Water Innovation in the Age of Decarbonization

A Report from the 2024 Aspen-Nicholas Water Forum

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The 2023 Aspen-Nicholas Water Forum is the thirteenth water forum in the Aspen Institute and Nicholas Institute partnership. The first, in 2005, on water, sanitation, and hygiene in the developing world, produced *A Silent Tsunami*, which made a material contribution in advancing priorities in U.S. foreign assistance for basic water services. The report ultimately helped spur passage of the Paul Simon Water for the Poor Act. The third forum, in 2015, on water and big data, catalyzed a dialogue series that led to the 2017 report: Internet of Water: Sharing and Integrating Water Data for Sustainability whose recommendations are currently being implemented by the Internet of Water project at the Nicholas Institute. The 2020 and 2021 forums on water affordability led to a dialogue series culminating in the 2022 report: Toward a National Water Affordability Strategy. The success of these endeavors provided the impetus for additional forums focused on water concerns in the United States. *https://www.aspeninstitute.org/programs/energy-and-environment-program/aspennicholaswaterforum*

Table of Contents

Vision & Process

The annual Aspen-Nicholas Water Forum convenes thought leaders to address ongoing challenges to water sustainability in the United States. Participants come from the private sector, government, academia, and non-governmental organizations—representing expertise in industry, finance, philanthropy, government, academia, agriculture, food and technology companies, investors and entrepreneurs. Past forums have explored topics such as big data, innovative financing, water quality, and water affordability. The common thread linking each forum is the fundamental question of what does good water governance look like for the United States?

The 2024 Aspen-Nicholas Water Forum focused on identifying innovative technologies, policy frameworks, business models, and institutional structures to enable decarbonization and adaptation within the water sector as well as the sector's role in decarbonizing the broader economy. Forum participants explored key questions such as: *How is innovation disrupting the water sector? How does water fit into broader decarbonization efforts? Is data an opportunity or challenge for water in decarbonization?*

Each year, Duke University's Nicholas Institute for Energy, Environment, and Sustainability and Aspen Institute coauthor a summary of the forum. **Not all views were unanimous nor was unanimity and consensus sought. Forum participants and sponsors are not responsible for this summary's content.**

We thank the following sponsors for their generous support of the forum: **The Cynthia & George Mitchell Foundation, Veolia, Xylem, The Freshwater Trust, ByWater Institute at Tulane University, ESRI, Raftelis, Might Arrow Family Foundation, The Water Research Foundation, Mortenson Center in Global Engineering at University of Colorado Boulder.**

Executive Summary

The water sector stands at a critical juncture. As the economy begins to pivot toward decarbonization, water utilities find themselves still managing long-standing challenges, while facing both intensifying new pressures and emerging opportunities. While change is challenging for any established industry, it presents a valuable opportunity to rethink and reimagine how systems are built and operated. Although there is no shortage of innovative solutions and technologies, these moments of transition create openings for their adoption, driving gradual progress and transformation. By embracing change strategically, industries can modernize their approaches, enhance efficiency, and position themselves for long-term resilience and success.

The main objective of the 2024 Aspen-Nicholas Water Forum was to identify these transition points and opportunity areas in the water sector. These insights will help the sector navigate emerging challenges–from climate resilience to infrastructure modernization–while also embracing decarbonization goals. By fostering collaboration among stakeholders, sharing best practices, and leveraging policy and technological advancements, this forum aims to accelerate the adoption of solutions that will ensure a sustainable and adaptive water sector for the future.

Key Findings

1. **Fundamental trade-offs exist between climate goals and water goals.**
   Actions to improve water quality often increase energy use and carbon emissions, while many climate solutions are highly water-intensive and can introduce new water quality concerns. As greater emphasis is placed on climate mitigation, water utilities face mounting pressure to meet increasingly stringent water quality standards while simultaneously reducing their carbon emissions. Temperature requirements for discharge water, nutrient removal processes, and treatment for emerging contaminants like PFAS all require substantial energy input. Meanwhile, decarbonization technologies—such as carbon capture, hydrogen production, and lithium mining—place heavy demands on water resources and can degrade water quality.

   Even achieving compliance with existing regulations, which many utilities currently fall short of[1], would lead to higher carbon emissions from the water sector. Meanwhile, the broader push to decarbonize the economy is driving up water demand and creating new water quality challenges in some regions. Water utilities must navigate the tension between protecting water quality, reducing emissions, and managing the growing demands of climate-driven industries. Balancing these priorities requires policy innovation and transformative technologies.

2. **The transition to clean energy and decarbonization strategies is creating new and intensifying demands on water resources.**
   The emerging clean energy economy is proving water-intensive across multiple technology families. For example:
   - Direct air capture facilities for carbon sequestration can require between 1 and 7 metric tons of water per metric ton of CO2 captured, depending on the technology used and local climate conditions.[2]
   - Some geothermal energy projects may significantly impact aquifer pressure by extracting fluids faster than natural recharge can replenish them, potentially leading to reduced well productivity and land subsidence.[3] In addition, if not properly reinjected, geothermal fluids can contaminate water with arsenic, boron, mercury, and other heavy metals.[4]
   - Hydrogen production through electrolysis is highly water-consumptive, requiring approximately 5-10 gallons of water per kilogram of hydrogen produced, but this

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[1] U.S. Environmental Protection Agency. (2023). *Providing safe drinking water in America: National public water systems compliance report, 2022*. Retrieved December 11, 2024, from https://www.epa.gov/compliance/providing-safe-drinking-water-america-national-public-water-systems-compliance-report

[2] Lebling, K., Leslie-Bole, H., Byrum, Z., & Bridgwater, L. (2022, May 2). *6 things to know about direct air capture*. World Resources Institute. Retrieved December 11, 2024, from https://www.wri.org/insights/direct-air-capture-resource-considerations-and-costs-carbon-removal

[3] Kamila, Z., Kaya, E., & Zarrouk, S. J. (2021). Reinjection in geothermal fields: An updated worldwide review 2020. *Geothermics, 89*, 101970. https://doi.org/10.1016/j.geothermics.2020.101970

[4] Kristmannsdóttir, H., & Ármannsson, H. (2003, May 19). *Environmental aspects of geothermal energy utilization. Geothermics, 32*(4-6), 451-461. https://doi.org/10.1016/S0375-6505(03)00052-X

amount can vary widely depending on the cooling process used.[5] Effluent from pretreatment processes and cooling systems can also contain high salt content and heavy metals.[6]

- Mining for lithium and other critical minerals essential for batteries and renewable energy technologies can significantly impact local water resources, with some operations consuming up to 500,000 gallons of water per metric ton of lithium extracted.[7] Lithium mining can also pollute both surface and groundwater through the release of toxic tailings waste and landscape alternations that disturb subsurface sediment. While open pit mining is particularly harmful, newer methods like brine evaporation, and direct lithium extraction (DLE), still have significant impacts.[8]
- Some forms of biomass energy production can require substantial water for irrigation and processing, with water requirements varying widely based on factors such as crop type, location, and production methods.[9] Also, several forms of biomass energy production can pollute water with nutrient-heavy run-off.

Yet these water-related constraints and impacts are typically a secondary consideration. This approach is creating concentrated demands in certain regions and raising concerns about long-term sustainability. While many clean energy sources have lower water requirements than traditional fossil fuel-based energy sources, they often create localized strain on water systems, particularly when sited in water-scarce regions. Yet water resource managers are rarely included in energy planning and siting decisions to ensure sustainable water for new industries and existing users.

3. **Climate Adaptation will be the lens through which the water sector transitions in a decarbonizing economy.**

For water utilities, the cost of service is steadily rising. Many factors contribute to this rise in cost, including more frequent and severe weather events, increased competition for energy, aging infrastructure, and new regulations. Yet outdated business models and political pressure to keep water rates low continues to constrain their revenue. Many water utilities are struggling just to maintain quality service, and as a result, must only pursue decarbonization initiatives that guarantee operational savings. However, the risk of financial losses due to extreme weather events, coupled with stronger external incentives, may push many water utilities to pursue innovative adaptation measures.

The water sector is central to climate adaptation. From floods, to wildfires, to droughts, water systems both anchor community preparedness and are at high risk of severe impacts. While

[5] Ramirez, K., Weiss, T., Kirk, T., & Gamage, C. (2023, August 2). *Hydrogen reality check: Distilling green hydrogen's water consumption*. RMI. Retrieved December 11, 2024, from https://rmi.org/hydrogen-reality-check-distilling-green-hydrogens-water-consumption/

[6] UK Environment Agency. (2024, March 28). *Hydrogen production by electrolysis of water: Emerging techniques.* Retrieved January 15, 2025, from https://www.gov.uk/guidance/hydrogen-production-by-electrolysis-of-water-emerging-techniques

[7] Institute for Energy Research. (2020, November 12). *The environmental impact of lithium batteries*. Retrieved December 11, 2024, from https://www.instituteforenergyresearch.org/renewable/the-environmental-impact-of-lithium-batteries/

[8] Blair, J. J. A., Vineyard, N., Mulvaney, D., Cantor, A., Sharbat, A., Berry, K., Bartholomew, E., & Firebaugh Ornelas, A. (2024). Lithium and water: Hydrosocial impacts across the life cycle of energy storage. WIREs Water, 2024, e1748. https://doi.org/10.1002/wat2.1748

[9] Gerbens-Leenes, P. W., Hoekstra, A. Y., & van der Meer, T. H. (2008). *Water footprint of bio-energy and other primary energy carriers*. UNESCO-IHE Institute for Water Education. Retrieved December 11, 2024, from https://www.waterfootprint.org/resources/Report29-WaterFootprintBioenergy.pdf

climate funding and attention has traditionally focused on mitigation efforts, adaptation is quickly becoming an equal concern. Consequently, funding for climate adaptation is projected to grow substantially in the coming decade. The water sector should position itself to receive adaptation funding to spur the kind of innovation within the sector that can fundamentally transform how water services are governed, managed, and delivered. Water utilities have the opportunity to implement solutions that simultaneously enhance climate resilience, cut emissions, and reduce long-term costs. Yet the path forward remains challenging. Without policy frameworks that address underlying fiscal constraints or create new business models, most utilities will continue to prioritize immediate operational imperatives over uptaking innovative solutions.

4. **Small and medium-sized systems are well-positioned to leapfrog traditional infrastructure models with modular, flexible solutions that address synergies across water, energy, and carbon.**
   Large and well-resourced utilities with sophisticated capabilities and stable funding have typically been the primary market for innovative solutions. However, the unique challenges faced by small and rural systems, including dispersed customer bases, limited staff and financial resources, and lack of technical capacity, may demand different approaches and solutions. While these utilities face significant barriers to adopting new technologies and business models, their circumstances may make them ideal candidates for innovative approaches like distributed systems, regional partnerships, or cooperative service agreements. Rather than waiting for solutions to trickle down from large utilities, researchers and entrepreneurs should intentionally develop technologies and business models that address the specific needs and constraints of small systems. When designed intentionally and adaptively, these innovations could not only transform rural water service delivery, but potentially offer valuable lessons for the broader sector.

5. **The water sector needs a coordination framework that can harmonize existing distributed governance systems, offer strategic guidance, and enable knowledge and resource-sharing while preserving regional decision-making autonomy.**
   The water sector faces a fundamental tension. Local expertise and flexibility are essential for effective water management, yet the current fragmented governance structure makes it difficult to address water challenges at the scale and speed required. Without some form of coordination, water managers, including utilities, irrigation districts, and infrastructure operators, struggle to learn from each other's experiences or implement innovative solutions beyond their individual jurisdictions. Centralized control is not the answer. Instead, a national framework that aligns priorities and facilitates collaboration, while preserving local decision-making authority, could help regions develop innovative solutions tailored to their unique circumstances. This framework should include policies that help water managers work effectively with stakeholders to implement energy and carbon solutions, capitalizing on opportunities where coordinated action can deliver greater environmental and economic value for communities. As climate impacts intensify and infrastructure continues to deteriorate across the country, such a framework would enable water systems to benefit from collective knowledge and resources while maintaining their critical connection to local conditions and community needs.

The State of Innovation in the Water Sector

The water sector does not typically seek disruption, and for good reason. Reliable water service is essential to public health, safety, and economic stability. Yet, the sector now faces an unprecedented convergence of challenges that could spur change. Yet staying 'boring'—ensuring dependable service and operational stability—amid such growing pressures and constantly changing surrounding conditions requires continuous innovation and adaptation. Over the next decade, these challenges could force a wave of innovation, driving the sector to embrace new technologies, business models, and policy frameworks, and transforming how water resources are managed and delivered in the United States.

While this transformation is increasingly imperative, the path forward will be neither simple nor swift. The sector has historically been slow to adopt innovative solutions, with new technologies typically taking upwards of three decades to achieve widespread implementation, and other forms of innovation following similar timescales. Fragmentation is one major barrier to innovation. There are approximately 50,000 community water systems[10] and some 17,000 publicly owned wastewater treatment works[11] diffused across the US and operating under a patchwork of different local, state, and federal regulations. Additionally, the essential nature of water services and public health responsibilities creates an understandable risk aversion among utility managers and regulators. While regulations around emerging contaminants like PFAS and microplastics may catalyze some changes in the near future, there is no equivalent to the transformative policies or rapidly changing markets that have accelerated innovation in the energy sector.

Innovation in the water sector encompasses far more than technological advancement alone. It includes evolving policy frameworks, novel business models, and reimagined institutional structures that can transform how water resources are managed and delivered. Often these varied types of innovation must be implemented in tandem to ensure viable pathways to adoption. Successful innovation is driven by clearly identified needs rather than predetermined solutions. Too often, new technologies or approaches are developed without a thorough understanding of the practical challenges faced by utilities, irrigators, industries, corporations, and water managers or in the absence of policy and financial tools that could enable them.

When there is a disconnect between solution development, operational realities, and policy levers, innovation fails through lack of adoption. This isolated development often results in solutions that do not address core needs or prove impractical to implement at scale. As utilities grapple with aging infrastructure, changing precipitation patterns, growing service demands, and new regulations, innovations that help them adapt are likely to see the greatest adoption. The most transformative changes will likely emerge from efforts to solve immediate operational challenges while incorporating longer-term goals, including decarbonization, as cost reduction measures or secondary benefits.

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[10] U.S. Environmental Protection Agency. (2024, December 2). *Community water system service area boundaries*. U.S. Environmental Protection Agency. Retrieved January 10, 2025, from https://www.epa.gov/ground-water-and-drinking-water/community-water-system-service-area-boundaries

[11] U.S. Environmental Protection Agency. (2024, April). *2022 Clean Watersheds Needs Survey: Report to Congress* (EPA 832-R-24-002). U.S. Environmental Protection Agency. Retrieved January 10, 2025, from https://www.epa.gov/system/files/documents/2024-05/2022-cwns-report-to-congress.pdf

Rethinking Water Infrastructure Priorities

America's water infrastructure faces severe challenges, particularly in depopulating and economically disadvantaged areas, where deterioration is most pronounced. These problems vary significantly between urban and rural settings. Many rural and tribal communities lack basic water infrastructure, while urban systems grapple with aging infrastructure, changing water demands, and the increasing pressures of climate change.

Infrastructure and maintenance challenges are pervasive across water systems in the US. Since 2000, 630 dams have failed, and approximately 74% of high or significant-hazard dams, those whose failure would likely result in loss of life, are rated as being in fair, poor, unsatisfactory, or unknown condition.[12] Drinking and wastewater infrastructure is also strained. About 50% of our nation's population depends on groundwater for their water supplies.[13] However, domestic wells face mounting challenges, with groundwater levels declining by 1-4 feet annually in many Western states over the past few decades.[14,15,16] Furthermore, widespread contamination of wells by tasteless but dangerous contaminants, including arsenic, uranium, and nitrates, poses a significant threat to water quality.[17] Septic systems serve approximately 25% of U.S. households[18], significantly higher than many other developed nations.[19,20,21] Some states and localities experience septic failure rates of up to 31%[22,23] due

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[12] Hwang, J., & Lall, U. (2024). Increasing dam failure risk in the USA due to compound rainfall clusters as climate changes. *NPJ Natural Hazards, 1*(27). https://doi.org/10.1038/s44304-024-00027-6

[13] U.S. Geological Survey (USGS). (2017, December 7). *The quality of the nation's groundwater: Progress on a national survey.* Retrieved January 15, 2025, from https://www.usgs.gov/news/featured-story/quality-nations-groundwater-progress-national-survey

[14] Kansas Geological Survey. (2022, March 23). *Groundwater levels fall across western and central Kansas*. Retrieved December 11, 2024, from https://www.kgs.ku.edu/General/News/2022/groundwater_levels.html

[15] Riordon, J. R. (2024, June 17). *Groundwater declines in the U.S. Southwest*. NASA Earth Science News Team, adapted by NASA Earth Observatory. Retrieved December 11, 2024, from https://earthobservatory.nasa.gov/images/152970/groundwater-declines-in-the-us-southwest

[16] California Department of Water Resources. (2021). *California groundwater conditions update – Spring 2021*. Retrieved December 11, 2024, from https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Data-and-Tools/Files/Maps/Groundwater-Level-Change/DOTMAP_Reports/Spring-2021-Groundwater-DOTMAP-Report.pdf

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[20] Gunady, M., Shishkina, N., Tan, H., & Rodriguez, C. (2015). A review of on-site wastewater treatment systems in Western Australia from 1997 to 2011. Journal of Environmental and Public Health, 2015, 716957. https://doi.org/10.1155/2015/716957

[21] Environment Canada. (2011). *2011 municipal water use report: Municipal water use 2009 statistics*. Retrieved December 11, 2024, from https://www.ec.gc.ca/doc/publications/eau-water/COM1454/survey8-eng.htm

[22] Ohio Department of Health. (2013, January). Household sewage treatment system failures in Ohio: A report on local health department survey responses for the 2012 Clean Watersheds Needs Survey. Retrieved December 11, 2024, from https://odh.ohio.gov/know-our-programs/sewage-treatment-systems/education-resources/2012hstsfailureratesinohio

[23] Hall, A. F. (2024, January 5). *Failure rate of Lake George septic systems exceeds 20%*. *Lake George Mirror*. Retrieved December 11, 2024, from https://www.lakegeorgemirror.com/failure-rate-of-lake-george-septic-systems-exceeds-20/

to poor maintenance and aging infrastructure. While reported drinking water violations have decreased according to federal databases, recent analysis suggests that approximately 26% of health violations may go unreported,[24] obscuring the true extent of water quality challenges.

Meanwhile, federal funding for water infrastructure has declined dramatically over recent decades, falling from 63% of capital expenditures in 1977 to just 9% in 2017.[25] While the 2021 Infrastructure Investment and Jobs Act (IIJA) provided $82.5 billion for water infrastructure,[26] this still falls far short of meeting the nation's estimated annual need of $123 billion over the next decade to achieve a state of good repair.[27] This gap is continuing to widen due to a variety of factors including aging and inadequately maintained infrastructure, increasingly stringent regulations, and new programmatic requirements such as PFAS remediation. If current trends continue, the annual funding gap is projected to grow to $136 billion by 2039.[28]

Communities are increasingly accepting degraded infrastructure as the new normal, representing a dangerous shift in baseline expectations.

Communities, particularly in disadvantaged areas, have begun to accept deteriorating infrastructure conditions as normal. This shifting baseline manifests in the tacit acceptance of recurring service interruptions, declining water quality, and aging or inefficient infrastructure. Many systems now operate in a continuous state of disrepair, with maintenance being deferred and improvements postponed due to financial constraints.[29] This normalization of substandard service threatens both public health and environmental quality while also deepening existing inequities in water access and reliability.

The problem is particularly acute in small and rural systems where limited resources and technical capacity often result in a cycle of deterioration.[30] As these systems approach or exceed their designed lifespans, they become increasingly vulnerable to catastrophic failures. The resulting service disparities between urban and rural areas continue to widen, with rural communities often lacking the economies of scale and technical expertise needed to implement lasting solutions. This acceptance

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[24] U.S. Government Accountability Office. (2011). Drinking water: Unreliable state data limit EPA's ability to target enforcement priorities and communicate water systems' performance (GAO-11-381). Published June 17, 2011; publicly released July 19, 2011. Retrieved December 11, 2024, from https://www.gao.gov/products/gao-11-381

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[27] U.S. Water Alliance. (2017). *The economic impact of investing in water infrastructure.* Retrieved January 15, 2025, from https://uswateralliance.org/wp-content/uploads/2023/09/Economic-Impact-of-Investing-in-Water-Infrastructure_VOW_FINAL_pages_0.pdf

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[29] Humphreys, E. H. (2023, December 18). *Drinking water infrastructure needs: Background and issues for Congress* (R47878). Congressional Research Service. Retrieved December 11, 2024, from https://crsreports.congress.gov/product/pdf/R/R47878/3

[30] Martin, D. (2021, September). *Affordability and capability issues of small water and wastewater systems: A case for regionalization of small systems*. Rural Community Assistance Partnership, Great Lakes RCAP. Retrieved December 11, 2024, from https://rcap.org/wp-content/uploads/2021/09/Regionalization-Great-Lakes-RCAP-final.pdf

of degraded infrastructure not only impacts current service levels but also threatens the long-term sustainability and resilience of these water systems.

While traditional infrastructure approaches remain entrenched, evolving challenges demand new models for water system design and delivery.

The infrastructure we build today will serve communities for the next 50-100 years, yet our current supply-driven, centralized approach often fails to account for future conditions such as shifting demographics, evolving water use patterns, and changing water availability. The water sector's traditional business model continues to favor large-scale infrastructure projects that often prove inflexible. Climate change will compound these challenges, requiring infrastructure to handle more extreme weather events while maintaining reliable service. Meanwhile, continued development in water-scarce areas, punctuated impacts from floods, and growing pressure on tribal water resources threaten to further strain already stressed systems.

Rather than replacing failing infrastructure, this trajectory of decline presents an opportunity to fundamentally rethink water systems. Communities can embrace innovative solutions that are better suited to future conditions, whether climatic or demographic, by moving beyond singular, top-down infrastructure projects. Alternative service delivery approaches could include distributed systems that scale with community growth, digital technologies like remote sensing and AI that enhance monitoring and maintenance, modular designs that allow for flexible adaptation, and solutions that serve multiple purposes while reducing reliance on traditional water sources. Success requires shifting from a purely supply-driven model to one that balances supply enhancement with demand management and system optimization. To meet modern challenges, water systems must be able to adapt over a period of years rather than decades. The water sector needs innovative policies, regulatory processes, and business models than can enable it to be more agile in face of change.

Small and medium-sized systems are well-positioned to leapfrog traditional infrastructure models with modular, flexible solutions that address synergies across water, energy, and carbon.

Large and well-resourced utilities with sophisticated capabilities and stable funding have typically been the primary market for innovative solutions. However, the unique challenges faced by small and rural systems, including dispersed customer bases, limited staff and financial resources, and lack of technical capacity, may demand different approaches and solutions. While these utilities face significant barriers to adopting new technologies and business models, their circumstances may make them ideal candidates for innovative approaches like distributed systems, regional partnerships, or cooperative service agreements. Rather than waiting for solutions to trickle down from large utilities, researchers and entrepreneurs should intentionally develop technologies and business models that address the specific needs and constraints of small systems. When designed intentionally and adaptively, these innovations could not only transform rural water service delivery, but potentially offer valuable lessons for the broader sector.

Balancing Water, Energy & Climate

Water and energy systems are fundamentally interlinked, with each sector heavily dependent on the other. Climate change is intensifying this relationship while creating new challenges for both sectors. The energy sector is the largest water user in the US, with thermoelectric power generation alone accounting for 41% of total water withdrawals.[31] Conversely, water and wastewater utilities rely heavily on energy for treatment and distribution emitting over 45 million tons of greenhouse gases annually.[32]

This interdependence means that constraints in either sector can cascade through the other, potentially leading to system-wide failures. However, it also presents opportunities where improvements in one sector can create compounding benefits in the other. Monitoring, reporting, and verification (MRV) systems enable stakeholders to quantify these interconnections and evaluate the effectiveness of new initiatives. Without standardized MRV protocols across organizations, it is difficult to demonstrate progress, maintain accountability, or secure investment for new water-energy solutions.

Focusing on synergistic solutions that address both water and energy challenges is essential for creating sustainable and resilient systems. Integrated approaches, such as leveraging renewable energy sources to power water treatment facilities or implementing water-efficient cooling systems in energy production, can optimize resource use and minimize waste and emissions while reducing environmental impacts. These solutions not only enhance efficiency but also build resilience against the interconnected risks posed by climate change, resource scarcity, and aging infrastructure. By prioritizing strategies that bridge water and energy sectors, we can unlock innovative opportunities to meet the needs of today and future generations.

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[31] Dieter, C. A., Maupin, M. A., Caldwell, R. R., Harris, M. A., Ivahnenko, T. I., Lovelace, J. K., Barber, N. L., & Linsey, K. S. (2018). Estimated use of water in the United States in 2015 (Circular 1441). U.S. Geological Survey. https://doi.org/10.3133/cir1441

[32] Environmental Protection Agency. (2022). Energy Efficiency for Water Utilities. Retrieved from https://www.epa.gov/sustainable-water-infrastructure/energy-efficiency-water-utilities

[33] U.S. Environmental Protection Agency. (2023). *Providing safe drinking water in America: National public water systems compliance report, 2022*. Retrieved December 11, 2024, from https://www.epa.gov/compliance/providing-safe-drinking-water-america-national-public-water-systems-compliance-report

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- Direct air capture facilities for carbon sequestration can require between 1 and 7 metric tons of water per metric ton of CO2 captured, depending on the technology used and local climate conditions.[34]
- Some geothermal energy projects may significantly impact aquifer pressure by extracting fluids faster than natural recharge can replenish them, potentially leading to reduced well productivity and land subsidence.[35] In addition, if not properly reinjected, geothermal fluids can contaminate water with arsenic, boron, mercury, and other heavy metals.[36]
- Hydrogen production through electrolysis is highly water-consumptive, requiring approximately 5-10 gallons of water per kilogram of hydrogen produced, but this amount can vary widely depending on the cooling process used.[37] Effluent from pretreatment processes and cooling systems can also contain high salt content and heavy metals.[38]
- Mining for lithium and other critical minerals essential for batteries and renewable energy technologies can significantly impact local water resources, with some operations consuming up to 500,000 gallons of water per metric ton of lithium extracted.[39] Lithium mining can also pollute both surface and groundwater through the release of toxic tailings waste and landscape alternations that disturb subsurface sediment. While openpit mining is particularly harmful, newer methods like brine evaporation, and direct lithium extraction (DLE), still have significant impacts.[40]
- Some forms of biomass energy production can require substantial water for irrigation and processing, with water requirements varying widely based on factors such as crop type, location, and production methods.[41] Also, several forms of biomass energy production can pollute water with nutrient-heavy run-off.

Yet these water-related constraints and impacts are typically a secondary consideration. This approach is creating concentrated demands in certain regions and raising concerns about long-term sustainability. While many clean energy sources have lower water requirements than traditional fossil

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[34] Lebling, K., Leslie-Bole, H., Byrum, Z., & Bridgwater, L. (2022, May 2). *6 things to know about direct air capture*. World Resources Institute. Retrieved December 11, 2024, from https://www.wri.org/insights/direct-air-capture-resource-considerations-and-costs-carbon-removal

[35] Kamila, Z., Kaya, E., & Zarrouk, S. J. (2021). Reinjection in geothermal fields: An updated worldwide review 2020. *Geothermics, 89*, 101970. https://doi.org/10.1016/j.geothermics.2020.101970

[36] Kristmannsdóttir, H., & Ármannsson, H. (2003, May 19). *Environmental aspects of geothermal energy utilization. Geothermics, 32*(4-6), 451-461. https://doi.org/10.1016/S0375-6505(03)00052-X

[37] Ramirez, K., Weiss, T., Kirk, T., & Gamage, C. (2023, August 2). *Hydrogen reality check: Distilling green hydrogen's water consumption*. RMI. Retrieved December 11, 2024, from https://rmi.org/hydrogen-reality-check-distilling-green-hydrogens-water-consumption/

[38] UK Environment Agency. (2024, March 28). *Hydrogen production by electrolysis of water: Emerging techniques.* Retrieved January 15, 2025, from https://www.gov.uk/guidance/hydrogen-production-by-electrolysis-of-water-emerging-techniques

[39] Institute for Energy Research. (2020, November 12). *The environmental impact of lithium batteries*. Retrieved December 11, 2024, from https://www.instituteforenergyresearch.org/renewable/the-environmental-impact-of-lithium-batteries/

[40] Blair, J. J. A., Vineyard, N., Mulvaney, D., Cantor, A., Sharbat, A., Berry, K., Bartholomew, E., & Firebaugh Ornelas, A. (2024). Lithium and water: Hydrosocial impacts across the life cycle of energy storage. WIREs Water, 2024, e1748. https://doi.org/10.1002/wat2.1748

[41] Gerbens-Leenes, P. W., Hoekstra, A. Y., & van der Meer, T. H. (2008). *Water footprint of bio-energy and other primary energy carriers*. UNESCO-IHE Institute for Water Education. Retrieved December 11, 2024, from https://www.waterfootprint.org/resources/Report29-WaterFootprintBioenergy.pdf

fuel-based energy sources, they often create localized strain on water systems, particularly when sited in water-scarce regions. Yet water resource managers are rarely included in energy planning and siting decisions to ensure sustainable water for new industries and existing users.

Adaptation will be the lens through which the water sector transitions in a decarbonizing economy.

For water utilities, the cost of service is steadily rising. Many factors contribute to this rise in cost, including more frequent and severe weather events, increased competition for energy, aging infrastructure, and new regulations. Yet outdated business models and political pressure to keep water rates low continues to constrain their revenue. Many water utilities are struggling just to maintain quality service, and as a result, must only pursue decarbonization initiatives that guarantee operational savings. However, the risk of financial losses due to extreme weather events, coupled with stronger external incentives, may push many water utilities to pursue innovative adaptation measures.

The water sector is central to climate adaptation. From floods, to wildfires, to droughts, water systems both anchor community preparedness and are at high risk of severe impacts. While climate funding and attention has traditionally focused on mitigation efforts, adaptation is quickly becoming an equal concern. Consequently, funding for climate adaptation is projected to grow substantially in the coming decade. The water sector should position itself to receive adaptation funding to spur the kind of innovation within the sector that can fundamentally transform how water services are governed, managed, and delivered. Water utilities have the opportunity to implement solutions that simultaneously enhance climate resilience, cut emissions, and reduce long-term costs. Yet the path forward remains challenging. Without policy frameworks that address underlying fiscal constraints or create new business models, most utilities will continue to prioritize immediate operational imperatives over uptaking innovative solutions.

Rising climate risks threaten water utilities' financial stability through insurance and bond markets.

Water utilities are facing growing financial pressure as insurance providers respond to emerging climate change risks. Insurers are increasingly raising premiums and restricting coverage for utilities in many high-risk regions, while also placing pressure on these utilities to develop climate action and adaptation plans. As significant municipal bond investors, these same insurance companies face exposure to emerging climate-related risks and are beginning to question whether climate change could increase default risks or degrade the value of some municipal bonds in which they are invested.[42] This increased market scrutiny could create a meaningful financial incentive for water utilities to develop climate resilience strategies, as the cost of inaction continues to grow.

Digital Transformation in the Water Sector

Technology adoption in the water sector is slow, with most innovations requiring decades to achieve widespread implementation. This reflects both the inherently conservative nature of the water sector and the practical challenge of driving change across thousands of independent water systems. The

[42] Association of Metropolitan Water Agencies. (2019, October). *Insurance, bond ratings, and climate risk: A primer for water utilities*. Retrieved December 11, 2024, from https://www.amwa.net/assets/Insurance-BondRatings-ClimateRisk-Paper.pdf

technology innovations that have been most successful in recent years tend to be "capital-light" digital solutions that can be deployed without major changes to infrastructure or organizational protocols. Today, remote sensing and artificial intelligence are transforming how utilities monitor and manage water infrastructure. New satellite and imaging technologies make it possible for utilities to map and monitor assets without physical access, while AI tools help fill critical data gaps and enable predictive maintenance.

The adoption of digital solutions, however, is not occurring evenly across the water sector. While many utilities still rely on paper records and manual processes, modernization is happening at both ends of the spectrum. Large utilities are implementing sophisticated monitoring and control systems that enable real-time operational oversight. At the same time, small utilities are adopting mobile applications for basic data collection, often in response to staffing shortages and operational necessities. The pace of digital technology adoption has accelerated as these tools have become more cost-effective and user-friendly, allowing utilities to modernize their operations without specialized technical expertise. This trend of accelerated digital adoption is likely to continue, but the most successful solutions will be those that align closely with utilities' operational constraints and capabilities.[43]

While advances in computational power enable improved water management capabilities, the rapid growth of data centers and chip manufacturing facilities is creating unprecedented water demands.

The increasing power of computational tools is driving advances in water management, from infrastructure mapping to predictive modeling, yet these same technologies create substantial demands on water resources. In a high-growth scenario, data centers could consume up to 9.1% of US electricity by 2030.[44] Currently, individual facilities can use 3-5 million gallons of water a day for cooling—roughly equivalent to the water needs of a small city.[45] Chip manufacturing facilities are also highly water-intensive, with average facilities today using up to 10 million gallons of ultrapure water a day. Ultrapure water is treated through advanced processes like deionization and reverse osmosis and requires 1.4-1.6 gallons of municipal water for every gallon of ultrapure water.[46] To make matters worse, both data centers and chip manufacturing facilities are frequently concentrated in arid regions. Water availability is rarely a top consideration in siting decisions. Other factors, such as land costs and energy availability tend to take precedence over water despite its importance to operations.

The technology sector's growing water footprint creates competing demands for the water sector. The computational capabilities enabled by AI and emerging technologies, which rely on data centers and

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[43] Bluefield Research. (2024, September 12). *U.S. & Canada digital water market to surge 107% by 2033 as utilities accelerate their own transformations*. Retrieved December 11, 2024, from https://www.bluefieldresearch.com/ns/u-s-canada-digital-water-market-to-surge-107-by-2033-as-utilities-accelerate-their-own-transformations/

[44] EPRI. (2024, May). *Powering intelligence: Analyzing artificial intelligence and data center energy consumption*. Retrieved December 11, 2024, from https://www.epri.com/research/products/3002028905

[45] O'Donnell, D. (2022, August 16). Data center water usage challenges and sustainability. Sensorex. Retrieved December 11, 2024, from https://sensorex.com/data-center-water-usage-challenges/

[46] James, K. (2024, July 19). *The water challenge for semiconductor manufacturing and big tech: What needs to be done.* World Economic Forum. Retrieved January 15, 2025, from https://www.weforum.org/stories/2024/07/the-water-challenge-for-semiconductor-manufacturing-and-big-tech-what-needs-to-be-done/

chip manufacturing, are becoming increasingly vital for modern water system management. However, their concentrated water demands can strain local resources, particularly in water-scarce regions. The situation is further complicated by pricing structures that sometimes allow technology companies to secure preferential water rates compared to residential users, reducing their incentive to invest in water conservation measures.[47] As these facilities proliferate across the country, greater coordination between the technology sector, land use planners, and water resource managers will be essential to reduce potential short-term and long-term impacts on local communities.

Modernizing Water Governance, Policy & Financing

Water governance in the US has evolved in ways that often impede rather than enable innovation. Oversight is distributed across more than twenty federal agencies and numerous state and local entities, with each operating within narrow mandates and focusing on compliance rather than transformation. This siloed structure makes it particularly difficult to implement innovative solutions that cut across traditional regulatory boundaries or require coordination between water, land use, and climate initiatives. At the state level, the lack of effective mechanisms for cross-jurisdictional coordination discourages watershed-based approaches. As a result, downstream states bear the impacts of upstream water management decisions without clear paths for collaborative problem-solving, and opportunities to implement the innovative system-wide approaches crucial for climate resilience are missed.

At the local level, utilities face a widening gap between the costs of providing water services and their ability to generate funds from users. Water rates are often suppressed due to political pressure, preventing utilities from charging rates that reflect the true cost of service. Even with these constrained rates, between 12.1 million and 19.2 million US households do not have access to affordable water services.[48] To make matters worse, high-volume users often pay lower per-gallon rates than individuals and retain the ability to relocate if the economic conditions in an area become less favorable. When this happens, as it has in many Rust Belt cities, communities are left to bear the costs of fixed capital infrastructure. This system is structurally unstable. As a result, utilities' ability to invest in new technologies or approaches is severely limited, even when such innovations could reduce long-term costs or improve resilience to climate impacts.

Rising infrastructure costs, new regulatory requirements, and extreme weather events are pushing many systems toward insolvency. Meanwhile, municipal and county governments, facing their own growing deficits, have diminished ability to provide financial backstops. High-income communities and large industrial users that traditionally helped support system costs are increasingly developing independent water solutions, exacerbating financial challenges for public systems and deepening existing inequities. While current federal funding through the Infrastructure Investment and Jobs Act provides critical near-term support, it does not address the fundamental governance and financial barriers to innovation. Without new models that enable costs and risks to be shared across broader

[47] Olson, E., Grau, A., & Tipton, T. (2024, July 19). *Data centers draining resources in water-stressed communities*. *Dallas Morning News*. Reprinted by the University of Tulsa. Retrieved December 11, 2024, from https://utulsa.edu/news/data-centers-draining-resources-in-water-stressed-communities/

[48] U.S. Environmental Protection Agency (EPA). (2024, December 17). EPA report highlights water affordability challenges in the U.S. Retrieved January 15, 2025, from https://www.epa.gov/newsreleases/epa-report-highlights-water-affordability-challenges-us

regions or that provide sustainable funding outside of traditional rate structures, many utilities will struggle to move beyond maintaining aging systems to implementing innovative solutions for climate resilience.

Without a stronger presence in policy-making and legislative spaces, water will continue to be a secondary consideration in decision-making processes.

The water sector's struggle to secure a meaningful seat at decision-making tables–with only a small number of advocates in Washington compared to hundreds representing transportation and energy–significantly hampers its ability to drive transformative change. While other infrastructure sectors maintain robust advocacy teams in Washington, water's limited lobbying presence constrains its ability to shape policy and secure essential funding. This challenge extends to local governance, where land use decisions are frequently made without water resource managers at the table, resulting in development patterns that strain water supplies and infrastructure. This disconnect is particularly evident in rapidly growing regions, where development decisions often proceed without adequate consideration of sustainable water resource capacity.

The water sector lacks risk-sharing tools common in other sectors, forcing utilities to bear the bulk of the burden of innovation and encouraging cautious decision-making.

Water utilities shoulder the majority of the risk when adopting innovations. This isn't sustainable. In other industries, risks are distributed across multiple stakeholders through insurance, financial instruments, and creative partnerships that protect both public and private interests. For example, the energy sector commonly uses public-private partnerships like Energy Savings Performance Contracts, where private companies finance and implement energy efficiency upgrades. Repayment is tied to verified savings, which effectively shares financial risks between public entities and private investors.[49] The sector is also increasingly using specialized insurance products like parametric insurance to manage risks associated with the development of renewable energy projects. While traditional insurance is limited to property damage, parametric insurance provides rapid payouts based on predefined triggers and can provide coverage for a wider variety of risks including start-up delays and loss of production.[50]

Water utilities, particularly small systems, often do not have access to such risk-sharing mechanisms when implementing new technologies or approaches, forcing them to take on most of the risk of potential failure. No utility manager wants their career defined by a risky choice (e.g., adopting a new technology) that didn't work out, especially when they know their organization will absorb the entire cost of any setbacks. As a result, they understandably choose proven but possibly outdated solutions over innovations that could significantly improve service delivery or reduce long-term costs. Creating mechanisms to share risk between public and private partners could help break this cycle of risk aversion and accelerate beneficial innovation in the water sector.

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[49] U.S. Department of Energy (DOE). (n.d.). *Energy savings performance contracts.* Retrieved January 15, 2025, from https://www.energy.gov/eere/ssl/energy-savings-performance-contracts

[50] Au, C. (2022, February 28). *Renewable energy and parametric insurance.* WTW. Retrieved January 15, 2025, from https://www.wtwco.com/en-th/insights/2022/02/renewable-energy-and-parametric-insurance

Capital stacking across infrastructure types and regional project bundling could help communities access funding more effectively.

Consider a municipality that needs to replace both its main street and the aging water lines beneath it. Under current federal programs, they must submit separate applications, follow different timelines, and meet distinct requirements for what is fundamentally one construction project. This fragmentation across funding programs doesn't just create an administrative burden–it often prevents communities from pursuing integrated solutions that could deliver enhanced outcomes more cost-effectively.

Two innovative financing approaches could help address these structural challenges. First, revising procurement processes to enable the "stacking" of capital across different programs would allow communities to combine funding sources for comprehensive infrastructure projects. This could include coordinating transportation and water infrastructure investments to achieve cost savings and minimize disruption to communities. Second, bundling smaller projects across regions could help them achieve the scale needed to access larger funding sources, similar to how bundling multiple small bonds into larger securities can achieve better credit ratings and lower financing costs. Such reforms would enable communities, particularly smaller ones, to access funding sources that would be out of reach individually while reducing administrative burden.

Tax policy innovation could drive water sector investment and technology adoption.

Renewable energy tax credits have helped to drive the growth of solar and wind energy adoption across the United States. Just as these incentives helped create clear financial signals for clean energy investment, tax policies designed to incentivize water conservation and technology adoption could help overcome financial barriers and reduce risk.[51] For example, investment tax credits for industrial water reuse infrastructure could decrease demands on public utilities while generating multiple public benefits, such as increased water availability, reduced wastewater discharges, and enhanced climate resilience.

However, any tax incentives must be thoroughly researched and carefully designed to ensure they deliver meaningful public benefits. Key questions include: how to structure credits so that they encourage additional investments rather than subsidizing business-as-usual activities; whether incentives should vary by sector or technology type; and how to avoid potential unintended consequences, such as more concentrated discharges to publically owned treatment works (POTWs). In addition, the measurement and verification framework would need to account for multiple types of benefits, such as reduced freshwater demand, decreased wastewater discharges, lower energy use from reduced treatment and conveyance needs, and enhanced drought resilience. The EPA is currently examining such questions as they evaluate options for tax incentive structures that could help scale private investment in water infrastructure while ensuring clear public benefits.[52]

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[51] Aldock, S. (2024, March 14). *What can the water industry learn from the success of the renewable power industry?* Bluefield Research. Retrieved January 15, 2025, from https://www.bluefieldresearch.com/what-can-the-water-industry-learn-from-the-success-of-the-renewable-power-industry/

[52] U.S. Environmental Protection Agency (EPA). (2023). *EFAB charge: Investment tax incentive for water reuse infrastructure.* Retrieved January 15, 2025, from https://www.epa.gov/system/files/documents/2023-10/private-reuse-investment-efab-proposed-charge.pdf

New market mechanisms, including pre-permit action credits and targeted water savings markets, could increase the effectiveness of water markets.

While water quality trading programs have existed for decades, the total volume of trading has remained low. These markets have struggled to build momentum due to a lack of regulatory drivers, uncertainty about the future value and availability of credits, challenges in accurate and consistent measurement, and complex participation requirements, among other factors.[53, 54, 55] However, new approaches are emerging that could help overcome some of these barriers. For example, some regions are piloting "pre-permit action" programs that allow cities or sanitation districts to voluntarily use private, philanthropic, or government funding for watershed restoration programs that can count against future permit allocations. This approach can reduce uncertainty by providing regulatory assurance that early actions will be credited, unlock new sources of capital by allowing private investment before permits are issued, and create additional financial incentives by linking water quality improvements to carbon credit markets.

Trading markets for water loss reduction are also starting to gain traction, as major companies increasingly set ambitious water conservation targets. These markets could function similarly to carbon markets, with companies able to purchase credits representing quantified reductions in water losses. Such markets could provide a flexible and cost-effective approach to water conservation while potentially generating new funding streams for water-saving initiatives. However, their success will depend on the development of standardized methods for measuring and verifying water savings and regulatory frameworks that ensure traded credits deliver real water savings.

The water sector needs a coordination framework that can harmonize existing distributed governance systems, offer strategic guidance, and enable knowledge and resource-sharing while preserving regional decision-making autonomy.

The water sector faces a fundamental tension. Local expertise and flexibility are essential for effective water management, yet the current fragmented governance structure makes it difficult to address water challenges at the scale and speed required. Without some form of coordination, water managers, including utilities, irrigation districts, and infrastructure operators, struggle to learn from each other's experiences or implement innovative solutions beyond their individual jurisdictions. Centralized control is not the answer. Instead, a national framework that aligns priorities and facilitates collaboration, while preserving local decision-making authority, could help regions develop innovative solutions tailored to their unique circumstances. This framework should include policies that help water managers work effectively with stakeholders to implement energy and carbon solutions, capitalizing on opportunities where coordinated action can deliver greater environmental and economic value for communities. As climate impacts intensify and infrastructure continues to deteriorate across the country, such a framework would enable water systems to benefit from collective knowledge and resources while maintaining their critical connection to local conditions and community needs.

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[53] Liu, H., & Brouwer, R. (2023). What is the future of water quality trading? Contemporary Economic Policy, 41(1), 194-217. https://doi.org/10.1111/coep.12583

[54] U.S. Government Accountability Office (GAO). (2017, October). *Water pollution: Some states have trading programs to help address nutrient pollution, but use has been limited* (GAO-18-84). Retrieved January 15, 2025, from https://www.gao.gov/assets/gao-18-84.pdf

[55] World Resources Institute. (2014, February). *Addressing risk and uncertainty in water quality trading markets*. Retrieved January 15, 2025, from https://www.usda.gov/sites/default/files/documents/WRI_Uncertainty_WQT.pdf

Rebuilding the Water Workforce

To transition to modernized, climate-resilient systems, the water sector needs a workforce equipped with new skills and capabilities. Yet at this critical moment, water management organizations–utilities, authorities, agencies, and advising groups–face unprecedented staffing challenges. Retirements are accelerating. Roughly one-third of the water sector workforce will be eligible to retire in the next 10 years.[56] At the same time, technical demands are growing. Small and rural systems struggle to maintain even basic operations with skeletal crews, while utilities of all sizes compete for talent with higher-paying sectors. The people who keep our taps flowing and our waterways clean are stretched thin.

These workforce pressures come as utilities grapple with increasingly complex operational demands. New technologies promise better ways to monitor and manage water systems, but implementing them requires specialized knowledge that many utilities lack. Regulations around emerging contaminants like PFAS demand sophisticated treatment approaches. More frequent extreme weather events test system resilience. In rural areas especially, utilities struggle to offer competitive salaries for technical talent. Many operate with just one or two staff members responsible for all aspects of operations, maintenance, and administration. In addition, many lack the grant writers they would need to access critical federal funding and technical assistance programs.

Regional collaboration and shared resources could help utilities build essential capabilities while making water sector careers more attractive.

To rebuild its workforce the water sector must explore new, more flexible approaches focused on shared resources and industry-academic partnerships. One promising trend in the US is the establishment of technical assistance networks, such as the Rural Community Assistance Partnership (RCAP), the Water/Wastewater Agency Response Network, and smaller regional alliances like Northern New Mexico's Aguas del Norte Alliance. These networks can provide specialized expertise across multiple systems, fostering knowledge sharing between utilities and helping small systems access critical capabilities they could never support on their own. In addition, novel approaches like residency programs for new engineers or externships that allow experienced professionals to split time between utilities could help bridge knowledge gaps while making water sector careers more attractive to emerging talent. Universities and technical schools could also engage with utilities to create programs that prepare students for careers in modern water utilities, incorporating both technical skills and the broader knowledge needed to manage complex systems.

Consultants must evolve from technical advisors to true innovation partners.

The consulting industry's traditional focus on standardized solutions and billable hours often restrains rather than enables innovation. Consultants can often favor proven approaches over newer solutions, partly due to liability concerns and partly due to business models that reward standardized designs over innovative alternatives. Forward-thinking firms are exploring new models that better serve utilities' changing needs. Some are developing performance-based contracts that reward creative problem-solving, while others are building collaborative partnerships focused on knowledge transfer

[56] U.S. Environmental Protection Agency (EPA). (2024, November 7). *Water infrastructure sector workforce.* Retrieved January 15, 2025, from https://www.epa.gov/sustainable-water-infrastructure/water-infrastructure-sector-workforce

and capacity building, rather than creating dependency. To evolve from gatekeepers to enablers of innovation consultants must be willing to share more risk and work more closely with utility staff to implement new approaches.

Technology adoption must be paired with investment in human capital to achieve lasting improvements in system performance.

New technologies can help utilities operate more efficiently and reliably, but only if staff are equipped to use them effectively. Remote operations and AI-enabled systems offer promising solutions to staffing constraints. However, their successful implementation demands more than installing new equipment—it requires rethinking how utilities train and support their workforce. This includes developing new operational protocols, ensuring robust cybersecurity, and building staff confidence with automated systems. The most successful utilities invest simultaneously in both technical systems and human capital, recognizing that lasting improvement requires advancing both in tandem. The water sector's ability to innovate and adapt to climate change ultimately depends on its people. Technology alone cannot solve our water challenges. We need dedicated professionals who understand both traditional water system operations and emerging tools for building climate resilience. By investing in workforce development and creating more collaborative approaches to building capacity, utilities can ensure they have the human capital needed to navigate an uncertain future.

Appendix I - Participant List

Peter Adriaens, Professor of Engineering, Finance and Entrepreneurship; Director of the Center for Digital Asset Finance and the Master of Engineering in Smart Infrastructure Finance, University of Michigan
Cristina Ahmadpour, President and Managing Director (Americas), Isle Utilities
Newsha Ajami, Chief Research and Development Officer for the Earth and Environmental Sciences Area, Lawrence Berkeley National Laboratory (co-chair)
Austin Alexander, Vice President, Sustainability and Social Impact, Xylem Inc.
Dean Amhaus, President & CEO, The Water Council
Jeffrey Bass, Founder, Bass Law
Kelly Bennett, Co-Founder and CEO, B3 Insight
Joey Bergstein, CEO, BlueTriton Brands
Budhendra Bhaduri, Corporate Research Fellow and Director of Science, Programs, and Partnerships, National Security Sciences, Oak Ridge National Laboratory
Margaret Bowman, Principal, Bowman Environmental Consulting
Christine Boyle, Partner, Burnt Island Ventures
Wendy Broley, Chief Technical Officer, Brown and Caldwell
Christa Campbell, Director, Industry Solutions: Water, ESRI
Albert Cho, SVP, Chief Strategy and External Affairs Officer, Xylem Inc.
Carter Christopher, Section Head for Human Dynamics R&D, Oak Ridge National Laboratory
Paula Conolly, Senior Director of Programs, US Water Alliance
Kimberlee Cornett, Director, Impact Investments, Robert Wood Johnson Foundation

Tim Dekker, President and CEO, LimnoTech
Sarah Diringer, Program Officer, Water & Climate, Pisces Foundation
Martin Doyle, Director, Water Policy Program, Nicholas Institute for Energy, Environment & Sustainability, Duke University (co-chair)
Radhika Fox, Principal, North Star Strategy
Derek Gardels, Associate Vice President and NE/IA Utility Management Services Business Class Lead, HDR, Inc.
Greg Gershuny, Vice President & Executive Director, Energy & Environment Program, The Aspen Institute
Peter Grevatt, CEO, The Water Research Foundation
Jimmy Hague, Senior Water Policy Advisor, The Nature Conservancy
Alaina Harkness, CEO, Current; CEO, Great Lakes ReNEW
David Henderson, Managing Partner, XPV Water Partners
Edward (Ted) Henifin, Interim Third-Party Manager, JXN Water, Inc
Melissa Ho, Conservation and Development Professional, formerly SVP of Freshwater & Food, World Wildlife Fund
Alex Johnson, Chief Strategy Officer, Virridy
Upmanu Lall, Director, Water Institute, Julie Ann Wrigley Global Futures Laboratory at Arizona State University
Henrietta Locklear, Vice President, Raftelis
Jessie Mahr, Director of Technology, Environmental Policy Innovation Center
Oluwole (OJ) McFoy, General Manager, Buffalo to Sewer Authority
Palencia Mobley, P.E., Funding Navigator - Midwest Manager, Environmental Policy Innovation Center
Emily Morris, Founder & CEO, Emrgy
Mark Owens, State Representative, Oregon House District 60
David Palumbo, Deputy Commissioner of Operations, Bureau of Reclamation, Department of the Interior
Lauren Patterson, Lead Climate & ESG Policy Scientist, ICE Data Services
Chuck Podolak, Director, Water Infrastructure Finance Authority of Arizona
Jordan Read, Executive Director, CUAHSI
Melissa Roberts, Founder and Executive Director, American Flood Coalition
David Ross, Chief Sustainability Officer, Veolia North America
John Sabo, Director, ByWater Institute, Tulane University
Phil Saksa, Co-founder and Chief Scientist, Blue Forest Conservation
Suleyman Saleem, Director, Sustainable Banking Solutions Group, Bank of America
Andrew Sawyers, Director of the Office of Wastewater Management, US Environmental Protection Agency
Allison Spector, Head of ESG, One Rock Capital Partners, LLC
Mae Stevens, Partner, Banner Public Affairs
John Take, EVP and Chief Growth & Innovation Officer, Stantec
Aaron Tartakovsky, Co-Founder & CEO, Epic Cleantec
Evan Thomas, Director, Mortenson Center, and Mortenson Endowed Chair in Global Engineering, University of Colorado Boulder
David Totman, Principal
Emily Warren Armitano, Director, Land Conservation and Water Programs, The Cynthia and George Mitchell Foundation
Lilli Watson, Policy Associate, Nicholas Institute for Energy, Environment & Sustainability, Duke University (rapporteur)
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