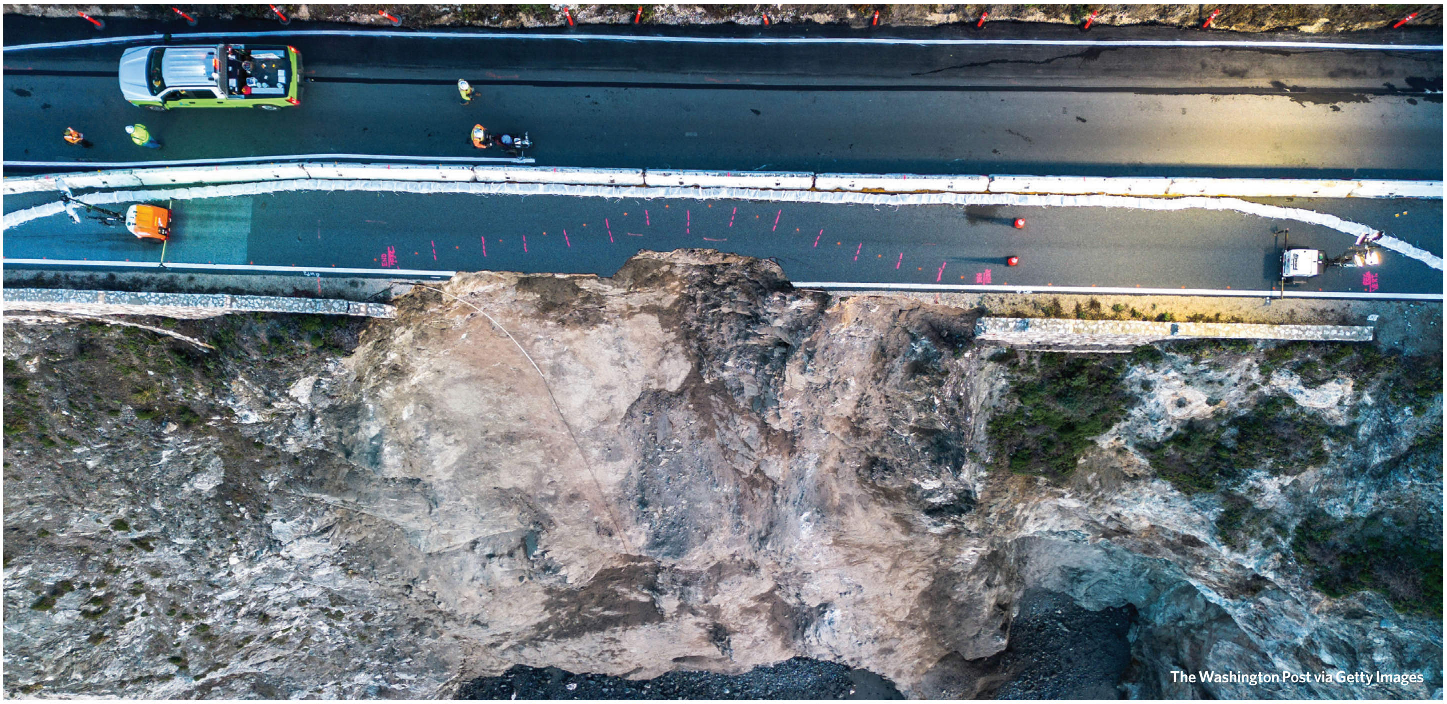

The Washington Post via Getty Images

Climate Change Poses Risks to Neglected Public Transportation and Water Systems

Extreme weather, other impacts exacerbate deferred maintenance costs for vital infrastructure

Overview

Communities around the world are increasingly suffering the consequences of accelerating changes in the global climate, such as more frequent and severe storms, extreme heat, rapid swings in precipitation patterns, and rising sea levels.[1] But for state and local governments in the U.S., these effects are also compounding challenges brought on by decades of underinvestment in critical public infrastructure, which have left the nation's roads, bridges, public transit, and drinking water systems highly vulnerable to shifting climate realities.

State and local governments spend a significant portion of their annual budgets on the construction, maintenance, and operation of roads, bridges, and public transit systems. Recent analyses show that in 2022, these governments spent roughly $180 billion—triple the federal government's infrastructure expenditures—on roads and bridges on the U.S. highway system alone.[2] And from 1956 to 2017, states and localities outspent the federal government by an average of $63 billion annually on water resources and utilities.[3]

Yet despite such investments, 43% of the nation's roadways were in poor or mediocre condition as of 2021, with the backlogged repair and maintenance costs estimated at $435 billion.[4]

Climate impacts will only aggravate these investment needs. By some estimates, climate-related damage to paved roads alone could cost up to $20 billion to repair by the end of the century, and upgrades to ensure that these roads can withstand changing conditions could cost an additional $5.8 billion to $10 billion.[5] Similarly, a recent survey of state and local governments concluded that they will need to spend roughly $625 billion over the next 20 years to maintain and improve the nation's drinking water infrastructure, with another $448 billion to $944 billion needed through 2050 to adapt drinking water and wastewater systems for the consequences of climate change.[6] And these challenges are likely to be even more intense in communities that have endured disproportionately prolonged and significant underinvestment in infrastructure systems.[7]

The potential economic impacts of climate change are broadly measured in terms of two kinds of risks:

- **Physical risks:** when people, assets, or income are damaged as a result of severe weather or natural disaster.
- **Transition risks:** the financial costs that may arise from efforts to limit the greenhouse gas (GHG) emissions that drive climate change.

Physical risks pose a particular threat to assets such as transportation and water infrastructure. They lead to immediate costs from the damaging effects of storms, hurricanes, floods, extreme heat, or other acute events. Over the long term, they drive increased costs for retrofitting and adapting infrastructure systems to lasting changes in climate patterns.

Transition risks, on the other hand, arise from government policies, new technologies, or economic market shifts that prioritize reducing GHG emissions, such as through taxes, caps, increased reporting requirements, and new modes of energy production. These changes can require additional upfront expenditures for technological upgrades or can reduce revenue from traditional sources, particularly motor fuel taxes.

Over the past two years, federal policymakers have taken historic steps to address these converging fiscal challenges, committing nearly $850 billion for core infrastructure priorities through the Infrastructure Investment and Jobs Act.[8] These funds are flowing primarily to state and local governments, which will need to consider how the changing climate will affect their infrastructure and to account for the costs of adapting transportation, water, and other assets to those impacts.

This brief looks at how changing climate conditions could materially affect critical public infrastructure systems and highlights three key financial implications for state and local governments: higher near-term costs for repairs and service disruptions; increased long-term maintenance, operations, design, and planning costs; and reductions in certain revenue streams because of government policies and economic activities designed to limit GHG emissions. It also examines recent local, state, and federal efforts to respond to infrastructure challenges and introduces a framework that governments can use to assess and account for needed investments.

The national scale of climate impacts

Climate-related damage and disruption to public infrastructure can have far-reaching economic implications for governments, necessitating costly repairs; increasing user rates for governments and residents; and depressing income-generating activities such as development, housing, agriculture, energy production, and associated revenue. (See Table 1.) This cycle of declining revenue and rising expenditures not only constrains state and local governments' existing budget resources but also could increase the costs of using debt to pay for infrastructure projects. States and localities issue bonds to finance nearly two-thirds of infrastructure projects in the U.S., and as climate impacts intensify and consume more budget resources, credit rating agencies may perceive an increased risk of default and lower the governments' credit ratings.[9] This in turn could lead to higher interest rates on those governments' bonds, increasing the cost of borrowing.

Table 1

Climate Effects on Transportation, Water Systems Pose Immediate and Long-Term Fiscal Threats

Risks and potential financial consequences for state and local capital spending

Physical risks: Financial shocks and enduring costs of damage		
Types of risks	**Acute:** Hurricanes, tornadoes, storm surges, extreme temperature changes, floods, wildfires	**Chronic:** Sustained higher temperatures, sea-level rise, changing precipitation patterns
Potential financial implications for state and local capital spending	• Increased capital costs for repair of unexpected damage • Reduced revenue and higher operating costs because of delays or disruptions in transportation or water services • Effects on a government's ability to borrow • Service disruptions that affect economic drivers in a region, reducing the tax base and associated state and local revenue	
Transition risks and opportunities: Government, policy, legal, or market responses to climate impacts or shifts intended to limit greenhouse gas (GHG) emissions and transition to sustainable energy sources		
Examples of risks	• Taxes or caps on GHG emissions for passenger and heavy-duty vehicles • Caps on GHG emissions that target water utilities' power sources and operational emissions • Increased federal emissions reporting requirements for state departments of transportation and for local and regional water utilities • State or local government exposure to litigation • Proliferation of new technologies, such as electric vehicles	
Potential financial implications for state and local capital spending	• Increased operating costs from higher compliance costs, insurance premiums, or fines or payouts for litigation • Write-offs, value impairment, and shorter life cycles for existing infrastructure assets • Increased capital investment needs to adapt existing systems and deploy new technologies, such as electric vehicle charging stations • Reduced revenue for state transportation funds from declining motor vehicle fuel taxes • Reduced capital availability, credit, and ability to borrow • Increased production costs from pricing of resources (e.g., energy, water) and output requirements (e.g., waste treatment) • Increased ridership and revenue for public transit systems	

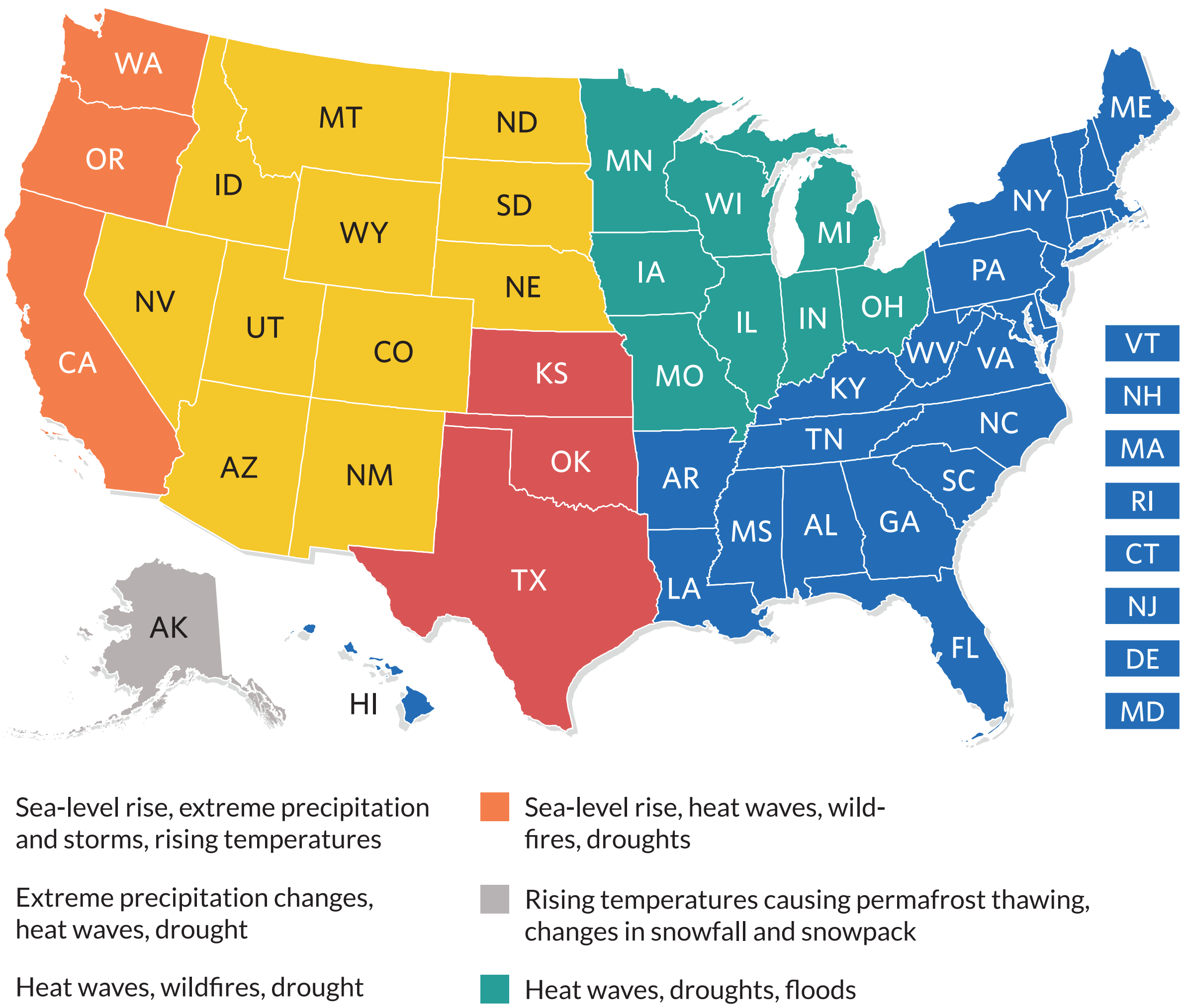
Source: Environmental Protection Agency, *Climate Risk and Opportunities Defined*, March 8, 2024

And these challenges are not unique to any specific area of the country. Although the U.S. Global Change Research Program expects considerable regional variance in the type and severity of expected climate impacts, increases in the harm and frequency of natural disasters and the intensity of prolonged climate stressors will affect infrastructure in every part of the country.[10] (See Figure 1.)

Figure 1

Rising Temperatures, Precipitation Changes Likely to Affect the Entire U.S.

Expected extreme weather and prolonged climate stressors through 2100, by state



Source: Allison R. Crimmins et al., *Fifth National Climate Assessment*, 2023

Additionally, the risk of two or more extreme events occurring simultaneously in a region is growing, exposing the complex vulnerability of undermaintained transportation and water systems across the nation. For example, a combination of record-breaking heat and widespread drought led to devastating wildfires across California, Oregon, and Washington in 2020, prompting road closures and threatening major highways and evacuation routes in the region while straining already scarce water resources.[11] After the fires were extinguished, the added burden on roads from mass evacuations and heavy emergency vehicles, coupled with damage to surrounding trees and soil erosion, significantly increased the chances of mudslides and washed out roads.[12]

Physical risks to transportation systems

Climate change poses various risks to the physical condition and operational continuity of transportation systems. The acute effects of severe weather can cause sudden and dramatic damage to roads, bridges, and other critical components of these systems, requiring immediate costly repairs. Similarly, interruptions in transportation services caused by extreme weather events can reduce revenue from user fees, rider fares, and tolls. In addition to acute shocks, chronic threats—prolonged environmental stressors—will shorten the life span of transportation infrastructure, and the more frequent repairs and replacements they necessitate will drain state and local financial resources.

Acute risks

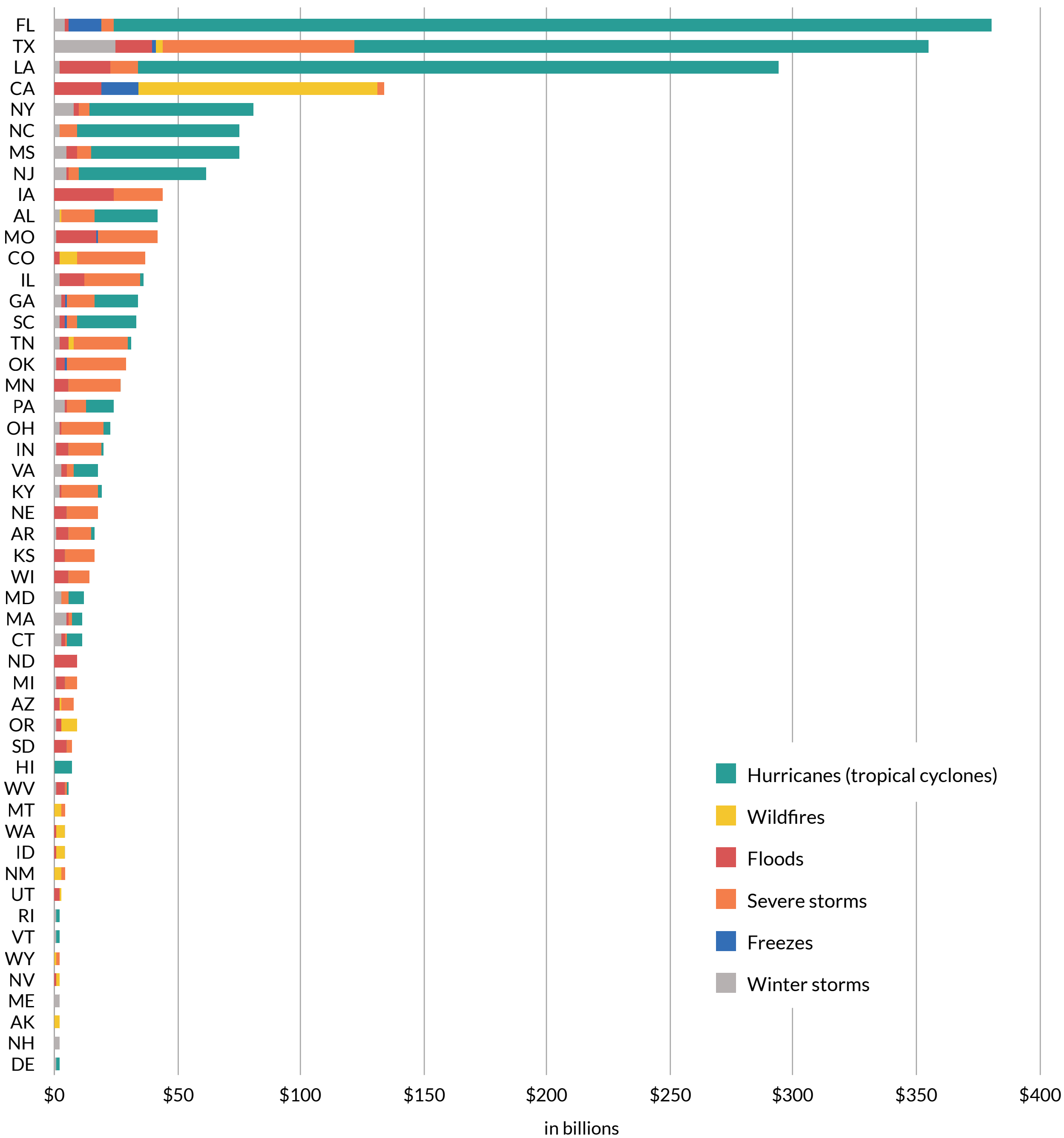
Because most roads, bridges, and public transit systems were designed to withstand local historical weather patterns, they are increasingly vulnerable to acute physical risks—such as hurricanes, tornadoes, flooding, winter storms, wildfires, droughts, and intense heat waves and cold waves. According to the National Oceanic and Atmospheric Administration (NOAA), 387 of the natural disasters that occurred in the U.S. between 1980 and June 2024 caused at least $1 billion each in economic losses.[13] Of those, hurricanes were the costliest, averaging $22.5 billion each for a total of more than $1.4 trillion.[14] (See Figure 2.)

NOAA also notes that since 1980, the central, south, and southeast regions of the country have experienced the most high-cost weather disasters. The transportation systems in these regions, which include roughly 60,000 miles of roads and bridges situated in coastal flood plains, cost state and local governments billions of dollars for repairs and maintenance from extreme storms and hurricanes.[15] For example, in 2022, Hurricane Ian, the third-costliest hurricane in U.S. history, caused roughly $109.5 billion in damage in Florida, making it the state's most expensive storm ever.[16] Devastating wind and storm surges destroyed access routes to Sanibel and Pine islands, stranding residents and hindering rescue efforts. In Sarasota County, part of Interstate 75 flooded, and in the central and eastern parts of the state, many roads and other structures were also damaged by flooding.[17]

Figure 2

Florida, Texas, and Louisiana Accounted for Almost Half of Major U.S. Disaster Costs Over 43 Years

Share of billion-dollar weather event damage, by disaster type and state, 1980-2023



Source: National Integrated Drought Information System, *Billion-Dollar Weather and Climate Disasters*, 2023

On the other side of the country, the Oregon Department of Transportation reported in its 2022 asset management plan that it had received more than $437 million in federal emergency relief since 1964 to address acute physical damage from weather emergencies. The agency further noted that in the late 1990s, in response to persistent challenges from weather-induced landslides and rockfalls, particularly in the western part of the state, it had set up a program to catalog and assess vulnerable sites along the state's highway system. As of 2022, with the project only about 45% complete, the inventory included roughly 4,200 sites with estimated repair costs of more than $2.7 billion.[18] Changes in the climate are likely to increase these landslides and rockfalls and associated costs significantly.

For public transit systems, the greater frequency and intensity of extreme weather will increase delays, service disruptions, and physical infrastructure damage. The 10 largest metropolitan area transit systems, which serve nearly 3.8 billion riders annually, are at particular risk because urban settings can magnify climate change impacts such as flash flooding and extreme heat, putting more stress on infrastructure.[19] In 2012, Hurricane Sandy devastated transit systems across New York and New Jersey. Dangerous tides of up to 14 feet flooded tunnels leading into New York City, forcing closures that lasted several weeks.

Chronic risks

In contrast to event-related shocks, chronic physical risks—enduring shifts in environmental conditions, such as higher temperatures, sea-level rise, and changes in precipitation patterns—are likely to exponentially increase the routine costs of preserving, repairing, and replacing undermaintained transportation infrastructure.

Extreme precipitation shifts and rising temperatures are already increasing maintenance and repair costs for roads and bridges nationwide, while flooding from sea-level rise, storm surges, and heavy precipitation threatens the long-term integrity of 60,000 miles of coastal roads and bridges that serve not only as critical transportation corridors but also as evacuation routes for millions of Americans.[20] According to the Fourth National Climate Assessment, "on the U.S. East Coast alone, more than 7,500 miles of roadway are located in high tide flooding zones."[21] For example, U.S. Route 17 in Charleston, South Carolina, which already floods more than 10 times a year, could experience up to 180 flood events annually by 2045, each costing roughly $13.8 million.[22] And, as sea levels rise, higher groundwater tables in lower coastal areas can undermine the foundations of tunnels and roadways even when these structures are not fully submerged underwater.[23]

Flooding, heavier rainfalls, and other prolonged changes in precipitation exacerbate water stress on roads and bridges, diminishing their durability and life span in several ways. Water can infiltrate pavement through cracks and holes, creating potholes and worsening cracks. It also may soften the top asphalt layers or detach them from the base materials, which can threaten a road's overall stability and contribute to rutting—the formation of deep tracks from vehicle pressure.[24] Additionally, more frequent and heavier rains can overload drainage systems, causing standing water on roads that exacerbates damage. Experts at the Federal Highway Administration have also noted that bridge failures are most common during prolonged flooding and that more frequent and intense rainfall can undermine the structural integrity of bridges, especially those with submerged foundations.[25] Adapting roads and bridges to these chronic harms—such as using water-resistant materials, restructuring drainage systems, and conducting more frequent maintenance to seal cracks and repair water damage—will be costly.

Rising temperatures and heat waves also affect pavement performance. Approximately 5.8 million miles of roads throughout the country face increasing risk of rutting, cracking, and buckling as temperatures higher than 90 degrees Fahrenheit become more frequent and sustained.[26] Elevated temperatures can also cause bridge joints to expand and the entire structure to shift, threatening bridge stability. And when combined with higher humidity, as climate models predict for the southeastern U.S., extreme heat conditions can hasten corrosion of bridge joints and concrete-based roads.[27]

Climate stressors also present challenges and add costs for public transit systems. For instance, flooding, sea-level rise, and extreme shifts in rainfall are already affecting the Massachusetts Bay Transportation Authority, requiring the commonwealth and the city of Boston to invest significant sums in flood doors, seawalls, and other adaptation measures.[28] Similarly, rising temperatures and extreme summer heat have caused increasing delays and disruptions in the Washington, D.C., Metrorail system and prompted concerns about the potential for steel rails to expand and buckle, which could increase derailments.[29]

To prepare for these challenges, state transportation officials will need to continuously assess the range of physical risks that a changing climate poses for their systems (see Table 2) and prioritize additional resources and investments accordingly.

Table 2

Climate Change Hazards Pose Complex Risks for Roads, Bridges, and Public Transit

Effects of changing environmental conditions on surface transportation systems

Environmental conditions	**Hazard**	**Impacts**	
		Roads and bridges*	**Public transit systems†**
Rising temperatures	Heat waves and extreme temperatures	• Rutting, cracking, premature pavement softening or expanding, potholes, road crumbling • Stress on bridge joints • Limited construction activities/capacity because of worker safety concerns, especially in areas with high humidity	• Buckling and expansion of aboveground tracks • Limited construction activities/capacity because of worker safety concerns, especially in areas with high humidity
	Melting glaciers and snowpacks	• Rutting of roads from water and snow • Landslides and washouts of roads and bridges	• Landslides and washout of tracks and rails • Flooding of underground pathways and tunnels
	Wildfires	• Heat damage, thermal cracking, or chipping • Pavement softening, rutting, expanding, and crumbling • Stress on bridge joints • Erosion, landslides, or washouts, particularly if followed by heavy rains	• Buckling, melting, and expansion of aboveground tracks

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Environmental conditions	Hazard	Impacts	
		Roads and bridges*	**Public transit systems†**
Changing precipitation patterns	Heavy precipitation and flooding	• Rutting of paved roads and erosion of unpaved roads • Traffic disruptions • Landslides and washouts of roads and bridges	• Accelerated wear and tear, requiring more frequent replacement or reconstruction of track lines, particularly in coastal areas • Landslides and washouts of tracks and rails • Flooding of underground pathways and tunnels
	Droughts	• Surface cracking and deterioration • Subsidence and sinkholes • Erosion and structural instability	• Accelerated wear and tear • Track damage from subsidence, sinkholes, and soil erosion
Sea-level rise	Coastal flooding and higher tides	• Shortening of life cycle and fidelity of roads and bridges	• Shortening of life cycle and fidelity of systems and rail in coastal areas • Landslides and washouts of tracks and rails • Flooding of underground pathways and tunnels
More frequent and intense storms	Higher tides, storm surges, and flooding	• Damage to roadways and bridges • Shortening of life cycle and fidelity of roads and bridges • Bridge washouts	• More delays, disruption, damage, and failures across systems • Landslides and washouts of tracks and rails • Flooding of underground pathways and tunnels • More immediate and immense stress on the infrastructure and overall transportation network • Shorter life expectancy of roads and bridges • Bridge, tunnel, and track washouts

* Includes roads paved with asphalt and concrete, unpaved roads, and steel and concrete bridges.

† Includes subways, surface rail, and buses.

Notes: Most roads have an expected life span of 20 to 35 years before requiring significant reconstruction, depending on the materials used and conditions. The typical life span of bridges is 50 to 75 years.

Sources: James E. Neumann et al., *Climate Change Risks to U.S. Infrastructure: Impacts on Roads, Bridges, Coastal Development, and Urban Drainage*, Jan. 23, 2014; Allison R. Crimmins et al., *Fifth National Climate Assessment*, 2023; Steve Muench et al., Pavement Resilience: State of the Practice, 2023; Transportation Research Board, *The Potential Impacts of Climate Change on U.S. Transportation*, 2008

Physical risks to water systems

In the U.S., water infrastructure is typically owned by under-resourced local governments. In a recent Environmental Protection Agency (EPA) survey, drinking water systems reported a 32% increase in financial need since 2015, owing in part to aging and deteriorating pipes and other failing infrastructure after years of underinvestment and disrepair.[30] Furthermore, some sources suggest that the aggregate cost to repair and maintain critical water infrastructure such as dams, levees, aqueducts, sewers, and water and wastewater treatment systems is in the trillions of dollars.[31]

The effects of aging infrastructure can be seen in localities throughout the country. For example, about 60% of Baltimore's water budget is used to address aging infrastructure and public safety concerns.[32] And a 2017 comptroller's report found that New York state's water infrastructure would need at least $40 billion in repairs over the next 20 years.[33]

Climate change will only exacerbate the problems facing water systems. Short-term acute climate risks, such as hurricanes, floods, and wildfires, and longer-term chronic risks, including sustained higher temperatures and droughts, sea-level rise, and changing precipitation patterns, will affect water supplies and infrastructure. (See Table 3.) The Fifth National Climate Assessment estimates that more than 1,000 community water systems, many of which serve disadvantaged populations, already struggle with failing infrastructure and poor water quality and are unprepared for climate-related challenges.[34]

Acute risks

Hurricanes, floods, high winds, tornadoes, and other events lead to broken pipes, loss of power, and poor water quality, which prevent water systems from operating effectively. Hurricane Ian severely damaged the Lee County, Florida, water system, creating water pressure and supply issues for nearly 760,000 residents and costing the county an estimated $56 million for repairs, nearly 20% of the hurricane's total cost in the county.[35]

Other acute risks, such as wildfires, also have devastating impacts on water systems, threatening not only the physical water treatment and distribution infrastructure but also water supply and quality. Fires can change water temperature, pH balance, and other factors, which can strain treatment facilities. Additionally, certain flame retardants used to put out fires contain forever chemicals, which can contaminate drinking water and are expensive to remove.[36]

In 2021, the Marshall Fire in Colorado, which was caused by drought and high winds, affected six drinking water systems, disrupting the power supply and destroying and depressurizing some physical infrastructure. The resulting system failures contributed to water contamination and service interruptions, which in turn hampered the firefighting effort. An American Water Works Association study estimated that the three largest affected water systems incurred about $6 million in expenses, not including revenue loss from voided customer bills.[37] And more recently, the Maui wildfire in Hawaii, which spread because of high winds from an offshore hurricane, was so intense that it melted water pipes in homes, causing depressurization in the water system and preventing firefighters from accessing water from hydrants.[38]

Chronic risks

In addition to these acute events, long-term chronic climate risks also threaten the nation's water infrastructure. Rising temperatures and droughts, which have become more prevalent in recent years, affect water supply and quality and, in turn, utilities' ability to serve customers, collect revenue, and borrow money.[39]

In the Great Plains region in 2022 and 2023, droughts had widespread impacts on underground water supplies and river flows. The city of Lincoln, Nebraska, announced a voluntary water conservation plan in June 2023 because of a lack of rainfall and low Platte River flows.[40] And in 2022, Nashville, Tennessee, experienced an increase in waterline breaks—to new as well as older lines—because of ground movement caused by drought.[41] At the other extreme, increasing precipitation and storm surges may overwhelm stormwater infrastructure and damage water treatment and other vital facilities. A 2023 report funded by the city of San Francisco predicted that the city could receive nearly 40% more precipitation by 2100, which would devastate its existing storm and wastewater infrastructure and cause widespread flooding.[42] And according to New York City's Wastewater Resiliency Plan, as of 2013, all 14 of the city's wastewater treatment plants and 60% of its pumping stations were at risk of flooding, with resulting damage possibly exceeding $2 billion over 50 years if no protective measures were taken.[43]

Table 3

Climate-Related Threats Will Have Far-Reaching Effects on Water Infrastructure

Impacts of changing environmental conditions on utilities and resources

Environmental conditions	Hazard	Impacts on water utilities*	Impacts on water resources†
Rising temperatures	Heat waves and extreme temperatures	• Increased evaporation, depletion of water flows, aquifer reserves because of drought conditions in drier areas • Delays and disruptions in water availability	• Depletion of groundwater resources in tandem with increased water demand • Significant changes to water cycles, misalignment between availability and demand for water resources
	Melting glaciers and snowpacks	• Contamination from sewer overflows and pipeline breaks or leaks • Stormwater containment overflows • Stress to municipal water supplies because of snow reductions	• Significant changes to water quality and reduced aboveground freshwater resources
	Wildfires	• Contamination of drinking water from debris in water-flow systems • Physical damage to critical system facilities (e.g., pipes, valves, meters) • Increased flooding and erosion of burned watersheds, which negatively affect reservoirs	• Rapid depletion of resources as water is diverted to combat wildfires

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Environmental conditions	Hazard	Impacts on water utilities*	Impacts on water resources†
Changes in precipitation patterns	Heavy precipitation; river, stream, and urban flooding	• Damage to water supply chain, delivery systems, and treatment facilities (e.g., pipes, valves, meters, aquifers) • Damage to sewer systems and wastewater treatment facilities	• Contamination of freshwater systems from saltwater or runoff intrusion
	Droughts	• Significant impacts on utility operations, including loss of water supply and pressure, leading to revenue losses or rate increases • Poor water quality that may require additional treatment to meet drinking water standards • Increased difficulty securing rights to water as overall supply declines	• Decreasing groundwater and freshwater supplies
Sea-level rise	Coastal flooding and high tides	• Damage to sewer systems and wastewater treatment facilities • Reduced drinking water supply	• Damage to freshwater aquifers and salinization of freshwater systems • Damage and overflow to sewer systems and water treatment plants, causing runoff and cross contamination
	Saltwater intrusion	• Reduction in drinking water supply	• Damage to freshwater aquifers and salinization of freshwater systems
More frequent and intense storms	Strong winds; urban, river, and stream flooding; and storm surges	• Damage to water supply chain, delivery systems, and treatment facilities (e.g., pipes, valves, meters, aquifers) • Damage to sewer systems and wastewater treatment facilities • Reduction in drinking water supply	• Damage and overflow to sewer systems and water treatment plants, causing runoff and contamination • Damage to freshwater aquifers and salinization of freshwater systems

* Includes drinking water supplies, sewerage, and wastewater treatment facilities.

† Includes water and stormwater containment systems such as dams, levees, reservoirs, and watersheds; and sources of freshwater lakes and rivers.

Source: Allison R. Crimmins et al., *Fifth National Climate Assessment*, 2023

Climate-related transition risks and opportunities

In the face of acute and chronic climate change risks to transportation and water infrastructure, efforts to adapt these public systems are vital to managing state and local costs over the long term. Some estimates predict that proper adaptation could reduce damage from climate-related extreme weather events by about a third.[44]

At the same time, global treaties such as the Paris Agreement have driven an increase in efforts to reduce GHG emissions.[45] And although these commitments are necessary to help stave off more severe climate impacts in the future, state and local officials will have to manage the risks that the global transition away from fossil fuels and other GHG-emitting energy sources poses for public infrastructure systems and related revenue and expenditures.[46]

The risk is particularly significant in the transportation sector, which is responsible for the largest share of GHG emissions in the U.S. (29%), as efforts to curb emissions are already affecting revenue sources that states rely on to pay for road, bridge, and transit maintenance.[47] For instance, the proliferation of electric vehicles—which could account for up to 50% of total U.S. car sales by 2030—will require state governments to replace motor vehicle fuel tax collections, which currently make up nearly 40% of states' transportation revenue.[48] Additionally, federal efforts to rapidly transition the transportation sector toward electric vehicles will incur added costs for infrastructure adaptation and upgrades, such as expanding the charging network.

And because water use and management account for about 10% of global GHG emissions, water systems and localities will also confront transition risks associated with emission-reduction efforts.[49] Cities and water systems that fail to maintain and update their infrastructure face the threat of lower credit ratings, which affects their ability to borrow and increases utility rates for customers. For example, Moody's downgraded the water and sewer bond rating for Shreveport, Louisiana, in 2023, citing concerns about the city's ability to meet its water and sewer infrastructure needs.[50] As the urgency of climate change adaptation grows, cities and water utilities will be under increasing pressure to update their infrastructure.

Notably, transition risks also present opportunities, particularly for transportation infrastructure. For example, policies intended to limit GHG emissions could encourage greater use of public transit systems, boosting revenue from rider fees.

A framework for action

In the face of deferred maintenance and escalating climate threats to public infrastructure, states and localities will need to invest strategically to ensure that they not only repair neglected systems, but also upgrade them to withstand changing environmental realities. And although the policies and approaches to building resiliency continue to evolve, researchers and policymakers are increasingly recognizing that taking proactive steps to address risk through vulnerability assessments, resiliency planning, and adaptation could result in profound cost savings.

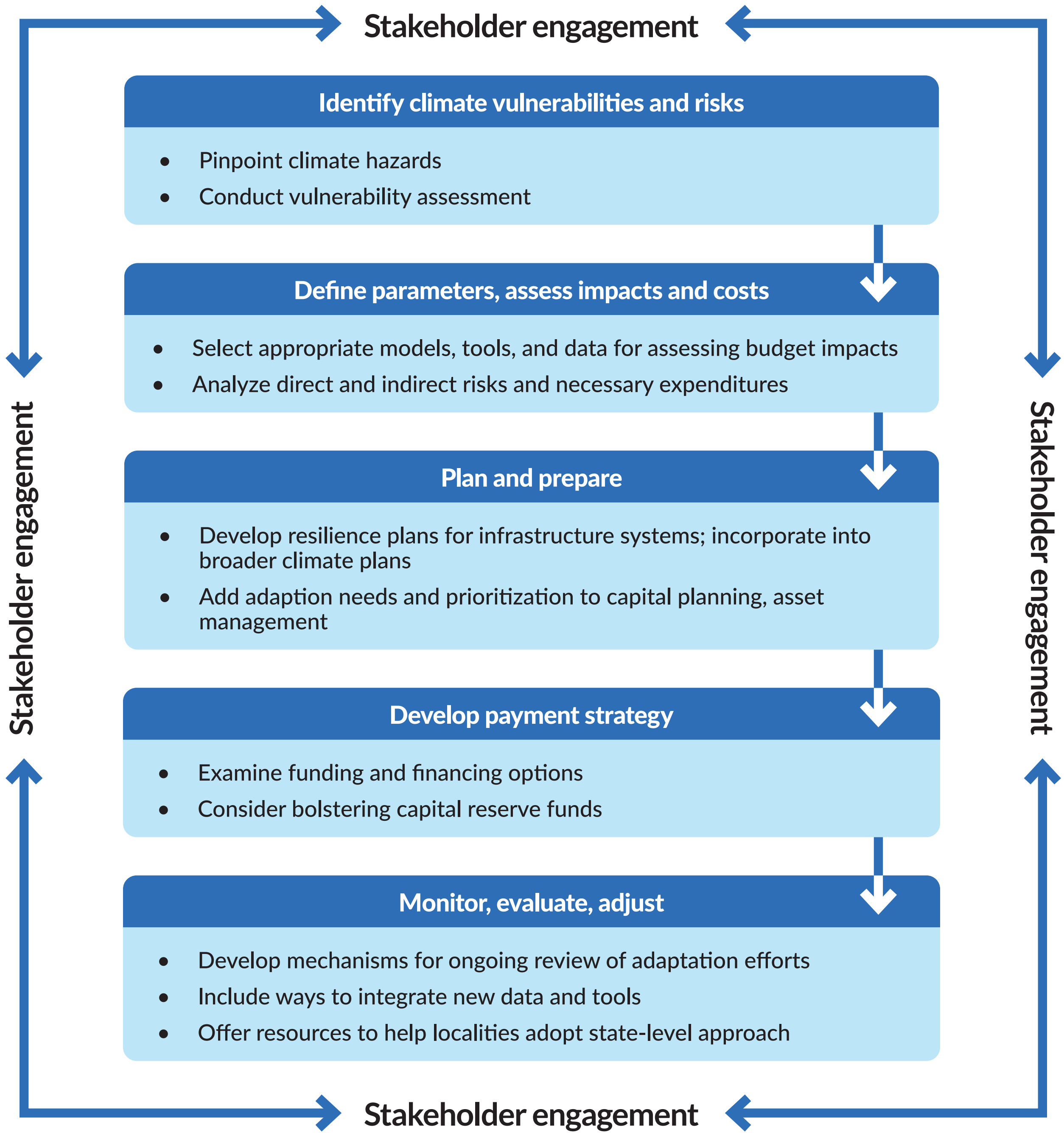
For example, a national study of climate impacts on roads, bridges, coastal areas, and urban drainage systems found that investing in adaptation could prevent up to $463 billion in damage by 2100.[51] And state and local studies have produced comparable findings. An analysis of Alaska concluded that although the state's public infrastructure—roads, buildings, airports, railroads, and pipelines—was at risk for $4.2 billion to $5.5 billion in damage from sea-level rise, storm surges, thawing permafrost, and coastal erosion by the end of the century, proactive adaptation measures could cut those costs by $1.3 billion to $2.6 billion.[52] Similarly, a 2013 study found that New York City's wastewater infrastructure could be exposed to more than $2 billion in damage from storm surges and flooding fueled by sea-level rise in the next 50 years.[53] But the report also noted that investments of just $315 million over that same time frame could significantly reduce this risk, demonstrating a cost-effective strategy for enhancing the resiliency of the city's wastewater system against future flood events.[54]

No single approach can address all the realities and uncertainties surrounding climate conditions and the fiscal risks they pose. However, a framework for assessing vulnerabilities and managing adaptation needs, priorities, and costs—based on promising examples from proactive governments and recommendations from resilience and capital planning experts—is emerging.[55] The process can enable decision-makers to better understand and prepare for added investments needed to preserve and enhance the resilience of critical public systems such as transportation and water.[56] (See Figure 3.)

Figure 3

How State and Local Governments Can Make Cost-Effective Investments in Resilience

A framework for assessing and prioritizing water and transportation infrastructure needs



Sources: Rawlings Miller, *A Roadmap: Matching Climate Assessments to Decision Making*, Nov. 13, 2023; Robert Lempert et al., *Fourth National Climate Assessment*, Volume II, Chapter 28: Reducing Risks Through Adaptation Actions, 2018

The basic steps outlined here should serve as a starting point. Governments will need to plan for ongoing updates and customization as more information and tools become available, and as environmental conditions continue to change over time.

1. **Identify climate vulnerabilities and risks by region and infrastructure type.** Conduct asset-based or systemwide climate vulnerability and risk assessments and consider integrating similar evaluations into planning for all new infrastructure projects.[57] For these assessments, states and localities will need to use existing data from their capital asset inventories or gather more information on the location and condition of infrastructure assets.
2. **Define the parameters of the analysis and assess direct and indirect climate risks and necessary expenditures.** Direct impacts and costs include acute and chronic physical risks and expenses related to increased maintenance and repairs as well as adaptation measures, such as using more resilient materials or designs, implementing green infrastructure solutions, or relocating vulnerable assets. Indirect impacts or costs include broader economic effects, such as revenue losses, increased borrowing costs, effects on economic development, and challenges to fiscal stability because of transition risks. Existing tools such as cost-benefit analyses conducted by state departments of transportation should also include potential costs and savings from adaptation measures.

   In several cases, states and localities can leverage existing tools for these analyses. For example, the Federal Highway Administration's Climate Vulnerability and Adaptation Framework and regional climate data processing tool are available for use in assessing potential climate-related impacts to roads and bridges and associated costs.[58] For water systems, the EPA's climate impact framework for water utilities and the federal Climate Resilience Toolkit's Water Resources Dashboard provide essential data and analysis to help utilities move toward resilience and adaptation.[59]
3. **Consider, plan, and prepare for meeting climate challenges.** Develop plans and approaches to improve resiliency by infrastructure type or integrate infrastructure systems into existing state climate action plans and embed those plans in statewide long-term capital improvement, long-range state transportation improvement, statewide water, or other long-term financial plans and budgeting processes. Governments also should devise a prioritization approach, criteria, or scoring methodology to help ensure that policymakers' spending decisions are based on the levels of exposure, vulnerability, and risk to critical assets or systems.
4. **Develop a strategy to pay for climate costs.** Identify a mix of potential funding and financing sources—such as federal grants for resilience and adaptation and debt—tailored to the types of infrastructure and their financial needs and resources. Additionally, states can establish or strengthen capital reserve funds to help respond to unexpected costs from natural disasters or extreme weather events.[60]
5. **Monitor, evaluate, and adjust periodically.** States should develop a routine and transparent process for ongoing review and assessment of climate impacts and the effectiveness of adaptation efforts. Approaches should include targets and metrics for resilience but be flexibly designed to integrate new information, data, or tools as they become available. To enhance coordination, states can also consider developing tools, templates, and guides to help localities apply state-level approaches.

Although aspects of this approach—such as initial data collection for climate vulnerability assessments and economic impact analyses as well as integration of findings into budget and planning processes—can be challenging, the process is flexible and customizable to each state or locality's specific needs and circumstances. For more information on Pew's research for this framework, see Appendix B.

Several states and localities have proactively applied elements of this framework to assess their climate vulnerabilities and adaptation needs and incorporated the findings into their broader infrastructure planning practices. For example, the North Carolina Department of Transportation recently conducted a vulnerability assessment of a 190-mile stretch of U.S. Route 74 between Charlotte and Wilmington, which is an important corridor for people and freight and serves as a central evacuation route for coastal communities during the region's frequent major storms.[61] The study focused on identifying the highway's long-term exposure to acute weather events to test proposed resilience and adaptation plans and used the findings to determine the goals of future resilience projects. However, the analysis found that damage from chronic climate stressors, such as precipitation and flooding, pose a greater threat to Route 74 and the local road systems it connects to and could lead to significant repair and replacement costs over the long term.[62] The analysis also emphasized that modest increases in the state's annual road maintenance and improvement investments to pay for adaptation measures would not only make residents along the route safer but also would yield considerable long-term savings by preventing damage and disruption. The state recently received a $1.8 million federal grant to support its resilience efforts and is pursuing an array of additional funding options to cover changes needed to enhance the corridor's safety.[63]

The California Department of Transportation (Caltrans) took a broader, systemwide approach in 2018 when it began a series of vulnerability assessments to identify the greatest climate risks for each of the state's 12 transportation districts. Then in 2021, Caltrans used the data it had collected to develop district-specific adaptation priorities and an online mapping tool to allow stakeholders to view climate change projections and identify the state highway system's exposed areas.[64] Further, in light of the assessment findings, the state Transportation Commission established the Local Transportation Climate Adaptation Program to provide local agencies with funding for initiatives to address each district's climate threats and resilience needs.[65] As of 2023, the program had awarded 15 resilience-focused projects a total of $309.2 million.[66]

Similarly, the Massachusetts Department of Transportation and the Boston region's Massachusetts Bay Transportation Authority conducted an assessment in 2018 to understand statewide public transit system vulnerabilities to various future climate conditions and potential damage, repair costs, and service loss impacts.[67] The results helped inform the development of a transit asset management program and scores for use in an assessment to identify projects in the commonwealth's $9.6 billion five-year Capital Investment Plan that have potential resiliency benefits and address vulnerability concerns early in project planning.[68] That information, in turn, helped guide asset management decisions, such as accelerating upgrades to the authority's Blue Line harbor tunnel to improve flood resilience and prevent water leaks and corrosion.[69]

Many local governments and water utilities also have undertaken similar assessment and planning efforts to make their water infrastructure more resilient. For example, Denver Water, which serves 1.5 million residents in the Denver metropolitan area, plans to reduce GHG emissions to 50% of 2015 levels by 2025.[70] And Jacksonville, Florida, has adopted a resilience strategy that identifies, among other things, the acute and chronic climate risks that the city faces, as well as the actions it will take to become more resilient to those risks.[71]

Other localities have embraced a collaborative approach. In New Mexico, a recent state law allows small water systems to consolidate into associations to share the financial and administrative burden of maintenance, resilience, and adaptation.[72] These partnerships will be better able than individual systems to prepare vital water infrastructure for drought, fires, and other climate-related impacts.

Federal incentives and support for state resilience efforts

In recent years, the federal government has pledged unprecedented financial support to state and local governments to strengthen the climate resilience of critical public infrastructure systems.[73] (See Figure 4.) The commitments include nearly $50 billion in the 2021 Infrastructure Investment and Jobs Act (IIJA) for projects aimed at emissions reduction and climate adaptation.[74] These funds will reach states via new initiatives, such as the Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation (PROTECT) Formula Program, and through changes to well-established initiatives—including the National Highway Performance Program—to place more emphasis on proactive environmental risk identification and management. The IIJA also provides funding to help states pay for electric vehicle charging infrastructure and develop tailored plans for reducing transportation-related emissions.[75]

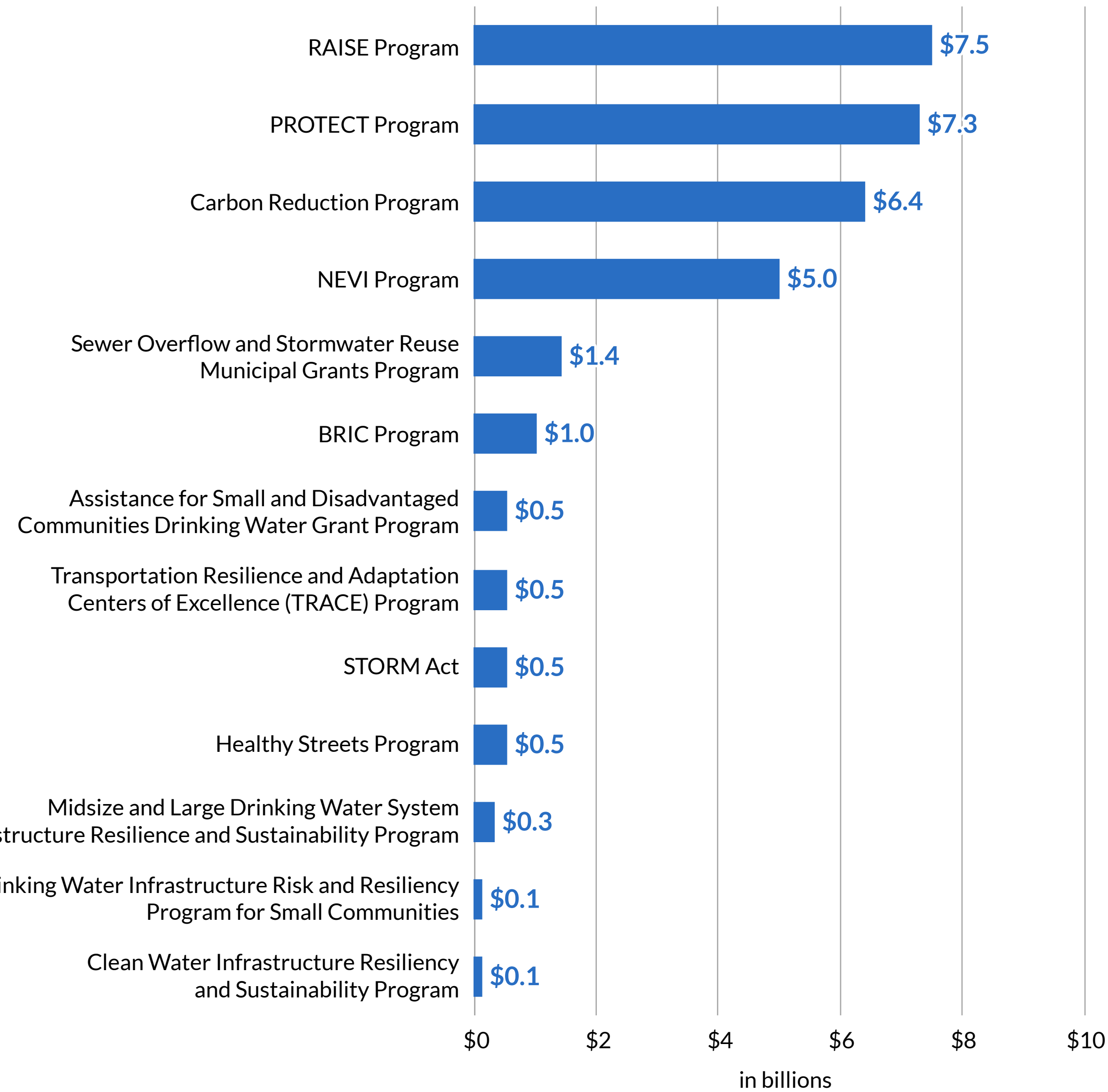
These initiatives come with an evolving suite of resources from federal agencies, including guidebooks for risk assessments, data on regional climate conditions, and modeling tools to help states develop tailored strategies for transportation and water infrastructure resilience.[76]

Water crashes over a bridge in Kemah, Texas, on Aug. 26, 2017, during Hurricane Harvey. The effects of climate change, such as increasingly severe storms, on ill-maintained critical transportation and water infrastructure present new and rising fiscal challenges for state and local governments. *Eric Overton/Getty Images*

Figure 4

Federal Resilience Programs Provide $31 Billion for Transportation and Water

Climate-focused investments in the Infrastructure Improvement and Jobs Centers



Notes: PROTECT Program is the Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation Formula Program. NEVI Program is the National Electric Vehicle Infrastructure Formula Program. BRIC is the Building Resilient Infrastructure and Communities program. STORM Act is the Safeguarding Tomorrow Through Ongoing Risk Mitigation Act. RAISE is the Rebuilding American Infrastructure with Sustainability and Equity Grant Program.

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Conclusion

Although governments at all levels are increasingly acknowledging and taking steps to address the mounting climate-related risks facing water and transportation systems, every state and locality will need to understand how acute and chronic physical climate stressors threaten their resources and budgets. This includes estimating the potential immediate and long-term costs of adapting critical infrastructure systems to rapidly changing conditions.

Tools such as vulnerability assessments and adaptation planning can help these governments anticipate and prepare for risks. And although these efforts can come with steep upfront estimates, in the tens or even hundreds of billions of dollars, the long-term savings from proactive investments to prevent or reduce damage will almost certainly be much greater.[77] Further, the significant strain that climate-related disasters and chronic stressors already are placing on state resources and the likelihood of accelerating severe weather conditions underscore why state and local governments cannot wait any longer to begin planning and adapting to protect their infrastructure against climate-related risks.

Appendix A: Resources

- **Federal Highway Administration:**
  - Vulnerability Assessment and Adaptation Framework, 3rd Edition, https://www.fhwa.dot.gov/environment/sustainability/resilience/adaptation_framework/index.cfm?_gl=1*1o31atm*_ga*OTU3ODkyODE5LjE2NDQ1MzAzNDk.*_ga_VW1SFWJKBB*MTcxNTI3MDI2My43NC4wLjE3MTUyNzAyNjMuMC4wLjA.Adaptation Framework-Resilience-Sustainability-Environment-FHWA.
  - Climate Data Processing Tool 2.1, https://fhwaapps.fhwa.dot.gov/cmip.
  - Addressing Resilience to Climate Change & Extreme Weather in Transportation Asset Management, https://www.fhwa.dot.gov/asset/pubs/hif23010.pdf.
- **EPA:**
  - Climate Impacts on Water Utilities, https://www.epa.gov/arc-x/climate-impacts-water-utilities.
  - Creating Resilient Water Utilities, https://www.epa.gov/crwu.
  - Resilient Strategies Guide for Water Utilities, https://www.epa.gov/crwu/resilient-strategies-guide-water-utilities#/?region=101&utilityType=4&utilitySize=1315&assets=&priorities=&strategies=&fundingSources=.
  - Climate Resilience Evaluation and Awareness Tool, https://www.epa.gov/crwu/climate-resilience-evaluation-and-awareness-tool.
- **U.S. Climate Resilience Toolkit:** Water Resources Dashboard, https://toolkit.climate.gov/topics/water/water-resources-dashboard.

Appendix B: Methodology

Pew began research for this brief by conducting a review of the relevant literature. From that scan, the fourth and fifth National Climate Assessment reports—published by the U.S. Global Change Research Program in 2018 and 2023, respectively—emerged as the foundational source for understanding and detailing the range of acute and chronic climate impacts and risks that threaten the integrity of transportation and water infrastructure systems throughout the nation.[78] Additionally, insights from the sessions of the 2023 Transportation Resilience Conference, hosted by the Transportation Research Board in November 2023, proved invaluable for identifying leading practices and promising approaches for incorporating climate adaption and resiliency costs into states' infrastructure planning and management practices.

To inform the framework design, Pew consulted capital budgeting and planning documents, including transportation asset management plans, climate vulnerability assessments, and climate action or adaptation plans, from a select group of state and local governments recognized for their leading practices.[79]

Limitations

The researchers relied on publicly available data sources, including federal data and reports from the Department of Transportation's Federal Highway Administration, the National Oceanic and Atmospheric Administration, the EPA, and state and local agency reports and websites. However, federal and state requirements and approaches for assessing and disclosing climate risks and costs are still evolving, and the research for this brief was based on a point-in-time survey. Other relevant state or federal reports may have been released since the brief was drafted. As a result, this brief is not intended to be a comprehensive landscape assessment of all states' approaches, and instead identifies general themes and provides an approach for states to consider when measuring and planning for climate costs for their infrastructure assets.

Expert reviewer

This report benefited from the insights and expertise of Dr. Rawlings Miller, Ph.D., vice president, climate risk and resilience, TRC Companies Inc. Although Dr. Miller reviewed the brief, neither she nor her organization necessarily endorse its findings or conclusions.

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For more information, please visit: pewtrusts.org/infrastructure

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