

Climate Change



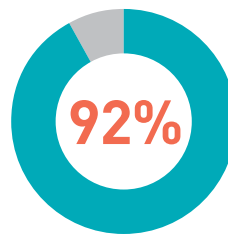
THE CHALLENGE

As Earth's temperatures rise at an unprecedented rate, the water sector will need to adjust to new norms to continue to provide critical services. Widespread shifts in weather patterns will likely persist in the foreseeable future; however, the rate and intensity of these shifts are not fully known. Even slight temperature increases can set off a chain of effects, such as lower dissolved oxygen levels, higher contaminant loads, reduced stream flows, algal blooms, and saltwater intrusion—forcing utilities to rethink traditional practices and find more innovative solutions. Adding to this challenge is the increased frequency of extreme weather, also linked to climate change. From storms and floods to drought and wildfires, these incidents can have devastating effects on critical water infrastructure.

What's more, the water sector will also need to play a key role in addressing the root cause of climate change: greenhouse gas (GHG) emissions. Global water use, storage, and distribution account for roughly 10% of GHG emissions, making this area a significant contributing factor.¹ Utilities will need to optimize treatment processes and increase energy efficiency to help the water sector drive down emissions and begin to walk back the effects of a changing climate.

THE RESEARCH

WRF has been at the forefront of a new climate paradigm, offering sound science to help the water sector continue



92% of Americans think their water utility should play a leadership role in helping communities prepare for the impacts of climate change.

Source: WRF Project #4381

to meet water demand and quality standards, as well as to plan for uncertain times. Research helps assess potential risks, prepare for and adapt to the effects on water sources and services, and offset changing climate trends by developing solutions that reduce GHGs and optimize energy use and treatment processes.

While WRF's body of research in this area dates to the 1980s, in 2008 WRF took a more deliberate approach, launching the Climate Change Strategic Initiative. The effort produced a series of integrated projects specifically dedicated to addressing the effects of long-term shifts in weather patterns. WRF now has more than 80 projects that explore climate-related topics, and hundreds of others that address related research, from energy and asset management to stormwater and cyanobacteria.

Because climate change has broad implications that cut across sectors, WRF partners strategically to produce the most informed science. Key collaborators include the U.S. Department of Energy, the National Oceanic and Atmospheric Administration (NOAA), the U.S. Environmental Protection Agency (EPA), the Global Water Research Coalition (GWRC), the Water Utility Climate Alliance (WUCA), and the Association of Metropolitan Water Agencies.



Risk Assessment

Recognizing that the first step in preparing for climate change is understanding the potential—and often variable—impacts these changes can have on water sources and systems, WRF research tracks a variety of potential risks. This science provides the foundation for tools to help facilities identify and address vulnerabilities in their operations and infrastructure.

Beginning in the early 2000s, WRF released some of the water sector's first research defining links between climate change and the impacts on water utilities. *Climate Change and Water Resources: A Primer for Municipal Water Providers* (2973) and *Implications of Climate Change for Adaptation by Wastewater and Stormwater Agencies* (CC2R08/1334) provided a realistic indication of how climate changes affect the water industry along with strategies to gauge facility vulnerability. *Water Quality Impacts of Extreme Weather-Related Events* (CC4C10/4324) also characterized potential effects, providing an encompassing collection of case studies on events such as hurricanes and heat waves and touching on everything from changes in nutrient levels to often unaccounted-for impacts, such as staffing needs brought on by catastrophic events.

WRF research also looks at how these changes pose a threat to water demand. *Changes in Water Use Under Regional Climate Change Scenarios* (4263) offers recommendations for utilities to help forecast demand based on anticipated weather shifts, which will likely require multiple models—laying the groundwork for standard regional methods to accurately predict water use.

As the water sector becomes more adept at understanding the consequences of climate change, WRF research is helping utilities recognize risk from a business perspective. *Mapping Climate Exposure and Climate Information Needs to Utility Business Functions* (4729), a collaborative effort with WUCA, produced an enterprise-level framework and step-by-step guide to help utilities understand and plan for threats to core business functions, accelerating the integration of climate considerations into everyday utility management. A follow-up project, *An Enhanced Climate-Related Risks and Opportunities Framework and Guidebook for Water Utilities Preparing for a Changing Climate* (5056), tested this framework at Denver Water and San Francisco Public Utilities Commission and used the results to refine the framework based on real-world insight.

Because the public also needs to understand the link between climate change and potential impacts to their water services, WRF research also focuses on identifying

strategies to communicate about potential vulnerabilities. WRF's 2014 guidebook, *Effective Climate Change Communication for Water Utilities* (4381), walks utilities through crafting evidence-based messages that resonate with audiences, with an emphasis on communicating risk effectively to build support for climate-related adaptation and mitigation investments. An accompanying worksheet guides users through the process and an educational video provides water professionals with the information they need to effectively communicate about the relationship between water, climate change impacts, and utility needs.

Adaptation

As a clearer picture of climate change emerges, evidence suggests that impacts will vary widely by region; however, it is relatively certain that no area will be untouched. Strategies to adapt to and meet these new challenges will be critical as the water sector moves forward. WRF has been working to provide solutions to help utilities create better adaptation plans for both the long- and short-term, respond more effectively to severe weather, and improve infrastructure and operations to meet changing needs.

Over the last decade, WRF has teamed up with several organizations to design resources to help water utilities build their resilience to climate-related impacts—as well as to make this information more accessible. One outcome, an online Water Resources Dashboard, is part of NOAA's web-based *U.S. Climate Resilience Toolkit*. The curated set of tools and resources uses real-time data and weather maps to help water professionals make decisions when facing extreme weather.

A collaborative process also played a key role in recent research into adapting to the variability of water quality brought on by natural hazards. Through a \$1.1M EPA grant, WRF and the University of Colorado Boulder investigated the impacts of events such as drought and flooding on water quality and availability. The 2019 project, *An Integrated Modeling and Decision Framework to Evaluate Adaptation Strategies for Sustainable Drinking Water Utility Management Under Drought and Climate Change* (4636), includes a decision-support tool that helps utilities adjust to changing source water conditions and improve the reliability and efficiency of their treatment processes.

That same year, as part of *Climate-Resilient Planning for Urban Stormwater and Wastewater Utilities* (5001), WRF brought together a global community of utilities to identify the research that was needed for the water sector to operate effectively under new and unpredictable



climate-driven conditions. Wet-weather flows and flood risk emerged as top challenges, and over the next five years, WRF worked to address these priorities through a series of projects and resulting resources, as detailed in the Deliverables Spotlight.

Mitigation: Addressing GHGs

Preparing for the future goes beyond just planning for the impacts of climate change—the water sector must also have an active hand in mitigating the principal causes. By pioneering research into approaches to improve energy efficiency and optimize processes, as well as reduce GHG emissions, WRF is helping the water sector reduce the activities that are driving these changes.

WRF's work in the area of GHGs began in the early 2000s, with studies breaking down the role the water sector plays in producing emissions, like methane (CH₄) and nitrous oxide (N₂O), and calculating contribution levels. The 2009 guidebook, *Greenhouse Gas Emission Inventory and Management Strategy Guidelines for Water Utilities* ([4156](#)), outlines a systematic method for tallying levels, helping water utilities evaluate emissions for potential projects and weigh alternatives. It also highlights emission-reduction strategies that can be incorporated into operations.

WRF is also leading efforts to zero in on the specific segments of the treatment process that can be leading GHG contributors. Between 2011 and 2020, WRF released a suite of studies providing some of the water sector's first science on exactly how and where in the treatment process these gases are being formed and how much is being emitted. *Flare Efficiency Estimator and Case Studies* ([1779](#)) explores emissions from gas flaring operations, resulting in a tool to calculate CH₄ from digester gas and landfill gas flares. *Quantifying Nitrous Oxide and Methane Emissions from Biofilm* ([4873](#)) investigates N₂O formation and emissions in biofilm systems, providing initial modeling and laying the groundwork for more accurate, long-term modeling. *Greenhouse Nitrogen Emissions from Wastewater Treatment Operations – Phase I and II* ([1791](#) and [1792](#)) offer some of the first insight into how atmospheric N₂O is formed during the biological nutrient removal process and the pathway for emissions.

WRF research is also bringing to light contributing factors that were once thought to have little impact on overall GHG emission totals. Released in 2020, *Conveyance Asset Prediction System (CAPS): Modeling and Mitigation* ([4885](#)) explores sewer-produced methane and its potential contribution to GHG emissions. Improved understanding of this potential source would allow for more informed decisions on how future GHG emissions could be affected,

DELIVERABLES SPOTLIGHT: **Guidance for Holistic Wet Weather and Flood Management under Climate Impacts**

As climate change ushers in a set of conditions primed to produce more severe storms and widespread floods—which are among the costliest disasters in the United States—WRF has been delivering the necessary tools to help the water sector cope with these more intense conditions.

Enhancement of Resilience to Extreme Weather and Climate Events: Proactive Flood Management

(4842) This guide highlights the best tools available to help utilities and flood management agencies assess and adapt to flood risk and implement actions in a sustainable and collaborative way. The guide covers everything from characterizing risk and planning for adaptation to identifying funding and engaging the public. It also provides an in-depth snapshot of the capabilities of several tools that allow users to do things like calculate potential damage and loss, analyze social vulnerability, and evaluate infrastructure investment decisions.

Holistic Approaches to Flood Mitigation Planning and Modeling under Extreme Events and Climate Impacts

(5084) This comprehensive technical guide is organized in an easy-to-use FAQ format allowing users to quickly find solutions for specific flood mitigation and planning issues. With answers to more than 70 questions, the guide takes a holistic approach to flood planning and breaks it down into modules on topics such as hydrologic modeling, risk assessment, and stakeholder communication, as well as innovative approaches to incorporating machine learning into the process. A decision tree is included to guide users to good starting points based on their needs and level of expertise, ranging from basic definitions of the different types of flooding, to more complex information, such as how to calculate extreme values of precipitation and streamflow. The guide also takes a deeper, more technical dive into several topics, such as various modeling approaches.



and if so, the cost and effort that would be required to comply with any future regulatory requirements.

While GHGs have been a more recent focus in WRF's climate change mitigation research, WRF also continues to concentrate on the area of energy optimization in the water sector. This body of research includes more than 100 research projects that work toward improving energy use, enhancing treatment processes and equipment design, and producing and using renewable energy.

WHAT'S NEXT?

While the exact scope of future climate change effects remains uncertain, the water sector will continue to be at the forefront of these impacts. Going forward, WRF will remain committed to strategic cross-sector partnerships, collaborating to address the challenges associated with environmental stability and public health—ultimately helping the water sector assess risks, adapt to the next norm, and integrate practices to offset the effects.

Funded in 2022, with support from WUCA, *Making the Case for Climate-Resilient Water Infrastructure and Supporting Strategies* [5222] is working to help utilities build support for investments in climate-resilient infrastructure using a forward-looking approach. The study will produce guidance and a related tool to identify hotspots for vulnerability and to more accurately weigh the costs and benefits of potential projects and approaches. *Developing an Environmental, Social, and Governance (ESG) Framework for Water Utilities* [5206] will also help utilities better evaluate and prepare for climate-related risks by developing an ESG framework tailored specifically to the water sector in a changing climate. Based on best practices across the industry, the framework will include metrics for tracking, reporting, and managing ESG topics by considering climate impacts. ESG frameworks can help utilities enhance water security, reduce costs, bolster funding opportunities, and build community engagement. WRF is also coordinating with the Alliance for Water Efficiency on *Evaluating Changes in Peak Water Demand and How That May Affect the Choice, Design, Management, and Evaluation of Demand Management Strategies* [5265] to track trends in water use patterns across different drivers, including climate-related

OTHER RESOURCES

- **Climate Change-Related Projects**
- **Stormwater Factsheet**
- **Cyanobacteria and Cyanotoxins Factsheet**
- **Resilience Factsheet**
- **Asset Management Factsheet**
- **Energy Optimization Factsheet**
- **Integrated Planning Factsheet**

impacts and extreme weather, in order to target the strategies that are most useful in reducing peak demand.

Several projects are also underway to assist the water sector in coping with the impacts of a changing climate. In 2022, WRF began work on *Holistic Wet Weather Management through Adaptive Volume and Pollutant Source Control at a Community Scale: Finding the Sweet Spot* [5131] to help utilities prepare for, manage, and treat the large amounts of water that go along with increasingly common severe storms. *Integrating Climate Change Impacts with Wet Weather Management, Capital Improvement, and Stream Network Enhancement* [5176], launched in 2023, is drafting a climate-ready wet weather planning manual to walk stormwater and wastewater utilities through making confident capital planning decisions in the face of climate uncertainty.

A series of ongoing projects is also supporting the water sector in its necessary role in mitigating the sources of climate change and reducing GHG emissions. In 2023, WRF began work on *Establishing Industry-Wide Guidance for Water Utility Life Cycle Greenhouse Gas Emission Inventories* [5188], which is designing a guidance document and tools to help utilities accurately measure and account for GHG emissions. By pinpointing where in their operations emissions are occurring, and to what degree, utilities can better target and address these issues. Another recently funded project, *Developing a Greenhouse Gas Emissions Library for Unit Processes by Water Utilities and Decentralized Systems* [5255], is building an electronic catalog of GHG emissions from common unit processes, which will give utilities a clearer picture of the role specific processes have on overall emissions and how implementing process changes could reverse emission trends.

¹ Carbon Disclosure Project. 2020. Global Water Report 2020. <https://www.cdp.net/en/research/global-reports/global-water-report-2020>.