U.S. DEPARTMENT of ENERGY | Office of Energy Efficiency and Renewable Energy

Water Power Technologies Office

Pacific Northwest NATIONAL LABORATORY

AMERICAN PUBLIC POWER ASSOCIATION
Powering Strong Communities

American Water Works Association

Resilience of Energy and Water Systems Workshop Summary

September 2025

PNNL-SA-216376

Table of Contents

Disclaimer

This presentation contains a summary of presentations and brainstorming discussions from the two-day resilience workshop. The content does not reflect agreement or recommendations by the Department of Energy, Pacific Northwest National Laboratory or other National Laboratories, the American Water Works Association (AWWA), the American Public Power Association (APPA), or any specific workshop participant.

1. Workshop Background and Key Takeaways

2025 Resilience Workshop Overview

- An invitation-only workshop on the Resilience of Energy and Water Systems was held in the D.C. metro area, on May 13th and 14th of 2025, sponsored by the Department of Energy’s Water Power Technologies Office and co-hosted by Pacific Northwest National Laboratory (PNNL), American Water Works Association (AWWA), and American Public Power Association (APPA).
- **Who Attended:**
  - Representatives from the Department of Energy, the Department of Defense, the Environmental Protection Agency, the U.S. Geologic Survey, and the Department of Commerce
  - Researchers from Academia, National Laboratories, and National Academies
  - Water, wastewater, and energy utilities, districts, and municipalities from across the United States
  - Private industry, non-profits, and consultants
- **Purpose:** to convene policymakers, researchers, consultants and utility leaders to understand challenges and co-develop solutions to improve and accelerate **the resilience of our national energy and water systems** in the face of emerging challenges including those that stem from large demand growth from data centers.
- **Major Themes:**
  - Operational Coordination for Resilience
  - Infrastructure Planning for Resilience
  - Data Centers and Demand Growth

Key takeaways from 2025 Workshop

- Water and power are **critical-interdependent systems** experiencing similar challenges and opportunities.
- **Incentives** for water and power **to collaborate are not the same**; there are different regulations and operational structures.
- Opportunities exist to **manage energy and water systems interdependently**, including assessing risks, planning for growth, and responding to events.
- **Regional and watershed-based partnerships and coordination** are key.
- Water and power utilities need to **strengthen ties and "signaling" and develop common hazard scenarios and decision frameworks**.
- **Data centers are planned and sited at rapid rates**, presenting a unique opportunity to address demand growth across both water and power systems, and consider community needs and impacts.
- To improve operational coordination, **a decision framework is needed to manage risk and uncertainty**; this includes mapping assets with critical loads, developing standards for disconnection and restoration, and identifying risk tolerance for key equipment to different conditions (e.g., wind, precipitation).
- There are opportunities to continue to **evolve standards and metrics** for planning frameworks, operational resilience, and interconnection of data centers in a way that considers both electric and water utilities and community outcomes.
- An emerging water/energy nexus challenge has to do with **water temperatures and excessive vegetation growth** that can hamper hydropower and thermoelectric cooling of power generation.
- **Water should be added as an Emergency Support Function** alongside energy, data, and communications to ensure inclusion in emergency planning and federal response frameworks.
- There are **tradeoffs associated with cooling data centers with air versus water**; regional energy and water assessments for data centers that include embedded resource use would be informative.

Overview of National and Regional Opportunities

Operational Coordination for Resilience

1. Empower regional coordination and data sharing
2. Strengthen "signaling" and risk tolerance
3. Develop shared guidelines and metrics

"Signaling" involves notifying users when there's an outage and plans to get service back up and running

Infrastructure Planning for Resilience

1. Align standards and metrics across energy and water
2. Build and apply regional scenario models
3. Explore and advance national water governance and institutional visibility
4. Incentivize and streamline integrated infrastructure
5. Foster regional and cross-sector partnerships
6. Promote innovation and flexibility

Data Centers & Demand Growth

1. Support a national energy-water strategy for data center siting and planning
2. Create a national data center consortium, resulting in improved coordination and governance
3. Enable infrastructure and resource optimization and modernization
4. Quantify and capture energy and water use through heat and cooling
5. Improve data collection, transparency, and tracking

2. Looking Back: Themes from Past Research and Convenings

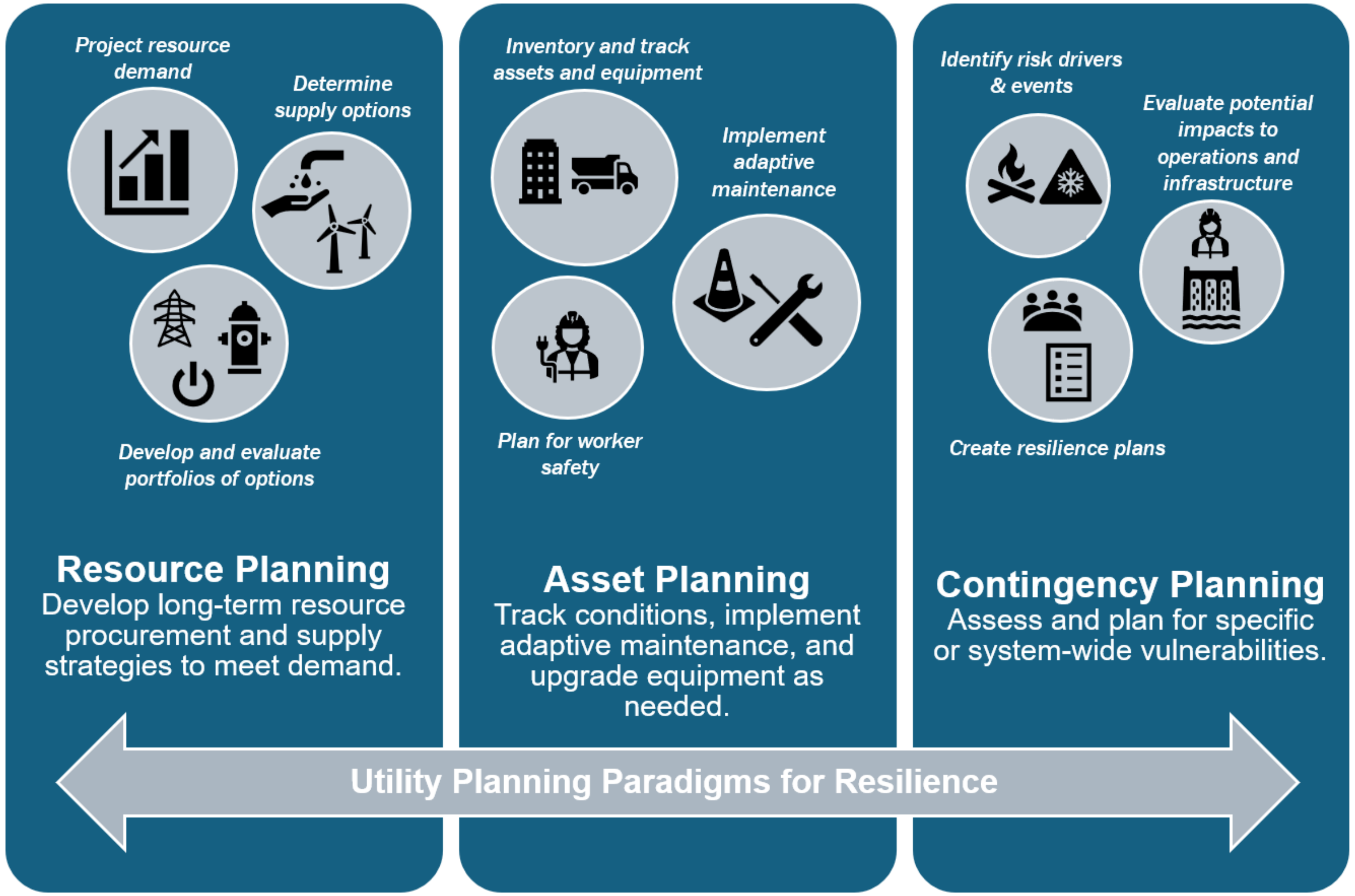
In Review: Key takeaways from 2021 Workshop

- Water and electricity are **critical interdependent systems** experiencing ever-growing physical and cyber-related challenges.
- During stress periods and extreme events, negative impacts can **cascade between energy and water systems**.
- Advanced **coordination, integrated planning, and co-developed** resilience strategies can help.
- Opportunities exist at the **community, utility, state, and federal levels**.
- **Innovation, good ideas, and solutions** can also cascade from one organization or place to others, so networking and communication/coordination are key.

- The **value proposition** of planning for and improving water and power systems resilience is huge! For example: the 2021 Texas freeze events cost ~ $120-180B, or $4k per Texan; $20k for a family of 5.
- At a minimum, **enhanced communication and outage/emergency response planning** are needed. **Updated forecasts are important,** so people know what to plan for.
- Distributed generation, energy efficiency, and electric demand flexibility potential exist in water, but **progress depends on a willing electric utility**.
- **Performance-based ratemaking or integrated resource planning requirements** could help foster connections.
- Areas of need include **data/information** availability; **scenario modeling;** clear and **common resilience definitions and standards;** distributed energy resources **interconnection and integration**; and sharing **best practices**.

What does a resilient energy and water utility of the future look like?

- Supply diversification and redundancy
- Balance centralization and decentralization
- Advanced forecasting methods
- Smart sensors, metering, and communications
- Flexible demand that can be responsive to grid needs
- Hardened system designs
- Cross-utility operational coordination and planning
- Communication and trust
- Understanding of potential for cascading events between systems & mitigation of negative outcomes
- Documented experience from operators, utility staff, and models to understand risks and changing conditions



Operational Strategies

- Identify a **champion** or point of contact for coordination
- **Exercise processes** through outage notification training, black sky training, and response exercises
- Develop and share a **list of critical facilities** and the operational wiggle room (or **adaptive capacity**) in each facility and supporting infrastructure
- Invest in **submetering and share price signals**, and data on demand, flexibility, and capacity
- Develop tools and techniques to **align operator efforts** with power & water costs

Planning Strategies

- Establish **shared resilience metrics and terminology**
- **Share risk scenarios** and data; utilize scenario modeling; jointly develop planning scenarios
- Include **water availability risks in power utilities' Integrated Resource Plans** and develop cross-sector Integrated Resource Plan best practices
- **Coordinate on capital investment planning and critical sites**, especially for upgrades that can be made in the same area and at the same time; consider opportunities for shared infrastructure, such as storage or microgrids
- Work together to understand, develop, and utilize **distributed and flexible energy resources at water facilities**
- Develop **standardization for energy savings opportunities** at water facilities
- Assess **financial risks** to water and electric utilities and identify options for **risk mitigation strategies** (e.g., risk pooling)

Practical Considerations

- Water utilities take their charge of protecting public health very seriously.
- Water and wastewater utilities are focused on meeting permit requirements.
    - Energy may be a simple pass-through expense and is a secondary consideration.
- Electric utilities have many types of large customers; getting attention may be challenging.
- Some water utilities have not had constructive engagement with electric utilities and they do not trust them, leading to strained relationships and limited exchange of information.
- Electric utilities may be less than enthusiastic about working with water utilities on energy generation or flexibility due to perceived loss of control and potential negative impact to revenue streams.
- Many water and electric utilities lack access to capital and struggle to make investments in areas outside their core mandate.

Example: How water systems can coordinate with grid operations

- With a price signal, contracting mechanism, and compensation, water utilities can provide capacity and/or frequency response to the grid. This includes coordinated pumping, managing unit processes, where flexibility exists, battery storage systems can help manage peak, and VFDs for frequency response.
- Hydraulic storage exists in most water distribution systems and can serve as a battery.
- For load shifting to be practical, differences in energy pricing between peak and off-peak times must be large enough to overcome the extra effort, risk, and potential headache of changing system operations.

3. 2025 Resilience Workshop

Major Themes Discussed during the 2025 Resilience Workshop

- Operational Coordination for Resilience
  - Organizing and integrating efforts across people, organizations, and processes to achieve common objectives for resilience of energy and water systems
- Planning for Infrastructure Resilience
  - Addressing infrastructure-specific needs to manage the interdependencies of energy and water resilience and achieve resilience of both
- Data Centers and Demand Growth
  - Understanding and quantifying demand growth associated with data center development and the opportunities and impact on communities and energy and water systems

Operational Coordination for Resilience: Key Themes

- **Opportunities exist to strengthen ties and “signaling” between energy & water utilities.**
  - Actions that strengthen ties and operational resilience include identifying key points of contact at corresponding water or electric utility, mapping assets with critical loads, practicing and refining emergency response actions, and coordinating outage notifications and plans to restore service. “Signaling” includes notifying users, and other interconnected community utility providers, when there’s an outage and plans to get service back up and running.
- **Operational coordination needs to happen top down and with boots on the ground.**
  - There are different incentives for water and power sectors to collaborate, like reduced operational costs related to peak demand management (e.g., water utilities can adjust pumping schedules to avoid peak electricity pricing periods) or improved infrastructure resilience through shared emergency preparedness planning. These sectors are regulated differently, with varying operational structures. There are, however, similarities to leverage in how each utility assesses risk, plans growth, and responds to events, by employing incentives at the top and champions on the ground.
  - There is a need and an opportunity to develop national and regional standards, guidelines, and metrics for operational coordination to understand efficiency opportunities and capacity requirements, with execution happening at the utility and regulator level.
- **Federal organizations offer research and funding to support the resilience of the water sector**
  - Examples include the EPA’s Water Infrastructure and Cyber Resilience Division and Water Infrastructure Finance and Innovation Act (WIFIA).

Operational Coordination for Resilience: Lessons from the Department of Defense

- **Department of Defense** organizations have **islanding requirements** associated with both energy and water. Islanding means being able to disconnect from the main electric or water system and operate independently.
- Planners conduct **water risk and resilience assessments and emergency response plans,** comprehensive asset management plans, and installation energy and water plans.
- **Tabletop exercises** are used to assess communication, performance of emergency and continuity plans and information gaps, especially through water resilience exercises.
- **Energy resilience readiness exercises require** cutting power to understand cascading impacts in loss of service across both water and power service providers.
- DOD organizations use an **overall resilience process** that includes the following steps:
  - Understand regional risks and threats
  - Plan for installation infrastructure risks and opportunities
  - Generate solutions/conceptual design
  - Develop implementation plan
  - Execute, evaluate, reassess

Operational Coordination for Resilience: Research and Resources (1)

- **Lawrence Berkeley National Laboratory is looking at drought as well as energy and water resilience.**
  - 2012-2015 California drought (half average snowpack, reservoirs, and hydropower at historic low) led to $2.5 billion in energy costs resulting from higher pumping loads, high natural gas prices, power generation shortfalls and the need to rely on the spot market to make up the difference.
  - In future scenarios, hydropower declines and energy use increases, especially in summer.
  - **Water system resilience measures can reduce costs and negative grid impacts during droughts.**
    - ✓ A portfolio approach provides the largest benefits. LBNL tested five measures: urban indoor and outdoor water conservation, agriculture water conservation, wastewater recycling, managed aquifer recharge.
  - **Resources:**
    - ✓ Evaluating How Climate Adaptation Measures Affect the Interconnected Water-Energy Resource Systems of the Western United States
    - ✓ A low to no snow future and its impacts on water resources in the western United States
    - ✓ Modeling the Water Systems of the Western US to Support Climate-Resilient Electricity System Planning
    - ✓ Climate change and its influence on water systems increases the cost of electricity system decarbonization

Operational Coordination for Resilience: Research and Resources (2)

- **The EPA's Water Infrastructure and Cyber Resilience Division has developed a suite of resources to help water utilities address energy and overall resilience.**
  - Resources:
    - ✓ Power Resilience Guide for Drinking Water and Wastewater Utilities
    - ✓ Power Resilience: An Achievable Goal - presents the business case for water utilities to implement water resilience strategies
    - ✓ Power Outage Incident Action Checklist
    - ✓ Public Safety Power Shutoffs (PSPS) Standard Operating Procedures for Water Utilities

- **The EPA's Water Infrastructure Finance and Innovation Act (WIFIA) program provides funding to accelerate investment in our nation's water and wastewater infrastructure.**
  - WIFIA provides long-term, low-cost, supplemental credit assistance under customized terms to creditworthy water and wastewater projects of national and regional significance.

Operational Coordination for Resilience: Research and Resources (3)

- **Electric Power Research Institute (EPRI)** and their partners are conducting studies and developing resources to support energy-water resilience assessments and planning and are interested in **tech transfer** and sharing research tools, outputs and methods.
  - Focus areas include integrated systems analysis, modeling water consumption for energy, and coordinating water system operations, including desalination and the electric grid, including electrification.
  - **Resources:**
    - ✓ Water Considerations for the Energy Transformation
    - ✓ Water Footprint Tool (members only)
    - ✓ Climate and Water Risk Assessment Tool
    - ✓ Optimizing Electric and Water Grid Coordination under Technical, Operational, and Environmental Considerations (Forthcoming)
    - ✓ Potential water-related risks to the electric power industry associated with changing surface water conditions

Operational Coordination for Resilience: Summary of Challenges and Opportunities

- **Challenges**
  - Balancing cost effectiveness with resilience investments; determining the right level of resilience spending.
  - Lack of resources (financial, physical, and personnel) to support resilience coordination.
  - Unstable policy environment and therefore no reliable funding.
- **Opportunities**
  - Regional or watershed-level coordination between electric and water utilities to encourage constant communication, develop a watershed-level playbook to plan for risks and extreme events and practice emergency response and recovery, and strengthen “signaling”, information exchange and sharing about lessons learned.
  - Strengthen “signaling”, map critical assets through a decision framework, and develop requirements associated with risk tolerance for key equipment to changing conditions (e.g., precipitation, temperature); ensure adequate training to manage risk and uncertainty.
  - Guidelines that address a cost-benefit analysis focused on resilience benefits that utilities can use and leverage in coordination to identify spending amounts.
  - Cooperative ownership of reliable back-up power systems.

Planning for Infrastructure Resilience – Key Themes (1)

- **Planning can be better coordinated between the energy and water systems.**
  - Co-benefits from the other sector can be included in cost-benefit analysis to inform investment decisions.
  - Siting and cyber resilience approaches can be better coordinated to minimize risks.
  - Technology can be used to identify similar pinch points in each system, which can impact the other.
  - Energy & water planning can be coordinated at different scales.
    - ✓ City-wide development planning, metro-wide system planning, water system master planning, power master planning.
- **Communities can help develop creative solutions that deliver positive outcomes.**
  - Communities are impacted by water and energy systems resilience, and data center development, and they can be a source of important information and solutions.
- **Regional models of hazard scenarios** can be used to support better decision-making for both water and electric utilities.
  - Shared hazard scenarios can help understand and characterize risks.
  - Critical needs analyses can include asset mapping, open data, vulnerability assessments, and advanced tools such as digital twins.
  - Decision-making under deep uncertainty (DMDU) approaches can be used; plans can be adaptable to multiple pathways.
  - Updated, scenario-informed precipitation forecasts are critical to resilience planning.

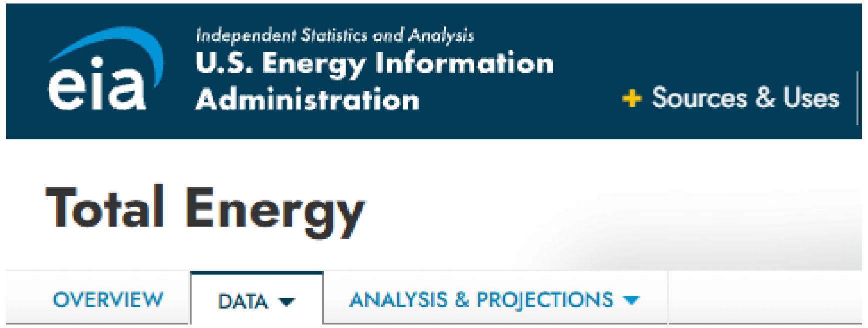
Planning for Infrastructure Resilience – Key Themes (2)

- Nationally, **water is treated differently from energy** in terms of **research, data collection, emergency response**.
  - There's no single **Department of Energy** equivalent for water. Water responsibilities are spread among many organizations.
    - ✓ There is no DOE-equivalent for water providing focused research in the national interest.
    - ✓ There is no Energy Information Administration (EIA) equivalent for water focused on collecting and sharing water data. Water data can be difficult to obtain. This is a key gap limiting visibility and coordinated action.
  - In the **National Response Framework** in the U.S., water doesn't currently have a solely designated Emergency Support Function (ESF). Rather, activities related to water are spread across several other ESFs.


Emergency Support Functions

Emergency Support Functions (ESFs) provide the structure for coordinating Federal interagency support for a Federal response to an incident. They are a way to group functions that provide federal support to states and federal-to-federal support, both for Stafford Act declared disasters and emergencies and for non-Stafford Act incidents.

ESF #1: Transportation
ESF #2: Communications
ESF #3: Public Works and Engineering
ESF #4: Firefighting
ESF #5: Information and Planning
ESF #6: Mass Care, Emergency Assistance, Temporary Housing, and Human Services
ESF #7: Logistics
ESF #8: Public Health and Medical Services
ESF #9: Search and Rescue
ESF #10: Oil and Hazardous Materials Response
ESF #11: Agriculture and Natural Resources Annex
ESF #12: Energy
ESF #13: Public Safety and Security
ESF #14: Cross-Sector Business and Infrastructure
ESF #15: External Affairs



Planning for Infrastructure Resilience: Lessons from the Tennessee Valley Authority (TVA)

- **Hydropower** is very important. TVA has partnered with EPRI and ORNL on several long-term future scenario models.
  - Seasonal and spatial distribution of moisture will change in the region; ~ 8% more hydropower production may be possible in the TVA.
- An emerging operational water/energy nexus challenge has to do with **water temperatures and excessive vegetation growth when it comes to hydropower and thermoelectric cooling of power generation.**
  - Water temperature compliance challenges exist in some areas, such as TVA, for some existing coal and nuclear plants.
  - Nuclear plants are of primary interest and a concern going forward.
  - Excessive vegetation is impacting both hydropower and nuclear facilities in the TVA fleet. Excessive vegetation fouls intake trash racks at dams and nuclear power plants. An eelgrass clogging event cost TVA $40 million in replacement power in 2020.

Planning for Infrastructure Resilience: Research and Resources

- **Pathways Climate Institute and Water Utilities Climate Alliance** are working to understand regional future precipitation change, including extreme events and storms. They are using storyline modeling and global models to develop extreme precipitation projections for the Mid-Atlantic region of the U.S.
    - ✓ Mid-Atlantic Extreme Precipitation Study (Forthcoming)
    - ✓ Extreme Precipitation Study for San Francisco Public Utilities Commission
    - ✓ Scaling and Application of Climate Projections to Stormwater and Wastewater Resilience Planning
- **Colorado State University** discussed an infrastructure systems approach for resilience, outlined five systems approach imperatives for informing complex water energy system decisions, and described the differences between engineering resilience and ecological resilience.
    - Engineering resilience has a single steady state, whereas ecological resilience has multiple steady states and perturbations represent growth opportunities. A systems of systems approach for interaction effects includes synergist effects, direct effects, and cascading effects.
        - ✓ A Distributed Renewable Energy Opportunities and Policy Workshop – Summary outcomes and policy recommendations (subscribers only)
        - ✓ Opportunities and Barriers for Distributed/Renewable Energy Resource Development at Water and Wastewater Utilities (subscribers only)

Planning for Infrastructure Resilience: Summary of Challenges and Opportunities

- **Challenges**
  - Lack of data and information to support coordinated planning in the water sector; planning is happening at multiple scales in an uncoordinated fashion
  - Few professionals are trained to work across energy and water sectors
  - Planners in both sectors lack understanding of future hazard scenarios to plan for
  - No baseline metrics for providing safe delivery of interdependent energy-water systems.
  - Lack of understanding of demands, critical asset requirements, and adaptive capacity of critical infrastructure in the corresponding water/energy sector
  - Lack of impetus and capacity to look beyond single-sector planning
- **Opportunities**
  - Centralize water governance at the national level
  - Streamline energy + water development and incentive structures, and coordinate between the structures
  - Develop integrated and coordinated standards and metrics for planning
  - To address cross-trained workforce, develop opportunities for interdisciplinary certificates, apprenticeships, internships, new job titles/categories, and trade schools
  - Share best practices of coordinated planning

Data Centers and Demand Growth: Key Themes - Power Focus

- **Data center electric demands are significant and growing, creating a need for significant new infrastructure investments**
  - Dominion Energy serves Data Center Alley in Virginia; approximately 70% of the world's internet traffic flows through Northern Virginia. Data center load growth projections indicate a continued increase in demand on the transmission system, with total summer peak demand projected to rise from just over 23 TW in 2025 to over 36 TW in 2033. The peak data center load on Dominion's system is 3,142 MW.
- **Utilities and data center customers must work together closely to overcome technical grid-related challenges. Recent events provide valuable lessons learned.**
  - Two recent events (July 2024 and February 2025) on Dominion's system resulted in 1,500 and 1,800 MW of data center loads unexpectedly and suddenly dropping off Dominion's system and switching to backup generation, which caused reliability issues on Dominion's system. Data center security settings are unique but need to be compatible with utilities; new action needed on ride-through settings.
  - Without advanced metering, power utilities have limited insight into data center power demand patterns, which can be a risk to grid stability. NERC's Data Center Information Collection Questionnaire can be used to gather more information from data centers before interconnecting.
- **Tech companies are focused on driving down power usage efficiency, with more efficient chips.**
  - However, based on experience, more efficient chips may not mean less data center electricity and water demands. Rather, data centers will simply increase density/compute capacity.

Data Centers and Demand Growth: Key Themes - Water Focus

- **Water is often used to cool microchips; data center growth is increasing the demand on water supplies**.
  - In Loudoun County, Virginia, there were an additional 117 data centers approved at the start of 2025. 40 MGD more water will be needed for these data centers, between potable and reclaimed water.
- **Some hyperscalers have water stewardship and sustainability goals, including water replenishment.**
  - Water replenishment balances the consumptive use of data centers in the same watershed through things like reforestation, irrigation technologies, rainwater harvesting, and wetlands restoration.
  - **Volumetric Water Benefits (VWBs)** are a measure of the volume of water resulting from water stewardship activities that modify the hydrology in a beneficial way and/or help reduce shared water challenges. VWBA 1.0 (2019) and VWBA 2.0 (2025) provide standardized approaches for quantifying VWBs.
  - Opportunity: encourage hyperscalers to invest in water distribution infrastructure prior to consumptive use.
- **There are potential water supply and quality implications of data centers.**
  - Questions were raised about water quality (mainly salinity and temperature) concerns from data center growth, including cascading impacts to downstream systems. In most instances, data centers receive and discharge water to municipal water and wastewater systems, alleviating the need for EPA permits.
- **There’s an opportunity for more transparency on the water footprint of data centers.**
  - In the case of Virginia and Loudoun Water, water utilities are not involved in data center planning and zoning processes and instead rely on other metrics to infer data center demand.

Data Centers and Demand Growth: Key Themes - Energy + Water Focus

- **There are energy-water tradeoffs between air and evaporative cooling for data centers.**
  - Evaporative cooling is more energy efficient and the largest driver of water consumption. Dry cooling requires less water and more energy.
- **A missing piece in the energy-water tradeoff picture is understanding the water demand associated with energy use for data centers.**
  - Tradeoffs between energy usage and water consumption should be evaluated on a regional basis and incorporated into corporate and possibly utility planning, especially in water-scarce areas.
- **There may be options for thermal heat recovery from sewers and data centers.**
  - DC Water is actively looking into wastewater thermal energy. They've determined they could provide up to 200-400 MW of thermal energy from the sewers, which could be part of a district energy approach for Washington, DC. Vancouver, Canada, among others, is using sewer heat for a series of private and public developments. There is potential synergy between district energy systems, data center cooling, and wastewater thermal that could be explored further, particularly in areas with growing data centers and greenfield community development.
- **There are opportunities to evolve interconnection standards for data centers in a way that considers both electric and water utilities and community outcomes.**
  - Potentially there could be an interconnection standard that that affects both sectors. This is an opportunity to identify and share best practices across the country.

Data Centers and Demand Growth: Research and Resources

- Research is happening at Pacific Northwest National Laboratory (PNNL) that will consider the **impacts of data center scenarios on electricity demand growth and grid stress in the Western Interconnection** and look at the impacts of data center demands, siting, and configuration on water stress and grid reliability across the country.
- PNNL is also identifying **drivers of data center siting** (land availability, electricity prices, access to water and fiber, and proximity to substations, among other factors) and then identifying potential locations of new data center development, which can help planners understand impacts to our energy and water systems under alternative futures.
- Available resources:
  - IM3 Open Source Data Center Atlas
  - Energy and AI: Evaluating Future Grid and Water Stress Due to Data Centers
  - Energy-water interdependencies across the three major United States electric grids: A multi-sectoral analysis
  - Water & Energy Interdependencies Across Economic Sectors of the United States

Data Centers and Demand Growth: Summary of Challenges and Opportunities

- **Challenges**
  - Building water and energy infrastructure at the scale and speed needed for data centers
  - Technical grid and electric utility/data center challenges, like visibility and ride-through settings
  - Water use in data centers is not visible, subject to EPA permits, or coordinated regionally or on a watershed basis
  - Gaps in calculations of energy/water cooling tradeoffs make understanding full implications difficult (i.e., embedded water in energy and embedded energy in water)
- **Opportunities**
  - Increased visibility for what to plan for through questionnaires for new data center connections based on NERC's Data Center Information Collection Questionnaire
  - Increased coordination between data centers and grid operators; advanced and coordinated metering
  - Increased, standardized, and/or community-informed water replenishment to balance data center water use
  - More comprehensive and life-cycle energy-water tradeoff analysis for data center cooling options, coordinated regionally
  - Reclaiming heat from data center waste streams, including wastewater; for example, the Resource Innovation Institute in Portland is identifying demonstration projects of Farm Parks that use data center waste heat to heat green houses
  - Evolve interconnection standards for data centers in a way that considers both electric and water utilities and community outcomes

4. National and Regional Opportunities

Opportunities for Operational Coordination

1. **Empower regional coordination and data sharing:** regional or watershed-level coordinators and governing bodies (e.g., joint water/power coordination authorities) can facilitate integrated energy-water forecasting, data exchange, energy-water resilience readiness exercises, workforce training, and resource planning.
   - Possible actions suggested by participants included:
     - ✓ **State energy and water regulators** embed joint authority structures (e.g., Joint Powers Authority), where multiple public agencies can jointly implement programs, build facilities and deliver services to jointly exercise power common to each agency
     - ✓ **Regional planning bodies** (e.g., Council of Governments (COGs), river basin commissions): serve as operational leads
     - ✓ **Utilities:** participate in shared planning processes
     - ✓ **National labs and universities:** provide modeling, analytics, and workforce development support (e.g., training), including to help preserve and capture organizational knowledge
   - Participants discussed funding opportunities from federal agencies via DOE or USACE, state/local grants and appropriations, or industry cost-sharing or utility ratepayer mechanisms

Opportunities for Operational Coordination

2. **Strengthen "signaling" and risk tolerance:** connect with counterparts at water/energy utilities/companies to pool knowledge and improve "signaling". "Signaling" entails utility providers notifying users when there's an outage and the plan to get service back up and running. Additional actions may include: mapping assets with critical loads, refining emergency response actions, coordinating on outage notifications and plans to restore service, identifying risk tolerance for key equipment to different conditions (precipitation, temperature, wind, etc.), developing minimum requirements and impacts if equipment fails, and regularly updating and coordinating on risk portfolios.
   - Possible actions suggested by participants included:
     - ✓ **Federal agencies (EPA, DOE, USACE):** provide seed funding and technical guidance
     - ✓ **Utilities and private sector:** develop signaling protocols and conduct and share risk tolerance mapping
     - ✓ **National labs and universities:** provide research on future scenario threats and hazard modeling
   - Participants discussed funding opportunities from state budgets or appropriations, embedded costs within utility operating budgets, and federal workforce training programs via DOE or Department of Labor.

Opportunities for Operational Coordination

3. **Develop shared guidelines and metrics:** develop national and regional standards for operational coordination, including shared metrics and frameworks for considering energy-water tradeoffs (including cost-benefit resilience analysis), and criteria for system “state of good repair.” Enable cooperative ownership of reliable back-up power systems.
   - Possible actions suggested by participants included:
     - ✓ **Federal agencies** (EPA, DOE, National Institute of Standards and Technology (NIST)): set standards through development of shared guidelines and metrics
     - ✓ **Professional organizations** (e.g., AWWA, National Association of Regulatory Utility Commissioners (NARUC), APPA, EPRI): provide sectoral input on metrics notified through membership and expertise
     - ✓ **Utilities and grid operators:** align planning practices with guidelines, which can also be supported by utility regulators for water and electricity
   - Participants discussed funding opportunities from federal research and standards grants, public-private research collaborations, and foundations or industry associations to pilot initial guidelines and metrics.

Opportunities for Infrastructure Planning

1. **Align standards and metrics across energy and water:** establish consistent metrics, regulations, and planning assumptions to reduce fragmentation across sectors and regions. Develop shared cost-benefit frameworks that include resilience co-benefits and enable better valuation of integrated infrastructure projects.
   - Possible actions suggested by participants included:
     - ✓ **Federal Agencies** (EPA, DOE, FEMA, CEQ): develop unified resilience metrics and planning assumptions
     - ✓ **National associations** (AWWA, NARUC, APPA, NARUC): co-develop joint guidance for risk assessments and integrated planning
     - ✓ **Public Utility Commissions (PUCs):** mandate the inclusion of water and atmospheric standards and metrics into Integrated Resources Plans
     - ✓ **Utilities:** adopt harmonized metrics in infrastructure assessments
   - Participants discussed funding opportunities from federal funding through DOE Office of Electricity, EPA State Revolving Fund (SRF) and Infrastructure Investment and Jobs Act (IIJA) technical assistant grants, or through state energy offices or water infrastructure banks to co-fund planning and standards adoption.

Opportunities for Infrastructure Planning

2. **Build and apply regional scenario models:** develop and scale regional hazard scenario models to improve infrastructure investment decisions and risk prioritization. Stakeholders can collaborate on future-looking scenario-based risk tools that feed into cost-benefit analysis, adaptive planning, and emergency preparedness. For example, regional modeling could support infrastructure planning for drought and water scarcity in the same power grid, enabling tailored resilience investments.
   - Possible actions suggested by participants included:
     - ✓ **National Labs and NOAA:** develop localized, open-access models for hazard forecasting
     - ✓ **Utilities and metropolitan planning organizations (MPOs):** apply regional models to infrastructure investment planning
     - ✓ **National labs and universities:** translate model outputs into decision tools for practitioners
   - Participants discussed funding opportunities from federal funding through DOE, National Science Foundation (NSF), and NOAA research grants for model development, state and regional resilience grants for model application (e.g., HUD Community Development Block Grant Disaster Recovery (CDBG-DR), FEMA Building Resilient Infrastructure Communities (BRIC)), and cost-sharing through utilities or regional compacts.

Opportunities for Infrastructure Planning

3. **Explore and advance national water governance and institutional visibility:** establish a centralized national structure for water governance to elevate the role of water in infrastructure and science policy. Water can be explicitly added as an Emergency Support Function (ESF) alongside energy, data, and communications to ensure inclusion in emergency planning and federal response frameworks; there is no national equivalent to the Energy Information Administration (EIA) for water.
   - Possible actions suggested by participants included:
     - ✓ **Congress and Executive Branch:** create or strengthen a federal entity focused on water security
     - ✓ **OMB and FEMA:** elevate water's role in ESFs and national response planning
     - ✓ **Data agencies (USGS and FEMA):** create a national water information repository equivalent to the EIA
   - Participants discussed funding opportunities from congressional appropriations (possibly within the Farm Bill, Water Resources Development Act, or future resilience legislation), reprogramming of existing interagency funds to centralize water oversight, and partnerships with major tech firms to co-invest in water data platforms.

Opportunities for Infrastructure Planning

4. **Incentivize and streamline integrated infrastructure:** financial incentives such as tax incentives and cost-sharing mechanisms could encourage public and private investment in integrated energy-water resilience projects. Permitting and development processes could be streamlined for dual-benefit projects (e.g., those that save both water and energy, like California's hot water efficiency programs).
   - Possible actions suggested by participants included:
     - ✓ **Treasury and IRS**: create new tax incentives for resilience investments (e.g., credits for co-optimized energy-water systems)
     - ✓ **EPA, DOE, USDA:** expand infrastructure finance programs (e.g., WIFIA, REAP, LPO loan guarantees) to reward integrated, resilient projects
     - ✓ **State agencies and PUCs:** Authorize cost-recovery mechanisms for long-term resilience investments
   - Participants discussed funding opportunities from a blend of federal infrastructure grants, green bonds, and public privatize partnerships, as well as expanding access to IIJA and Inflation Reduction Act (IRA) funds for dual-benefit projects, and using cost-benefit frameworks that capture resilience co-benefits to attract investors.

Opportunities for Infrastructure Planning

5. **Foster regional and cross-sector partnerships:** facilitate cross-sectoral and cross-jurisdictional collaboration through local and regional partnerships (e.g., city-utility alliances). Opportunities include connecting water and energy utilities that share risks or have overlapping jurisdictions. For example, power and water utilities with overlapping service areas can team up on joint atmospheric modeling and resilience planning to create shared value and reduce duplication.
   - Possible actions suggested by participants included:
     - ✓ **Regional planning entities, COGs, state compacts:** facilitate joint infrastructure planning across sectors and jurisdictions
     - ✓ **Utilities and municipalities:** pilot shared planning platforms (e.g., “dating app” for utilities) to connect water and energy partners
     - ✓ **Philanthropic organizations and NGOs:** fund case studies and best practice pilots
   - Participants discussed funding opportunities from competitive grants from FEMA BRIC, DOE Grid Resilience and Innovation Partnerships (GRIP) or EPA Environmental Finance Centers, regional innovations hubs (e.g., via U.S. Economic Development Administration (EDA) or National Science Foundation (NSF)), and local governments through SRF set-asides or resilience hubs funding.

Opportunities for Infrastructure Planning

6. **Promote innovation and flexibility:** support technology innovation pilots, especially those that demonstrate resilience under uncertainty or support distributed infrastructure. Encourage phased and adaptable planning pathways with flexible regulatory and funding structures. Build momentum for change by engaging hyperscalers (large tech or data firms) as resilience advocates and early adopters of integrated infrastructure solutions.
   - Possible actions suggested by participants included:
     - ✓ **Federal R&D agencies (DOE, ARPA-E, NSF):** fund pilot technologies that advance flexible, distributed, or modular systems
     - ✓ **PUCs and regulatory innovation offices**: allow for regulatory sandboxes or pilot exemptions to test new resilience approaches
     - ✓ **Tech sector and large-scale infrastructure users:** partner on demonstration process and advocate for innovation
   - Participants discussed funding opportunities from federal innovation funding (e.g., ARPA-E, DOE’s Office of Clean Energy Demonstrations, or NSF Convergence Accelerator), utility innovation funds or public-private investments, early-stage philanthropic or impact capital to seed local pilots.

Opportunities for Data Centers and Demand Growth

1. **Support a national energy-water strategy for data center siting and planning:** develop and support a comprehensive, national strategy and siting framework that ensures data centers are right-sized on a regional scale, considering proximity to existing power and infrastructure. Frameworks already exist that consider land, water, and environmental risks (e.g., fire and flood), as well as regulated siting based on local capacity and other potential constraints. For example, siting a smaller data center build is more appropriate in a constrained electric area.
   - Possible actions suggested by participants included:
     - ✓ **Federal Agencies (DOE, EPA, CEQ):** develop national siting principles and strategy based on environmental, regulatory, and capacity-informed criteria
     - ✓ **State and local governments:** integrate siting frameworks into zoning and permitting
     - ✓ **Tech companies and developers**: proactively choose sites based on infrastructure readiness and community input (NERC's Data Center Information Collection Questionnaire)
     - ✓ **Regional planning authorities:** coordinate across sectors to assess cumulative siting impacts
   - Participants discussed funding opportunities from federal resilience and planning grants (DOE or EPA), state planning and infrastructure funds, developer contributions or permitting-linked fees, and public-private partnerships for shared infrastructure.

Opportunities for Data Centers and Demand Growth

2. **Create a national data center consortium, resulting in improved coordination and governance:** develop a permitting system that considers regulations and decision-making across local, state, grid levels, and utility providers to manage demand growth and siting implications. Accelerate regulatory processes to enable win-win outcomes, streamline decision processes, and incorporate best management practices. Involve varied stakeholders: rural communities, regional planners, professional organizations, technical experts, construction firms, permitting offices, and cooling technology companies.
   - Possible actions suggested by participants included:
     - ✓ **Federal agencies (EPA, DOE):** issue guidance on integrated governance
     - ✓ **State and local governments (state PUCs):** lead streamlined permitting and regulatory modernization
     - ✓ **Tech companies and developers**: participate in regulatory planning early and share growth projections
     - ✓ **Regional planning authorities, utilities, industry groups:** facilitate ongoing communication and planning
   - Participants discussed funding opportunities from federal grants for permitting reform and interagency coordination, cost-sharing among utilities, technical assistance and regulatory modernization programs (e.g., via DOE, NARUC).

Opportunities for Data Centers and Demand Growth

3. **Enable infrastructure and resource optimization and modernization:** collaborate across utilities and local governments to more intentionally forecast infrastructure planning and optimize infrastructure investments (e.g., power lines, cooling systems, substations), so that supply and distribution can keep up with increased demand. By classifying data centers by type and intensity, infrastructure can be appropriately optimized and modernized to accommodate, especially with shared infrastructure across co-located or nearby data centers (in more hot-spot "data center hubs").
   - Possible actions suggested by participants included:
     - ✓ **Utilities and grid operators:** lead load forecasting and infrastructure planning
     - ✓ **Local governments:** support through land-use planning and incentives for infrastructure co-location
     - ✓ **Data center developers**: provide transparent forecasts and consider shared infrastructure models
     - ✓ **National labs and universities:** create classification schemes and scenario tools
   - Participants discussed funding opportunities from utility capital improvement plans and recovery, industry-funded projects through joint infrastructure agreements and public-private partnerships, and state or federal energy infrastructure modernization grants.

Opportunities for Data Centers and Demand Growth

4. **Quantify and capture energy and water use through heat and cooling:** ensure energy and water use is quantified, captured, and used efficiently to preserve necessary resources and extend useful supply life. For energy, capture and reuse any “waste heat” through innovation in closed-loop thermal systems and co-location with heat users (e.g., district heating). For water, plan long-term cooling strategies, favoring liquid and low-water-use systems, advance use of treated or reclaimed water and rainwater harvesting, and implement water reuse systems.
   - Possible actions suggested by participants included:
     - ✓ **State agencies:** set permitting frameworks to support innovative cooling
     - ✓ **Local governments and utilities**: identify users and networks that can benefit from waste heat and reused water
     - ✓ **Data center operators and designers:** incorporate heat capture systems into facility design; design systems to reduce freshwater dependence
     - ✓ **National labs and universities, researchers, tech:** pilot new thermal technologies and integrated design, share best practices and push innovation across members
   - Participants discussed funding opportunities from federal clean energy and decarbonization incentives (e.g., IRS tax credits), federal water innovation programs WIFIA loans for water reuse infrastructure, municipal infrastructure bonds, innovation grants (ESG-driven industry investment or offset markets), and developer capital investment.

Opportunities for Data Centers and Demand Growth

5. **Improve data collection, transparency, and tracking:** better understand demand signals and ensure appropriate supply. This can be achieved by tracking and sharing regional data center demand, energy use, and water use. By increasing transparency on siting decisions, timelines, performance, and lifecycle planning, data center developers, utilities, and local communities have a better understanding of shared requirements. Stakeholders can share forecasts and operational needs with utilities, planners, and communities and develop 10–20-year impact frameworks and scenario/outlook planning tools to improve forecasting.
   - Possible actions suggested by participants included:
     - ✓ **Federal Agencies (DOE, NIST):** establish transparency standards and data disclosure frameworks
     - ✓ **Regional utilities and grid operators:** incorporate demand tracking into planning
     - ✓ **Tech companies and developers**: report usage, siting rationale, and projected needs
     - ✓ **National labs, universities, researchers:** build forecasting tools and perform lifecycle analysis
     - ✓ **Local communities:** be involved in data collection and impact assessment
   - Participants discussed funding opportunities from federal grants or mandates tied to permitting (e.g., DOE, EPA, NIST), industry-supported coalitions for open data and impact reporting, and public research funds for scenario modeling and community access to information (public-private partnerships).

5. Summary and Next Steps

Summary and Next Steps

- Energy and water systems are critical interdependent systems that experience similar challenges and opportunities, yet tend to be governed differently
- National and regional opportunities for leadership and collaboration exist to address challenges associated with future growth, threats and hazards, and long-term resilience
- Tools and resources exist to ensure utilities and local governments are co-managing risks and achieving resilience of both energy and water systems
- More research and collaboration will further enable technological advancement, operational resilience, co-management of resource allocations and system operation, and planning amidst rapid growth

Acknowledgements

The authors would like to acknowledge the Department of Energy's Water Power Technologies Office for supporting the facilitation of this resilience workshop and development of the workshop summary. We would also like to thank AWWA and APPA for their partnership and co-facilitation of the workshop.

Contact

Kelsey Semrod,
Senior Water Resources Scientist, PNNL
kelsey.semrod@pnnl.gov

Juliet Homer,
Chief Systems Engineer, PNNL
juliet.homer@pnnl.gov

Reference: PNNL-SA-216376