service protections, and funding mechanisms to the goal of ensuring universal, affordable, and climate-resilient access to water.

Taken together, the evidence suggests that breaking the Water Affordability-Climate Disaster Feedback Loop will require moving beyond fragmented, reactive responses toward integrated strategies that align disaster preparedness, infrastructure planning, climate-informed management, equitable funding and rate design, and durable legal protections. Water affordability under climate change is not simply a matter of household ability to pay but a function of how institutions anticipate risk,

allocate costs, and protect access. Strengthening resilience therefore depends on building governance and finance systems that reduce vulnerability before crises occur and ensure that the costs of adaptation are distributed in ways that do not deepen existing inequities.

Although this report focuses on the financial, infrastructural, and household affordability dynamics of the feedback loop, implementation of many of the strategies described here will also depend on political and governance conditions. Because water and wastewater systems in the United States are largely governed locally, efforts to advance climate resilience, affordability protections, consolidation, regionalization, or alternative funding structures may encounter resistance when they are perceived to conflict with local preferences, ratepayer tolerance, or elected officials' short-term priorities. These political challenges are beyond the scope of this report but warrant further attention, particularly because breaking the feedback loop may require state or federal standards, incentives, or interventions that reshape local decision-making.

5. Priority Research Gaps at the Intersection of Water Affordability, Climate Change, and Equity

Although the potential for climate change to increase water system costs has long been recognized, important gaps remain in understanding how those costs translate into household affordability burdens (Feinstein et al. 2017; Gleick and Adams 2000; NACWA and AMWA 2009; River Network 2021). The Fifth US National Climate Assessment underscores the high economic costs of increasing temperature, rising sea levels, and more frequent and intense weather-related events across many sectors, including water (Hsiang et al. 2023). Some recent work has emerged connecting these climate-driven economic costs, particularly for supply shortages and extreme drought, to household affordability. However, in general, there is much left to explore and untangle. The following topics summarize some of the more pressing knowledge gaps in understanding the Water Affordability-Climate Disaster Feedback Loop: how climate-driven costs flow through utility finance to household bills, where and for whom the loop is occurring, which equitable strategies and approaches can disrupt it, and how climate-related affordability burdens differ for households relying on decentralized systems such as private wells and septic systems.

5.1 UTILITY FINANCE AND AFFORDABILITY

The causal pathways discussed above show that climate stress can raise utility costs and household bills, especially under drought. Yet an important gap remains in tracing the full chain from utility financial impacts to household affordability burdens. Heyman and co-authors (2022) connected future potential water resource scenarios affected by climate change to affordability challenges for households in El Paso, Texas. Skerker (2025) and Skerker and co-authors (2026) provided analysis of this causal pathway between climate-driven water supply gaps, utility investment decisions, and household-level water affordability impacts. However, they concluded that the magnitude of climate-related affordability effects depends on local context. As a result, their findings are most applicable to Santa Cruz, California, and communities facing similar water supply constraints, highlighting the need for additional city-scale assessments. Severe drought can force utilities to rely on expensive emergency supplies, infrastructure expansion, and drought surcharges, and rate design shapes who bears those costs (Nayak et al. 2023; Rachunok and Fletcher 2023).

Flood and drought risks can increase the cost of bond financing for water utilities, indicating that climate hazards can affect utility finances even before costs are passed through to customers (D. Li et al. 2024). The studies above mostly stopped at modeling rates, surcharges, or capital costs rather than tracing how utilities actually cope financially with climate disasters in practice, how those

responses are translated into fees and charges, and how those changes affect household affordability across service areas (D. Li et al. 2024; Nayak et al. 2023; Skerker 2025). Furthermore, bond rating methodologies for water and wastewater utilities explicitly incorporate service-area income and poverty, treating low household incomes as a constraint on a utility's capacity to raise rates (Moody's Ratings 2024; S&P Global Ratings 2022). This suggests, but does not prove, that utilities serving lower-income communities may receive lower credit ratings and face higher borrowing costs even before a climate disaster. It remains unclear whether observed utility data show that these socioeconomic characteristics are associated with higher borrowing costs after accounting for other determinants of credit risk.

For wildfires, the gap is even larger. The literature is largely about asset damage, contamination, or financing risk, not the downstream distributional consequences for households (Bladon et al. 2014; Proctor et al. 2020; Wibbenmeyer et al. 2023). The economic impacts of flooding, extreme precipitation, and hurricanes are well established (Austin et al. 2024; Congressional Research Service 2006; Moussavi et al. 2024; NACWA and Moonshot Missions 2021; US Congress Joint Economic Committee 2024; US GAO 2025; Wing et al. 2022). For example, the US Congress Joint Economic Committee (2024) estimated that the total annual economic burden of flooding in the US is between $179.8 and $496.0 billion (in 2023 dollars). The report noted that climate change will likely compound these figures. Wing and co-authors (2022) estimated average annual flood losses in the US were $32.1 billion in 2020 but will rise to $40.6 billion by 2050 (under the RCP 4.5 scenario). Other research documented event-specific costs, such as an estimate by the North Carolina Office of State Budget and Management that $3.7 billion would be needed for water, sewer, and stormwater systems to recover from Hurricane Helene (North Carolina Office of State Budget and Management 2024). However, research is lacking that links the costs borne by water systems to quantifiable water rate or bill impacts at the household level.

Even less is known about how other climate-driven cost pressures, such as increased energy use, O&M, compliance costs, insurance and financial risks, and climate migration, translate into household affordability impacts. In terms of the feedback loop, this gap sits at the transition from utility cost drivers to financial response and affordability impact (Figure 1).

5.2 GEOGRAPHIES AND POPULATIONS AT MOST RISK

Another important research gap is identifying where climate-related water affordability challenges are occurring in the United States and which populations are most vulnerable to them. Research on water affordability has broadly examined these questions, but without the added layer of climate disasters (e.g., Cardoso and Wichman 2022; Mack and Wrase 2017; Meehan et al. 2020; US EPA 2024). The water affordability literature demonstrates that unaffordability clusters in places where water rates are high and household incomes are low, but more understanding of where these geographies overlap with extreme climate stress is critical for better tailoring strategies to address climate resilience in an equitable way (McNeeley et al. 2025).

Rachunok and Fletcher (2023), for example, showed that in water-stressed regions, drought resilience strategies could lead to divergent water bill impacts, with raised bills for low-income households and lower or smaller increases for high-income households, underscoring the need for more equity-oriented solutions. Butts and Gasteyer (2011) demonstrated that affordability burdens fall inequitably on communities with higher proportions of Black people and other people of color; they argued this results from divestment in working-class jobs in urban areas and subsequent population loss, leaving fewer households, a higher proportion of which are non-White, to cover the fixed costs through their utility bills. Similarly, frontline communities that bear the worst impacts of climate

change on their water and sanitation are disproportionately Black, Indigenous, other people of color, people with disabilities, and other marginalized groups (Pacific Institute and DigDeep 2024). Better understanding of where climate risk and water affordability burdens intersect and which populations are most vulnerable remains a critical research priority for advancing equitable climate resilience. Closing this gap would show where in the country the loop in Figure 1 is already occurring and for whom the affordability impact and water access challenges are most severe.



5.3 EQUITABLE, CLIMATE-RESILIENT STRATEGIES AND OTHER APPROACHES

Despite growing interest in equitable, climate-resilient water management, relatively little research has evaluated which strategies effectively reduce climate-driven water affordability burdens. Governments and utilities are already implementing a variety of equitable, climate-resilient strategies, but their distributional and affordability effects, particularly for low-income households, remain insufficiently understood. For instance, there is little research at the intersection of hydrological drought, economic rate design, and legal regulation (Nayak et al. 2023). Drought-response strategies can produce unequal affordability impacts, yet existing models have limited capacity to evaluate how hydrological variability and utility decisions affect household water bills, particularly for low-income households (Rachunok and Fletcher 2023).

Research on water assistance and affordability programs has expanded considerably over the past decade (Bipartisan Policy Center 2017; Environmental Financial Advisory Board 2025; Patterson and Doyle 2020; Pierce et al. 2021; River Network 2021; Shimabuku et al. 2025; US EPA 2016a), yet few studies have evaluated whether these programs can offset affordability burdens associated with climate adaptation and resilience investments (Skerker 2025; Skerker et al. 2026). Valero and co-authors (2023) argued that climate-resilience and adaptation efforts can overlook existing disparities

in water access, participation in decision-making, and ability to pay, thereby failing to address the multidimensional nature of water poverty. Although McNeeley and co-authors (2025) provided an overview of affordable, climate-resilient water and sanitation solutions, those approaches were not specifically evaluated for their ability to address climate-driven increases in water bills but rather for water affordability challenges more broadly. As explained in Section 3, the broader climate-driven pressures discussed here accumulate through operations, financing, planning, and demographic changes, making them harder to trace but still important for household affordability. More work is needed to identify and test local, state, and national strategies that can equitably reduce climate-driven water affordability burdens and disrupt the Water Affordability-Climate Disaster Feedback Loop.

Governments and utilities are already implementing a variety of equitable, climate-resilient strategies, but their distributional and affordability effects, particularly for low-income households, remain insufficiently understood.

5.4 WATER AFFORDABILITY IN DECENTRALIZED SYSTEMS

Although beyond the scope of this report, which focuses on centralized systems, there is an underexamined question of whether and how the causal pathways differ for households served by centralized utilities versus those relying on private wells or septic systems. Evidence and policy responses for households served by decentralized water systems in the United States remain limited, partly because these households are inconsistently documented and their water-access challenges remain incompletely understood (Cropper et al. 2025; Dobbin et al. 2024; Murray et al. 2021). Although existing affordability studies traced how drought, supply uncertainty, and infrastructure costs can raise bills through municipal utility planning and rate-setting, with impacts that fall hardest on low-income households (Heyman et al. 2022; Rachunok and Fletcher 2023; Skerker 2025), the decentralized-system literature focuses more on vulnerability and failure rather than on affordability feedbacks (Pacific Institute and DigDeep 2024; Pauloo et al. 2020).

Pacific Institute and DigDeep (2024) discussed private wells and septic systems under climate stress, and Pauloo and co-authors (2020) showed that domestic well failure can impose household repair costs and that solutions remain largely underexplored. Calabretta and co-authors (2022) discussed available options for funding and financing onsite wastewater systems with a particular focus on support for middle- and low-income households. Their work examined regionalization approaches like Miami-Dade County's Connect 2 Protect program to address septic systems impacted by sea level rise and the need to make grant programs available to renters, noncitizens, and other groups that face septic system challenges due to climate change. What remains thin is an integrated comparison that follows climate shocks through different infrastructure types all the way to household financial burden for decentralized systems (Howard et al. 2016). For these households, the loop in Figure 1 may occur when household-level repair and replacement costs create the same self-reinforcing dynamic, but this is largely untested.

Together, these research gaps highlight the need for a stronger evidence base to understand, anticipate, and disrupt the Water Affordability-Climate Disaster Feedback Loop before climate change further exacerbates existing water affordability and access inequities.

6. Conclusion

Water affordability in the United States is an existing and growing challenge, with an estimated 12 to 19 million households unable to reliably afford their water and wastewater bills. If these households fail to pay their water and wastewater bills, they may be shut off from accessing water. Climate change is a force multiplier that threatens to accelerate and compound the affordability challenges that frontline communities already face. This report has argued that this dynamic is best understood through the lens of a feedback loop (Figure 1): when climate disasters damage infrastructure and disrupt services, utilities face mounting costs; when those costs are passed on to ratepayers who cannot afford them, households lose water access and revenue shortfalls force utilities to cut maintenance and defer investment; when displacement shrinks the ratepayer base, the households that remain shoulder even more; and when the next disaster arrives, these weakened systems are even less equipped to respond. For communities already living at the margins of affordability, this loop can be self-reinforcing and difficult to escape.

Understanding this feedback loop has direct implications for how water systems plan, how government agencies design financial assistance programs, how technical assistance providers prioritize support, and how communities advocate for protection. The causal pathways documented in this report, from the acute damage inflicted by droughts, wildfires, floods, and temperature extremes to subtler pressures from rising energy demand and climate migration, illustrate that climate-related water affordability pressures are systemic and interconnected. Addressing these pressures independently will fall short. Solutions are needed at the scale of the water and wastewater system, not just the household, and they need to integrate equity considerations and prioritize frontline communities.

> Climate change is a force multiplier that threatens to accelerate and compound the affordability challenges that frontline communities already face.

The feedback loop is not inevitable. This report summarizes a number of strategies and approaches that include disaster preparedness, climate-informed management and planning, equitable funding and financing, intentional rate design paired with customer assistance, and legal and regulatory protections. These solutions can break the cycle at different points. Preparedness and system redundancy reduce the likelihood that a climate disaster results in system damage. Climate-informed planning and demand management reduce the risk that a disaster disrupts service and the costs it can generate. The capacity to do that planning is itself unevenly distributed: for the many small systems that lack the technical, managerial, and financial capacity to manage climate risk, organizational consolidation may be a necessary, though not sufficient, precondition for these strat-

egies to work at all, and its equity benefits remain uncertain. Government funding and relevant financing approaches limit how much of those costs must be recovered through rates, while rate design and assistance programs buffer households from the increases that do occur. Codified shutoff protections and utility policy that supports arrearage relief keep households connected and revenue flowing, preventing the loop from continuing. These tools work best in combination, helping to convert a self-reinforcing cycle of vulnerability into one of resilience. The key is for affordability to be integrated as a design criterion for climate adaptation, considered before a climate disaster strikes and before rates are set, rather than after households are already in arrears.

Closing these knowledge gaps remains urgent. This report identifies several priority research areas, including how utilities are managing climate-related financial pressures, which geographies and populations face the greatest overlapping exposure to climate stress and unaffordability, and which interventions most effectively protect frontline communities. Notably, while the economic costs of floods and hurricanes are well documented, little research addresses the costs to water systems directly, and no existing research links those costs to household bills; the emerging affordability modeling literature remains concentrated almost entirely on drought. Furthermore, the evidence base for how climate change affects water affordability for households with decentralized water and sanitation infrastructure remains especially limited, as do strategies to help mitigate those impacts. The political and governance conditions that determine whether these strategies can be adopted locally are similarly underexamined. Until that evidence base is built, communities will be left to navigate a growing challenge with inadequate tools.

The Water Affordability-Climate Disaster Feedback Loop framework offered here is intended as a foundation for that work: a starting point for researchers, utilities, policymakers, and advocates who are committed to ensuring that everyone, regardless of income or zip code, has access to safe, reliable, and affordable water and sanitation.



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