PNNL-31880

Coordination and Planning for Water and Power System Resilience

Workshop Report

November 2021

Juliet S Homer
Jennie S Rice
Kendall Mongird
Kostantinos Oikonomou

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
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Pacific Northwest National Laboratory
Richland, Washington 99354

Summary

Water and power utilities are interdependent, subject to many of the same natural and manmade hazards, and critical for the well-being of communities and society. In April 2021, a virtual workshop was held that brought together representatives from water, wastewater, and electric utilities; government organizations; water and electricity based professional associations; consulting firms; and researcher organizations to explore water and power system interdependencies and resilience. The workshop, organized by Pacific Northwest National Laboratory (PNNL) and funded by the United States Department of Energy (DOE) Water Power Technologies Office (WPTO), explored a vision for coordinated and resilient water and electric utilities of the future and identified barriers and strategies for increased coordination and integrated planning between water and power utilities. Workshop participants suggested next steps and areas where federal research and support would be beneficial.

Key Workshop Takeaways

Key takeaways from the workshop are described below.

More action is needed on water and power systems coordination for resilience and **state regulators and policymakers as well as the federal government** have important roles to play. Workshop participants recommended that a federal-level department of water be established to foster new ideas, host data, and be a repository of examples for best practices to speed implementation. The department of water could work closely with existing professional organizations (American Water Works Association, Water Environment Federation, Water Research Foundation, Electric Power Research Institute, and others) to gather input and ensure research and products are relevant and useful.

- **Water infrastructure funding** has not kept pace with system needs. Forthcoming water infrastructure investments represent an opportunity to build new infrastructure that is energy efficient, smart, connected, and flexible and can support resilient operations.
- Water and electric utilities can **work together to prepare for climate change and extreme events**. Utilities can develop common threat scenarios, conduct joint outage notification and black sky[1] training exercises, and share climate scenario modeling data. Regulators and policymakers can encourage this type of coordination. Tools should be developed for modeling climate change and extreme events to help guide and justify prudent investment in hardening and resilience.
- Increased **metering and submetering** of energy and water use would enable energy intensity trending, coordination of water pumping and other water system energy use with the electric grid needs, and energy and cost savings programs.
- **Audits and assessments** of energy and water efficiency potential, flexible demand potential, and renewable energy development potential at water and wastewater facilities would support resilience planning and operations by water and electric utilities. No-cost audits and assessments would help speed implementation and could be the basis for impactful **financing or gap funding** programs.
- **Relationship and trust issues** need to be addressed between water and electric utilities if co-developed resilience strategies are to be realized. Regulators could support coordinated

[1] Black sky events are defined as long-term, catastrophic, widespread events.

operations and planning for resilience through working groups, requirements in planning dockets, or financial incentives.

- The renewable energy electric system **interconnection process and limits established by electric utilities on the amount of power water utilities can generate on site** are barriers to increased local generation in the water and wastewater sectors. Utility cost recovery concerns and revenue disincentives limit utility enthusiasm for efficiency programs and onsite self-generation. Regulators can help address these issues.
- Workshop participants expressed interest in **future workshops** and information on extreme weather resilience response and integrated resource planning for water and electricity.

Workshop Summary

At the workshop, keynote speakers and solutions panelists provided valuable insights and helped set the stage for the explorations that followed. Jennie Rice from PNNL illustrated how severe weather events are increasing and how poorer communities are being disproportionately impacted. The magnitude of costs to water and power utilities of natural and humanmade hazards are significant—in the billions of dollars. Keynote speaker Michael Webber pointed out that the February 2021 cold snap power and water outages in Texas cost the state between $120 and $180 million, or roughly $4,000 for every man, woman, and child living in Texas. As with the cold snap in Texas, hazardous events can result in cascading impacts between water and energy systems. Michael Webber emphasized that due to climate change, future conditions cannot simply be predicted by analyzing the past. Water and electric utilities and policy makers need to understand climate science and plan for more uncertainty than they currently do. They need to plan for the weather and conditions of the future rather than the weather and conditions of the past.

Speaker Greg Characklis addressed how environmental financial risks result in large potential costs to utilities that can impact utility credit ratings and borrowing costs. Integrated water and power system solutions can decrease environmental risk. Opportunities exist for pooling risk between water utilities and between power and water utilities across the United States.

At the workshop, positive examples of water-power resilience and integration were shared. These examples are still the exceptions, but they can be emulated around the country:

- Supply diversification and redundancy support resilience in the operation of the **Central Arizona Project (CAP)**, which delivers Colorado River water to 80% of Arizona’s population. Large CAP water pumping stations can coordinate with grid operations, reducing costs and improving reliability. Due to excess reservoir capacity, during the February 2021 Texas freeze, CAP was able to curtail and shift significant pumping loads from February to March and April, which saved CAP an estimated $2.2 million in electricity costs by avoiding pumping at times of extremely high market prices.
- **DC Water** and **Constellation Energy** enjoy a win-win contractual arrangement where Constellation operates a biogas power and steam plant on DC Water property. DC water also has an innovative thermal hydrolysis process (THP) they use to develop biogas and biosolids that they sell on the market. Heat from wastewater collection pipes is used to heat DC Water’s headquarters building.
- **Massachusetts Department of Environmental Protection** has demonstrated a successful cohort model and gap funding program that’s provided support to 15% of water and

wastewater utilities in the state. Gap funded energy efficiency and renewable generation projects save water utilities money, support local economies, and increase resilience.

- **St. Cloud, Minnesota** has achieved 92% energy self-sufficiency at their wastewater treatment plant and saves approximately $500,000 per year in energy costs. Their journey started with an energy neutrality goal and tracking their energy use and trends. It grew into a phased program that includes energy efficiency, solar power generation, advanced treatment of biosolids, biogas storage, and biogas power generation.

<u>Resilient Utilities of the Future</u>

Workshop participants envisioned resilient water, wastewater, and electric utilities of the future and then developed a list of common characteristics of resilient utilities of the future, including the following:

- Water and electricity supply diversification and redundancy
- Balance between centralized and decentralized systems
- Utilization of advanced forecasting methodologies
- Targeted data collection through extensive sensors, metering, and communications
- Extensive use of renewable energy, energy efficiency, and flexible loads that can be responsive to grid needs, electricity price signals, and dynamic water supply conditions
- Hardened system designs (to extreme weather and earthquakes) and more robust natural disaster planning and response
- Cross-utility coordinated planning, operations, and maintenance
- Greater focus on community participation and equity
- Advanced cybersecurity
- Prepared and cross-trained workforce
- More integrated policy and regulatory landscape.

<u>Operational Strategies for Resilience</u>

Workshop participants identified operational strategies that would improve resilience of water and electric utilities, including the following:

- Each utility can identify a champion or point of contact to be the central point for coordination with other utility types. Utilities can exercise coordination channels through outage notification trainings and black sky training and response exercises.
- Water, wastewater, and electric utilities can share information and data with each other. Water utilities can share information on energy and water use, efficiency and flexible load potential, onsite self-generation capacity and timing, and critical loads. Electric utilities can share information on grid needs by location, circuit hosting capacity limits, peak and low-cost electricity price hours, non-wires alternatives solicitations, demand response offerings, and energy efficiency incentives and program support.
- Water systems flexible loads can be used to support grid needs and respond to price signals. Tools and techniques can be developed to help align operator efforts with power costs.

- Water and electric utilities can work together to conduct integrated workforce cross-training and coordinate on maintenance activities, where beneficial.

Planning Strategies for Resilience

The workshop group brainstormed planning strategies to increase resilience. The following suggestions are noteworthy:

- Water and electric utilities could work together to develop and share climate scenarios and data.
- Water and power utilities could coordinate on capital investment planning. Critical sites for water and wastewater system planning service delivery could be identified and electric utilities could prioritize microgrids and/or hardening power lines to key sites. As part of capital planning, both utility types could explore options for shared infrastructure such as energy storage.
- Water and electric utilities could plan to perform infrastructure projects in the same area at the same time to minimize cost and disruption. Water and wastewater utilities can also work together on customer outreach and stakeholder engagement for capital and resilience planning.
- Water and wastewater utilities have significant potential for renewable power generation and flexible electricity demand that can support electric system reliability and resilience. As part of electric utility system planning, electric utilities can coordinate with water and wastewater utilities to understand, include, and potentially incentivize energy generation and flexible demand projects, thereby reducing the need and cost for traditional investments.

Regulatory/Structural Strategies for Resilience

Workshop participants brainstormed regulatory and structural strategies that can support increased resilience of electric and water utilities. Key suggestions are:

- Municipalities, public utility commissions (PUCs), and/or other community or state agencies can establish energy-water stakeholder working groups to address threat scenarios, needs, and priorities. These energy-water working groups can be formed either as standalone activities, or as part of formal planning or resilience proceedings.
- PUCs can consider favorable ratemaking treatment for integrated and proactive investments that minimize the impact of disasters across sectors and customer classes.
- PUCs can also consider implementing decoupling mechanisms in the water sector to decouple revenues from sales to incentivize water conservation, as has been done extensively with electric utilities.
- PUCs can consider performance-based regulation (PBR) incentives that support energy-water coordination and resilience. PBR incentives could be associated with energy efficiency, flexible demand, renewable energy targets specific to water utilities, and/or cross-sector carbon reduction or resilience targets.
- To incentivize more energy projects in the water sector, state and federal policymakers can develop a clear path for no-cost water and energy conservation audits, flexible demand potential studies, and renewable energy assessments at water and wastewater facilities. As with the Massachusetts Gap Funding program, these assessments can be tied to state grant funding or other financing mechanisms.

- To enable energy tracking, flexible demand, and energy optimization, policymakers and municipal boards can support investments in energy submetering and communications systems at water and wastewater facilities.
- Regulators can encourage or require appropriate data sharing and safeguards between water and power utilities.

Federal-Level Opportunities

Workshop participants identified specific research or federal-level opportunities that would advance water and power system integration and resilience, including the following:

- Designing a national roadmap for water energy resilience and/or a federal department of water to foster new ideas, host data, and share best practices
- Providing infrastructure funding, potentially tied to requirements for efficient, smart, connected and flexibility-enabled equipment
- Creating a federal initiative to help modernize utilities with power and water flow metering to support energy intensity trending
- Developing and sharing climate modeling data, severe event damage and impact prediction models, and updated intensity-duration-frequency curves for water planning
- Developing a DOE Uniform Methods Project[1] for determining energy efficiency savings for specific water and wastewater measures
- Helping develop methodologies for assessing financial environmental risks to water and electric utilities and identifying options for risk pooling and other risk mitigation strategies.

Conclusions

Opportunities exist at the community, utility, state, and federal level to move beyond existing silos and consider interdependencies, cascading impacts, and risks that face water and electric utilities and take action to realize the benefits of energy and water systems collaboration and coordination. The frequency and magnitude of hazards and extreme events that impact both the water and power sector are increasing. Costs are extensive and risks can cascade from one sector to the next. Just as risks and negative impacts can cascade from one sector to another, innovation, good ideas, and solutions can also cascade within and between sectors.

This workshop brought together people from diverse backgrounds and perspectives who shared experiences, ideas, stories, and hope for more resilient and integrated communities. Some workshop participants noted that a lot of talk, thought pieces, and workshops have happened on energy water coordination, with little action. It’s time to move beyond talking and thought pieces to action and projects. Recommended next steps include developing state and federal programs to incentivize and fund energy audits, renewable energy assessments, and energy metering programs and to provide gap or support funding for installing upgrades. We also recommend federal entities work states with state and national level professional organizations to create a forum for water and electric utilities to meet, develop relationships, establish shared goals, and coordinate operations and planning for increased resilience in the face of climate change and hazardous events.

[1] https://www.energy.gov/eere/about-us/ump-protocols

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Acronyms and Abbreviations

CAP	Central Arizona Project
CHP	combined heat and power
DER	distributed energy resource
DERMS	distributed energy resource management systems
DOE	Department of Energy
IDF	intensity-duration-frequency
NARUC	National Association of Regulatory Utility Commissions
NWA	non-wires alternatives
PBR	performance-based regulation
PFAS	perfluoroalkyl and polyfluoroalkyl substances
PFOS	perfluorooctane sulfonic acid
PNNL	Pacific Northwest National Laboratory
PUC	public utility commissions
SCADA	Supervisory Control and Data Acquisition
THP	thermal hydrolysis process
WPTO	Water Power Technologies Office

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1.0 Introduction

An online workshop funded by the United States Department of Energy (DOE) and hosted by Pacific Northwest National Laboratory (PNNL) was held on April 13 and 14, 2021. The purpose of the workshop was to explore how water and electric utilities can better coordinate operations and planning to increase resilience and to identify federal research and development areas to support integrated resilience.

The workshop brought together a targeted group of water and electric system planners and decision-makers; local, state, and federal policymakers and regulators; and researchers to explore needs and opportunities for increasing resilience of water and power systems through coordinated operations and planning. The workshop brought together over seventy people from the organizations listed in Table 1. Workshop participants were asked for their individual feedback based on their own expertise and experience. The findings presented below do not represent consensus findings on the part of participants, but rather recurring themes from individual feedback provided during the workshop as summarized by the authors.

Table 1. Workshop Participant Organizations

Participant Type	Participants
Utilities - Electric Investor-owned	Constellation Energy Hawaiian Electric Company National Grid Portland General Electric
Utilities - Water	Central Arizona Project DC Water Great Lakes Water Authority Metropolitan Council, Saint Paul, Minnesota Saint Cloud, Minnesota Southern Nevada Water Authority Stephens Point Department of Public Utilities SUEZ
Utilities - Combined Water & Electric Municipals	Eugene Water and Electric Board Los Angeles Dept. of Water and Power Miami-Dade County
Consultants	Broadview Collaborative, Inc. CDM Smith ENGIE Greeley and Hansen ICF RMI Water Resource Recovery Solutions
Professional Associations	American Water Works Association Electric Infrastructure Security Council Electric Power Research Institute National Rural Electric Cooperatives Association Water Environment Federation Water Research Foundation
Federal Entities	U.S. Department of Energy – Water Power Technologies Office U.S. Department of Energy – Office of Electricity U.S. Department of Interior – Bureau of Reclamation U.S. Environmental Protection Agency

Participant Type	Participants
State Organizations	California Public Utilities Commission Massachusetts Department of Environmental Protection
National Laboratories	Idaho National Laboratory Pacific Northwest National Laboratory National Renewable Energy Laboratory Sandia National Laboratory
Universities	Colorado State University Michigan State University Stanford University University of Minnesota University of Texas at Austin

The goals of the workshop were to

- Develop and discuss a common vision of resilient and coordinated water and power utilities of the future
- Discuss barriers to and opportunities for coordinated operations and integrated long-term planning between water and power utilities to improve resilience
- Identify federal research and development areas that would support increased coordination.

This report summarizes the workshop motivation and background as well as key workshop findings.

2.0 Project Background and Workshop Motivation

The interdependencies between water and power systems in the United States are well documented: Energy is used in a wide range of processes delivering and treating water and water is withdrawn or consumed for many energy-related processes. The concept of resilience is increasingly an objective in the water and power sectors. In this project, we define resilience as a multifaceted capability of complex systems that enables systems to persist over time in the face of short- and long-term risks and maintain the same basic structure. We talk specifically about restorative, adaptive, and absorptive aspects of resilience.[1]

A wide range of compounding influences, such as increasing populations, aging infrastructure, natural disasters, cybersecurity threats, and climate change, increasingly threaten the ability of water and power systems to persist and continue to provide essential goods and services with acceptable levels of reliability and cost over the long term. Figure 1 shows that the number and type of billion-dollar disasters in the United States. are increasing (NOAA 2021).

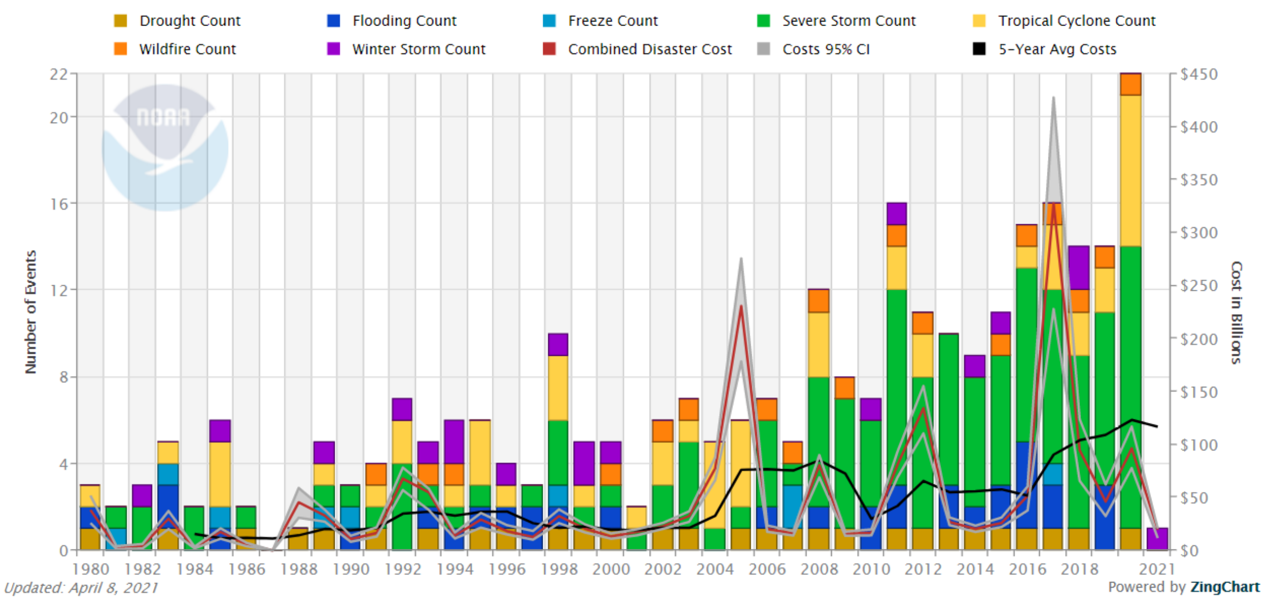

Figure 1. United States Billion-Dollar Disaster Events 1980-2021 (CPI adjusted); Source: NOAA 2021

Disasters are impacting power and water utilities. McKinsey estimates average storm damage costs and lost revenues total $1.4 billion per power utility over the last 20 years for ten power utilities in seven states (Alabama, Florida, Georgia, Louisiana, North Carolina, South Carolina, and Texas, plus New Jersey, where hurricanes are less common but dense coastal populations mean damage from storms can be particularly costly) (Brody et al. 2019). The cost of repairing Hurricane Sandy's damage to sewage treatment plants in New York is nearly $2 billion. The New Jersey Department of Environmental Protection plans to allocate nearly $1 billion for recovery and repair of facilities, and another $1.7 billion for building resilience into the system (Climate Central 2013).

[1] Restorative capacity refers to ability of a system to restore functionality after a disturbance. Adaptive capacity refers to the ability of a system to face and adapt to change. Absorptive capacity refers to the capacity of a system to absorb shocks and still maintain functionality.

This workshop was designed to gather stakeholder input on key challenges and opportunities as well as specific strategies and research areas that support integrated water-power resilience. The workshop built upon previous workshops on energy-water coordination that provided valuable insights and recommendations. The Johnson Foundation, in their 2013 workshop Building Resilient Utilities: How Water and Electric Utilities Can Co-Create Their Futures, identified a framework for change for building resilience water and electric utilities, shown in Figure 2 (Johnson Foundation 2013). Phase 1 of the framework is to optimize existing systems, Phase 2 is to transition to more resilient systems, and Phase 3 is to implement transformative systems. A DOE/University of California workshop held in May 2016, Capturing the Benefits of Integrated Resource Management for Water & Electricity Utilities and their Partners, recommended an implementation framework, shown in Figure 3 (DOE and University of California 2016). The framework includes three key action areas with sub-goals and next steps.

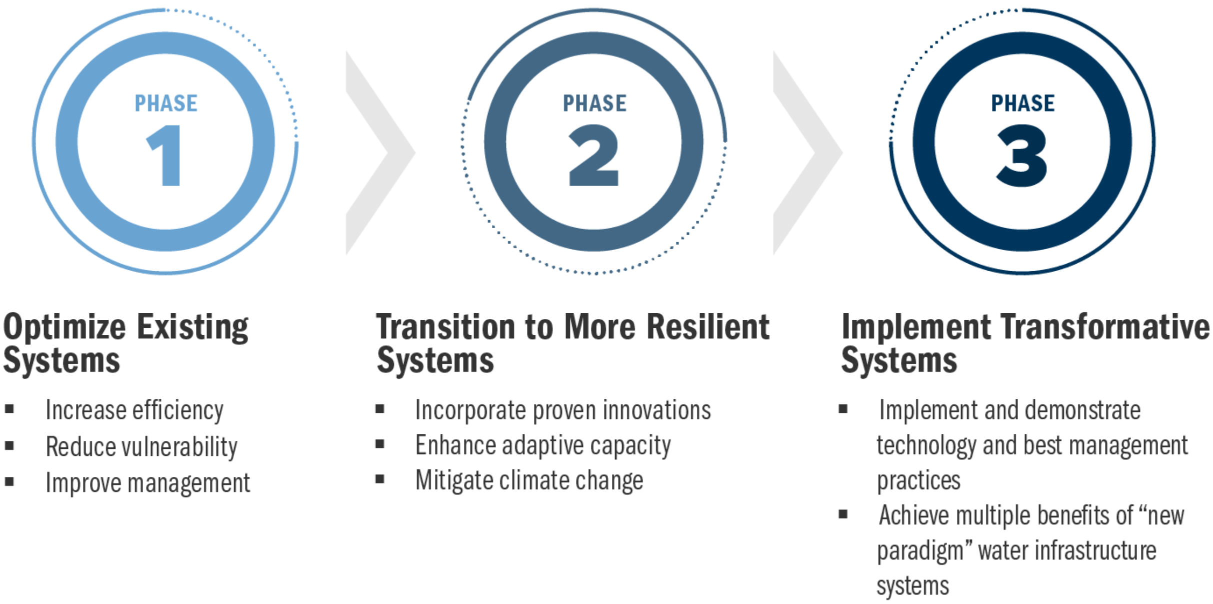

Figure 2. Framework for Change for Building Resilient Water and Electric Utilities (adapted from Johnson Foundation 2013)

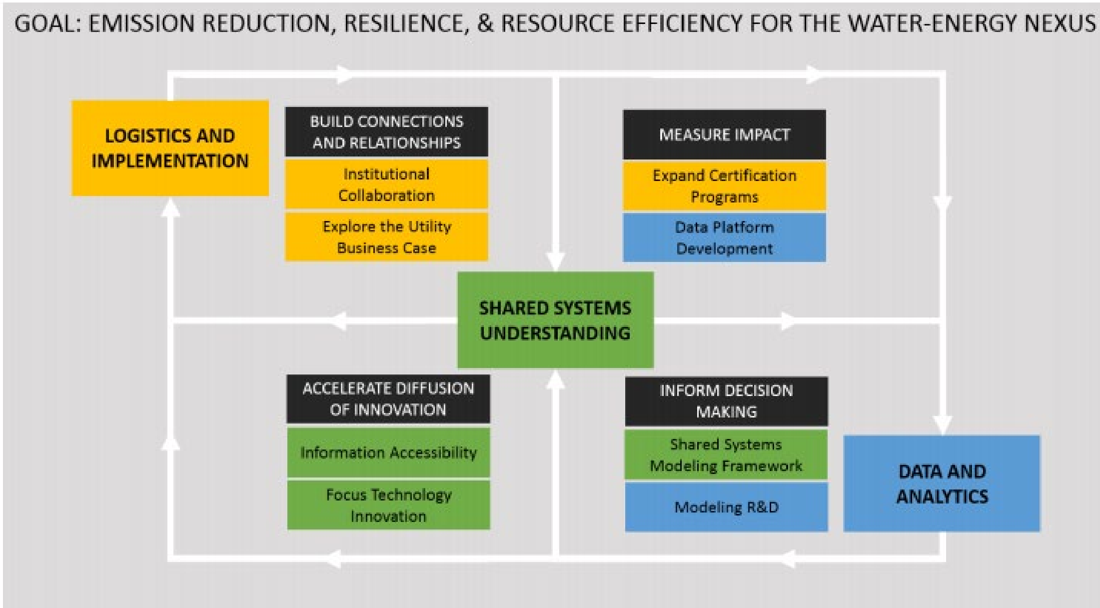

Figure 3. Implementation Framework from DOE/University of California 2016 Workshop (DOE/University of California 2016)

DOE is interested in exploring research and development opportunities in water and energy resilience. In 2015, DOE conducted a six-part Energy-Water Nexus Roundtable series. Key takeaways from that workshop include the following (DOE 2016):

- Climate change is exacerbating collisions between energy and water, effectively addressing that climate change requires new approaches to technology, policies, and markets.
- Unsynchronized changes in the energy and water sectors add complexity to understanding the challenges and developing solutions.
- Many of the effects in the energy-water nexus are felt at a regional level and interactions between regions can lead to additional indirect effects.
- Data, models, and analyses are important to inform the understanding of implications of change and interactions among regions.

This workshop builds on past efforts and was designed to help identify needs, opportunities, and challenges to realizing improved water-power resilience in the United States.

3.0 Key Points from Workshop Presentations

Three keynote presentations and a solutions panel provided context for the two day workshop. The sections below describe some important takeaways from the keynote addresses on day 1 of the workshop and the solutions panel on day 2.

3.1 Keynote Addresses

Jennie Rice, PNNL

Jennie Rice[1] from Pacific Northwest National Laboratory defined resilience and described how resilience is more than reliability. She pointed out that the number of billion-dollar disasters and costs in the United States are increasing and poorer communities are being disproportionately impacted. Jennie shared data demonstrating that disaster costs to water and power utilities are of a similar magnitude (in the billions). Jennie also talked about the significant capital investment needs in electricity, water, and wastewater infrastructure, and mentioned that investment needs for aging infrastructure provide opportunities to improve resilience. Jennie described that significant resilience planning is ongoing in the water and power sectors, but in a siloed fashion. Water and power utilities are interdependent, subject to many of the same hazards, and could benefit from common resilience strategies. Jennie described the integrated water-power resilience project at PNNL, the hypothesis of which is that if water and power utilities coordinate planning, investment, and operations, multiple benefits can be achieved, including increased long-term economic viability, increased reliability, reduced outage recovery times, reduced impact to vulnerable communities, and improved environmental outcomes.

Michael Webber,
University of Texas at Austin

Michael Webber[2] from University of Texas at Austin provided a keynote address on day 1 of the workshop on water and power interdependencies and resilience. Michael Webber talked about the February 2021 Texas power and water outages. He described the specific climate change dynamics that were creating the conditions that led to the cascading outages between the gas, electricity, and water systems in Texas. Michael said that the estimated cost of the February 2021 Texas outage was between $120 and $180 million, or roughly $4k for every man, woman, and child living in Texas. For his family of five, that would be $20k. Michael emphasized the fact that utilities need to look ahead. They cannot just plan based on the weather of the past—they need to look ahead and

[1] Jennie Rice's workshop presentation: https://epe.pnnl.gov/pdfs/Rice_W-P_Resilience_Project_Motivation_FINAL.pdf
[2] Information about Michael Webber's work: http://www.webberenergygroup.com/

plan for the weather of the future. They need to work with climate scientists to do this. In response to a question about whether distributed or bulk systems were more resilient, Michael said that bulk/transmission systems are more robust, but local/distributed systems are more resilient. Michael emphasized that planning for resilience is hard, and utilities need to look out for the cascading impacts between water, electricity, and gas.

Greg Characklis[1] from the University of North Carolina at Chapel Hill gave a keynote presentation on Financial Risk Management on day 1 of the workshop. Greg spoke about environmental risks that water and electric utilities are subject to and he talked about several risk analysis and mitigation projects his team has undertaken with water and electric utilities across the United States. Greg talked about how environmental risks translate to large potential costs that can impact utility credit ratings, which can significantly impact borrowing costs. Greg pointed out that integrated solutions can decrease environmental risk. Different water utilities can work together to help hedge against risks, as can water and electric utilities. Greg pointed out that the incidence of droughts in the United States are correlated regionally, but not across the country. Greg talked about the concept of risk pooling and the opportunities for risk pooling between water and power utilities across the United States. Greg also talked about the importance of communicating in a language the decision-makers will resonate with. Greg has found that characterizing the potential return on equity impacts of risk mitigating behaviors is a good way to communicate to utility management.


Greg Characklis, UNC Chapel Hill

3.2 Keynote Solutions Panel

A keynote Solutions Panel and a participant sharing session was held on day 2 of the workshop, featuring the following individuals:

- Darrin Francom, Central Arizona Project
- Bipin Pathak, DC Water
- Wayne Deczynski, Constellation Energy
- Michael DiBara, Massachusetts Department of Environmental Protection
- Liz Kramer, St. Cloud, Minnesota.

Some key points from each panel presentation are shared below.


Darrin Francom,
Central Arizona Project

[1] For more information on Greg Characklis' work: https://sph.unc.edu/cfres/center-on-financial-risk-in-environmental-systems/

Darrin Francom[1] from Central Arizona Project (CAP) described the role of CAP as delivering 1.4 million acre-feet of water each year through 336 miles of canals and 15 pumping plants. The CAP pumping takes 2.5 million megawatt hours each year. CAP has diverse sources of energy, which leads to resiliency. CAP times their pumping away from peak summer power demand times in Arizona, which saves money due to power costs being lower in off-peak periods. Their systems is built with extra pumping capacity, which allows them to respond to market stimuli. They can go from using five pumps to only using one pump during high-cost hours. Because they had excess storage capacity, during the extreme market prices in February during the Texas disaster CAP was able to cut back on pumping/energy use and sell their contracted energy in the market when it was needed elsewhere. In reaction to the February 2021 Texas deep freeze, CAP was able to shift pumping to reservoirs from February to March and April, saving an estimated $2.2 million in electricity costs.

Bipin Pathak, DC Water

Bipin Pathak[2] from DC Water described the innovative energy projects that DC Water has developed over the last 10 years. DC Water has installed the world's largest thermal hydrolysis process (THP) and built four anaerobic digesters that generate biogas and Class-A biosolids. The biogas runs an onsite combined heat and power (CHP) system that generates 10 MW of green energy. Class-A biosolids are sold on the market as a Blooms™ product. The THP process saved half the footprint of digestors using conventional treatment. The CHP project was built and is operated by Constellation in a cooperative arrangement with DC Water through Potomac Electric Power Company (PEPCO). The waste heat from the CHP generators is utilized to generate steam for the THP. In addition, DC Water extracts heat from sewers to heat DC Water's headquarters building.

Wayne Deczynski, Constellation Energy

Wayne Deczynski[3] from Constellation described the CHP partnership Constellation has with DC Water. The system conceptual design was developed by DC Water. The detailed design, construction, and start-up were all the responsibility of Constellation. DC Water is the asset owner. There is a 15-year operation and maintenance contract in place between Constellation and DC Water, initiated in July 2016. Constellation has a performance guarantee in place with DC Water that is linked to a supply of digester gas from DC Water. Wayne explained that there has to be appetite for water utilities to invest in these kinds of systems. Some water utilities are not interested in putting their capital in these systems, as DC Water was. The cost of producing energy through the CHP system is about 2 cents/kWh. The continued success of the CHP project and DC Water partnership depends on communication, collaboration in solving unanticipated problems, and cooperation in being flexible to help each other in changing conditions.

[1] Darrin Francom's full presentation: https://epe.pnnl.gov/pdfs/Francom_Central_Arizona_Project.pdf
[2] Bipin Pathak can be contacted at: bipin.pathak@dcwater.com.
[3] Wayne Deczynski's full presentation: https://epe.pnnl.gov/pdfs/Deczynski_Constellation.pdf

Michael DiBara, Massachusetts DEP

Michael DiBara[1] from the Massachusetts Department of Environmental Protection described the Massachusetts Gap Funding Model as a way to bring energy and resiliency results to the water sector. As part of an energy pilot, water and wastewater utilities in Massachusetts had access to no-cost energy utility audits and no-cost renewable energy assessments. The Massachusetts Gap Funding program provides grant assistance (up to $200,000/community) for implementing energy efficiency and clean energy projects at water and wastewater plants. Two rounds of gap funding were held, in 2014 and 2018. A cost-benefit analysis that was conducted on the first round of gap funding found the benefits were 15 times the cost of the program. In the second round of the Gap Funding program, $4 million dollars in grants led to $17 million of energy projects going forward and $1.3 million in annual cost savings for facilities. A foundation for the success of the Massachusetts program was an Energy Leader Roundtable initiative instituted from 2008–2014 during which a coalition of water and wastewater facility operators, managers, and decision makers engaged with state, federal, and community energy efficiency providers, and the University of Massachusetts Lowell in 17 roundtable meetings across the state.

Liz Kramer, City of St. Cloud

Liz Kramer[2] from the City of St. Cloud, Minnesota described St. Cloud's innovative nutrient, energy, and water recovery system at the St. Cloud 10 million gallon per day wastewater treatment plant. The wastewater facility began an energy neutrality goal in 2015 and they started tracking energy use and trends. To begin, energy efficiency measures were put in place in 2015. Two solar arrays (240 kW) were installed in 2016. A biogas conditioning unit and a biogas-powered generator were installed in 2017. A nutrient recovery process for Class A Biosolids was installed in 2018. A gas membrane and primary digester conversion happened in 2019. In 2020, a second generator and two more solar arrays (290 kW) were installed. In 2020, they generated 92% of their energy onsite and saved over a half a million dollars in energy costs.

[1] Michael DiBara's full presentation: https://epe.pnnl.gov/pdfs/DiBarra_MA_Gap_Funding.pdf
[2] Liz Kramer's presentation and supporting material:
https://epe.pnnl.gov/pdfs/Kramer_St_Cloud_NEW_Recovery_Facility_Overview_and_Timeline.pdf
https://epe.pnnl.gov/pdfs/St_Clouds_Waste_to_Energy_Program_Feb_2021.pdf

4.0 Water and Electric Utilities of the Future

The workshop participants were asked to identify what resilient water, wastewater, and electric utilities will look like in the future and then identify common aspects of these resilient utilities. The sections below summarize the visions of resilient water utilities, wastewater utilities, and electric utilities as well as the common aspects of resilient utilities. In some cases, utilities are already making positive strides toward the vision described here.

4.1 Resilient Water Utilities of the Future

According to workshop participants, resilient water utilities of the future will be able to draw on **multiple, diversified water sources, and** source water use will be tailored based on water quality and end-use needs. Resilient water utilities of the future will also account and design for emerging contaminants of concern and water sources and treated water quality will be fit for a specific purpose.

Water utilities will have **redundancy** in water and power supplies and all critical treatment and pumping processes. Resilient water utilities will have solar or other **renewable energy sources** in addition to grid-supplied electricity and will also have onsite **backup generation**. Some water utilities will be part of renewably powered **microgrids**.

Resilient water utilities of the future will be **metered, smart, connected, and integrated,** with features such as extensive metering and submetering, intelligent pipelines, inline analyzers, tracking of water loss in the system, and real-time efficiency and cost savings capabilities. Water utilities of the future will be able to respond to electricity price signals and dynamic water supply conditions.

In resilient water utilities of the future, water will be **supplied and treated locally**. Modular decentralized systems will support and enhance centralized systems. Water utilities will use reclaimed water for both direct and indirect potable reuse with full public trust.

Water utilities of the future will leverage **advanced forecasting technologies** to guide management and planning. Water utilities will be planning for **climate change and extreme events**. Water utilities will understand how different types of emergencies, including power outages, will impact their facilities and recovery plans will be in place. Water utilities will actively be collaborating with other water utilities, wastewater utilities, and electric utilities and the most vulnerable customers will be supported during extreme events and outages. Water utilities will be engaged with policy makers and regulators on relevant issues.

Water utilities of the future will be **physically secure** from extreme weather (e.g., stormwater and coastal flooding), seismic events, and malicious acts. They will also utilize advanced **cybersecurity** capabilities.

Resilient water utilities of the future will have robust **water and energy conservation and efficiency** programs. They will utilize up-to-date pump system efficiency and operations. They will have dedicated energy demand management programs and they will decrease energy and cost by using variable frequency drive motors and software to time pumping at periods of lower electric rates. They will participate in load shedding during peak power demand and be equitably compensated.

Resilient water utilities of the future will have **adequate funding** for infrastructure upkeep. Utilities will be proactive in managing and replacing assets to provide high quality water at affordable rates. In addition, a **prepared and energy-savvy workforce** will be in place to support the treatment and delivery of water. An established pipeline of new operators and engineers will keep the industry healthy and advancing.

4.2 Resilient Wastewater Utilities of the Future

According to workshop participants, resilient wastewater utilities of the future will be **self-sufficient with energy production** and improved wastewater treatment processes will lower energy use and enable energy recovery. Wastewater utilities will be net energy generators and may be part of and provide energy to microgrids. Wastewater utilities will have **a diversity of energy sources**, including different onsite generation methods and equipment. Onsite backup generation will be available for all distributed wastewater treatment facilities. Utilities will be able to import and export power as needed. Wastewater utilities will have clear information about how much energy is being used at water and wastewater facilities.

Resilient wastewater utilities of the future will feature **distributed wastewater capture and treatment**. Wastewater utilities of the future support **direct and indirect potable reuse** for water supply. Treated wastewater will also support recharge of groundwater aquifers.

Resilient wastewater utilities will **recover all resources** (nutrients, energy, heat, and water) with no waste. Digester gas will be used for power generation and organics will be used cooperatively in the agriculture sector. **Innovative agreements and contracting mechanisms** will be in place with energy companies and other third parties who may leverage resources at wastewater facilities to generate energy, recover energy, or generate material, such as algae, from which other materials or energy may be developed. Energy generation systems at wastewater plants may be owned and/or operated by a private or other third-party entity in a mutually beneficial arrangement.

Resilient wastewater utilities of the future will have **increased integration and cooperation with electric utilities**. They will coordinate loads with electric system needs and will have the ability to shed loads during peak power demand. Shared financial incentives will be available between water and electric utilities. Wastewater utilities will also have closer integration and engagement with customers, industries, and businesses.

Resilient wastewater utilities of the future will be good **environmental stewards**. Combined sewer overflow systems will be eliminated. Green infrastructure and passive/nature-based treatment systems will be used where applicable.

4.3 Resilient Electric Utilities of the Future

According to participants, resilient electric utilities of the future will be characterized by **dynamic loads and supply balance** where loads can readily be curtailed in event of grid stress in a way that does not cause unfavorable outcomes for customers. **Flexible demand** will be an integral part of balancing the grid for resilient electric utilities of the future. **Microgrids** (both permanent and mobile) will be available and used to serve critical loads.

For resilient electric utilities of the future, the grid will be **decarbonized**, net zero, and served by new mixes of power and energy, including a diverse mix of energy generation. Electric utilities will be at or near 100% renewable power. Resilient electric utilities of the future will make use of significant **distributed energy resources (DERs),** including flexible loads and distributed generation. Nested centralized and decentralized systems will exist and be coordinated. Local generation will be coupled with **energy storage** and energy storage will replace most natural gas peaking plants. Long-duration storage will be available to balance renewables. Energy storage, and other distributed energy resources will be optimized for the grid through distributed energy resource management systems (DERMS).

In resilient electric utilities of the future, **integrated planning** will be happening between water and electricity. Water will be appropriately valued and accounted for in risk planning.

In resilient electric utilities of the future, **transmission and distribution systems** will be hardened against earthquakes, extreme wind/weather, and natural disasters. Improved weather prediction and damage prediction will be in place. Strategic operations and maintenance (including tree trimming) will be in place to minimize outages and impacts. Complimentary uses of local resources will be matched to resilience needs. Hardened circuitry will be in place to community lifeline customers (including water). Electric utilities will actively be coordinating with the community on critical infrastructure. Utilities will have partnerships with organizations in the community, such as big chain stores to leverage backup energy sources. Redundancy of operations will exist to support continued operations during contingency events. The electric grid will be highly connected and cybersecure from the system down to customers.

4.4 Common Aspects of Future Resilient Utilities

Based on the characteristics of resilient water, wastewater, and electric utilities described in the sections above, workshop participants brainstormed common characteristics of future resilient utilities. These are summarized in Table 2 below.

Table 2. Common Characteristics of Resilient Utilities of the Future

Characteristic	Description	Example
Balance between centralized and decentralized	Assets and operations are more decentralized. Coordination exists between distributed and centralized systems.	Local water supply, treatment and reuse and distributed energy resources in combination with central plants
Targeted data collection and use	Extensive sensors, metering/submetering, and communication systems support data for decision-making.	Metering/submetering at water utilities and visibility into real-time prices, grid needs, and load shedding potential.
Community participation and equity	Greater community involvement in decisions, and planning and more consideration of equity and environmental justice.	Public input in capital and emergency planning and consideration of resilience impacts to traditionally disadvantaged communities.
Supply diversification and redundancy	Multiple sources of energy and water supply. Redundancy for critical components and processes.	Multiple water sources, redundant power feeds, microgrids, and diversified generation and flexible load resources.
Hardened infrastructure and cybersecurity	Infrastructure and operations are cybersecure and physically secure against extreme weather and earthquakes.	Hardened infrastructure against natural disasters, especially for critical facilities.

Characteristic	Description	Example
Robust natural disaster planning and response	Utilities proactively coordinate and plan for natural disasters.	Utilities have natural disaster response plans in place and participate in training exercises.
Efficiency, renewable energy, and flexible loads	Utilities are water and energy efficient, utilize renewable resources and resource recovery, and make use of flexible loads.	Efficiency/conservation programs, renewable energy interconnection agreements, and demand response programs.
Integrated policy and regulatory landscape	Policies and regulation are less siloed and address resilience and cross-sector solutions.	Regulators support and incentivize efficiency and cross-sector coordination for resilience including cross-sector working groups.
Prepared workforce	Workforce is prepared and trained to plan, design, and operate the resilient utilities of the future.	Water operators trained in energy optimization. Energy operators understand critical water system needs.

5.0 Current Conditions and Key Challenges

Workshop participants brainstormed the key challenges that need to be overcome to realize coordination and resilience of water and power systems. In brainstorming activities, an iceberg concept, shared by RMI and illustrated in Figure 4, was used to help identify and unpack different layers associated with key challenges. Relative to the challenges, the group explored the following:

- Events – What is happening? What is visible?
- Patterns and trends – What trends have there been over time?
- Underlying structures – What has influenced the patterns? What are the relationships between the parts?
- Mental models – What assumptions, beliefs, and values do people hold about the system? What beliefs keep the system in place?

The most long-lasting change is achieved by addressing patterns and trends, underlying structures and mental models rather than focus on events that are immediately visible.

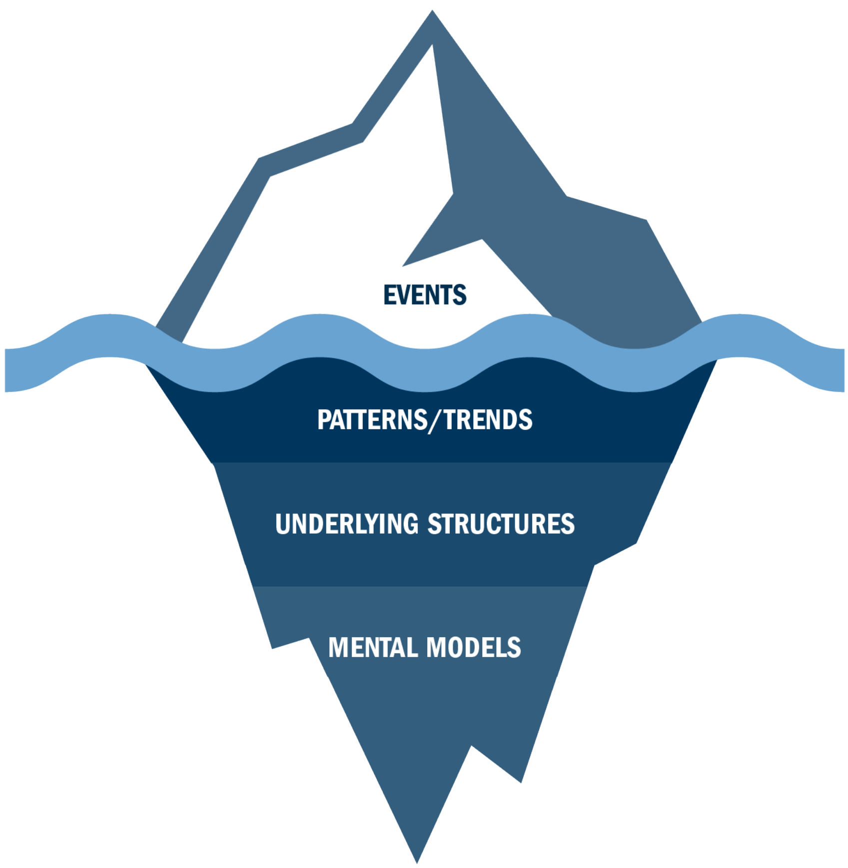

Figure 4. Iceberg Model for Systems Thinking[1]

[1] Image by Kelly Machart, graphic designer at PNNL

The following sections summarize stakeholder input on current events and challenges, patterns and trends, underlying structures, and mental models.

5.1 Events and Challenges – What is Happening?

Workshop participants identified current conditions and existing challenges related to water-power coordination and resilience. A foundational challenge that was identified is a lack of **trust, communication, and coordination** between power and water/wastewater utilities. Some electric utilities are not supportive of water utilities generating their own power or developing microgrids. Water and electric utilities have not connected on shared goals and do not coordinate in operations or in planning for shared resources. In some cases, water utilities are viewed by electric utilities as industrial customers rather than potential strategic partners. Water and electric utilities and are still largely acting in silos. This lack of coordination is particularly challenging before or during outages or in emergency situations and can lead to cascading impacts and longer than necessary response times. Water utility representatives at the workshop indicated that sometimes water utilities are not notified of anticipated forthcoming power outages.

There is a lack of **data and information sharing** data between water and electric utilities. There is also a lack of incentives—financial, regulatory, or otherwise—to encourage utilities to share data and information and coordinate with each other. Utilities are not seeing "what's in it for me," regarding coordination between sectors. This is particularly true for electric utilities.

New **metering technologies and mesh communication networks** create new communication pathways to manage resources for both water and wastewater utilities. Digitalization and the increasing penetration of Supervisory Control and Data Acquisition (SCADA) systems can facilitate coordination across water and power utilities.

A key challenge faced by water and electric utilities is **climate change and extreme weather.** Climate change and extreme weather are impacting both water and electricity systems. However, the **benefits and costs of resilience strategies** are not clear. Existing risk assessment methodologies are not comprehensive enough to handle climate/water dependency. While increasing in frequency, disasters still occur infrequently relative to elections and infrastructure development cycles. As a result, it can be challenging to obtain the political will needed to proactively address resilience.

A challenge faced by water and wastewater is that they can struggle to develop **renewable energy**. Water and wastewater utilities have significant untapped potential to generate renewable energy through hydropower, biogas, heat recovery, solar, or wind. Some electric utilities are not supportive of water utilities generating their own power or developing microgrids. Renewable energy interconnection requirements are a major barrier for water and wastewater utilities to develop renewable energy projects. In some cases, water utilities are prohibited from exporting energy to the grid or there are limits on how much energy can be exported. One workshop participant lamented that their electric utility requires their water facility to pay a sizable amount of money to provide backup power capacity for all renewable energy projects. Another mentioned that their electric utility has a cap on the amount they can generate. These challenges are difficult for water utilities to overcome.

Another existing challenge experienced by both water and electric utilities is that utilities may be conflicted when it comes to **energy and water conservation**. Utilities need to maintain revenue streams and revenues may be negatively impacted by conservation. Revenue decoupling, a regulatory mechanism used to decouple utility revenues from sales to incentivize conservation, has been used broadly in the electricity sector, but not as much in water. It was also noted that water conservation can have adverse impacts to water quality if water stays too long in pipes or storage tanks and disinfectant levels degrade as water ages.

Existing infrastructure does not support **integrated operations** between water and electric utilities. There is a lack of shared infrastructure between water and electric utilities and a lack of integrated control and telemetry options. There is also a lack of integrated resource planning between electricity and water (as well as gas and agriculture). **Integrated resource plans**, required by some electric and water utilities, represent opportunities for water and power utilities to plan together to reduce costs and risks.

A challenge faced by water and wastewater utilities is that **infrastructure funding** has not kept pace with system needs. Addressing replacement infrastructure will be costly and take years to complete, which may limit funding for targeted energy or resilience investments. However, infrastructure replacements may create a window of opportunity to develop infrastructure that is energy efficient, smart, and flexible that can support integrated and resilient operations.

Finally, for both water and electric utilities, there has been limited involvement by **a diverse range of stakeholders** in planning and decision-making. Some workshop participants suggested there is a lack of decision-making tools and processes addressing “all” stakeholder interests.

5.2 Patterns/Trends that have Existed over Time

In addition to the items mentioned above, workshop participants identified patterns and trends that impact water and power system coordination and resilience. One pattern or trend is the largely **siloed regulation** of water and electric utilities and the lack of regulatory incentives for coordination at the state and federal level.

One positive trend is the increasing amount of **onsite power generation** (solar, wind, batteries) and CHP at water utilities. Wastewater utilities in particular are developing energy generation and conservation. There has also been an increased interest in non-wires alternatives (NWA) to traditional investments in electricity planning. Water and wastewater utility energy projects, flexible loads, and efficiency can be part of NWA.

Another trend that was discussed is increasing concerns about **water quality**. Clean source water is no longer a given. The quality of water supplies varies from region to region, affecting the amount of energy required for treatment. Groundwater is quietly being polluted with salts and nitrate and contaminants of emerging concern, such as perfluorooctane sulfonic acid (PFOS), are becoming more ubiquitous. At the same time, water reuse is becoming more widespread—moving east and north from the southwest, where it has been relatively common for decades.

Finally, it was noted that there has been a lot of talk, thought pieces, and workshops on energy-water coordination, but **little action**. Action, positive examples, and best practices are needed on energy-water coordination.

5.3 Underlying Structures

Workshop participants identified underlying structures that influence patterns, relationships, and challenges related to water and power system coordination. A foundational structural issue has to do with the significant **differences in the size, scope, and ownership** (public vs. private) of water versus electric utilities. Figure 5 demonstrates the differences between electric and water utilities in the United States. Although water utilities and electric utilities serve roughly the same number of customers, water utilities tend to be smaller and cover smaller geographic areas. There are roughly 17 times more water utilities operating in the United States than electric utilities. The majority of electricity customers are served by privately-owned utilities, while the majority of water customers are served by publicly-owned utilities. With the exception of some explicit interconnections, water utilities are not linked the way the electric grid is. There are different drivers, revenue models, and infrastructure funding mechanisms for municipal utilities and privately-owned utilities.

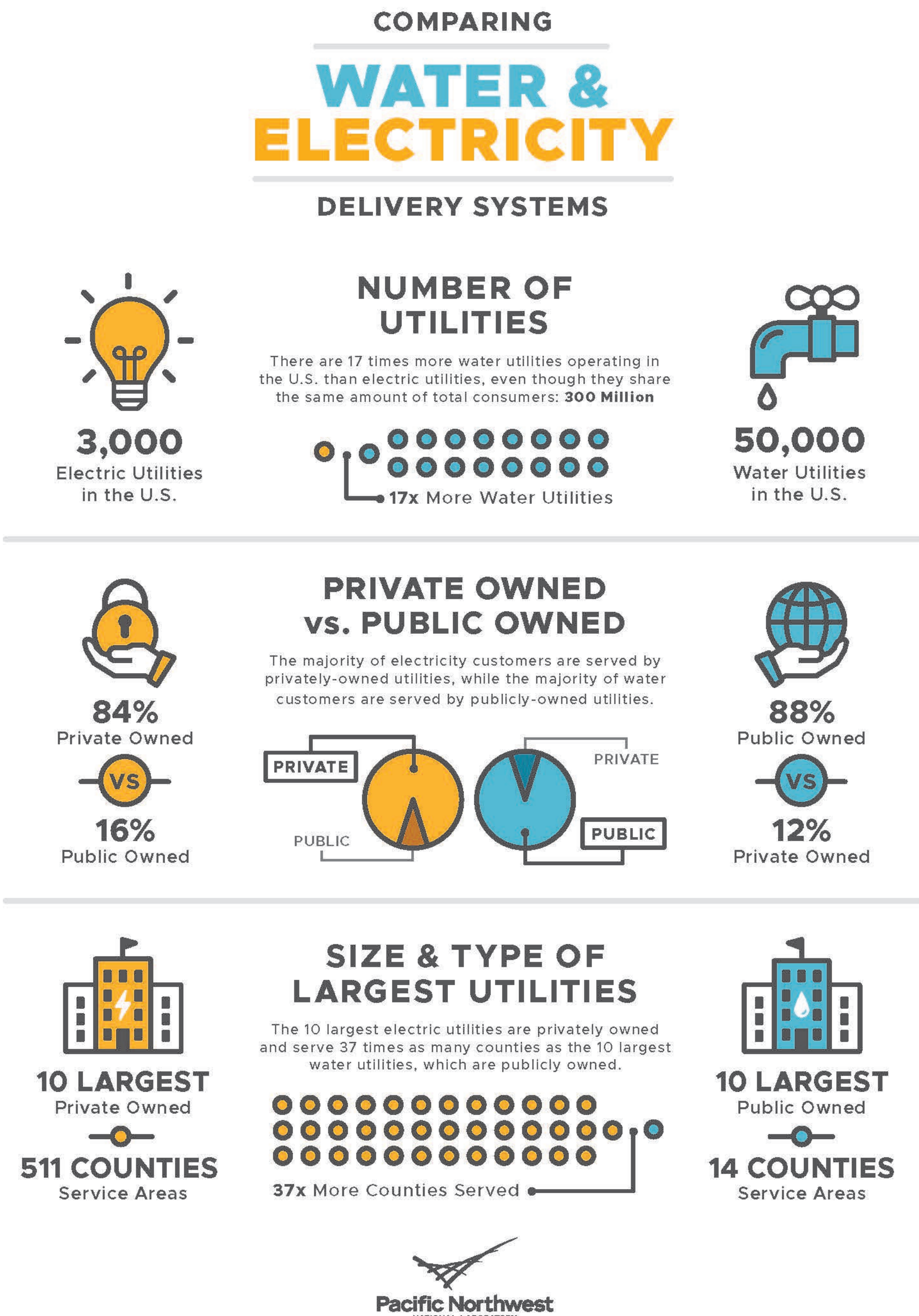

Figure 5. Comparison of Water and Electricity Delivery Systems in the United States[1]

[1]Infographic developed by Danielle Preziuso, Rebecca O'Neil, and Donald Jorgenson at PNNL, using information from U.S. Energy Information Administration (EIA 2019a, EIA 2019b, EIA 2018), U.S. Environmental Protection Agency (EPA 2020), and Global Water Intelligence (GWA 2009).

Water and electric utilities also have different **policy, statutory, and regulatory landscapes** by geography and utility type. Structures and incentives vary geographically based on where in the United States you are located. Regulation and rules for investor-owned electric and water utility regulatory agencies vary from state to state. Different state, federal, and local organizations/agencies have responsibility over resource and infrastructure management. Public utility commissions (PUCs) regulate water and electric utilities separately and, in most cases, there is a lack of regulatory oversight encouraging or requiring water and electric utilities to coordinate.

Another structural consideration is the **relationship between water and electric utilities**. In most cases, water utilities are viewed as one of many large "industrial" customers that electric utilities serve. Water utilities do not receive special treatment on account of the role of water as a key determinant for public health and well-being. As a result, water utilities may have a hard time garnering the time and attention needed from electric utilities for the type of coordination and integration required for increased resilience. Electric utilities have designated key account managers for many different large customer types. In some cases, water utilities have multiple dispersed power meters throughout their system, rather than one large meter, so they are not viewed as large customers from the electric utility perspective. In many cases, water utilities do not trust their electric utilities.

Structural issues associated with **energy-water research** were discussed. There was a sentiment expressed that federal research can be disconnected from implementation when it comes to water. In the water sector, scientific research is funded by federal science research organizations and there are concerns that research is not making its way to implementation and improvements in water industry.

Issues associated with **education of water and energy professionals** were also discussed. Workshop participants pointed out that education systems are siloed. Water engineers and operators learn about water and not about energy optimization. There is a lack of integrated workforce training. Distinct accreditation and professional associations exist for water and power and there is not a lot of crossover or coordination.

5.4 Mental Models

Workshop participants identified the beliefs or underlying mental models that shape patterns, structures, and events related to water and power system coordination and resilience. Relevant beliefs or mental models that were discussed include the following:

- **Belief that "Silos are good and needed"** – There is a belief that expanding beyond the current jobs (i.e., treatment) of water and wastewater utilities might threaten compliance and quality. There is also a fear of releasing responsibilities or jobs. Along with this is a belief that each utility type should strictly provide one service and should focus on improving their own infrastructure capabilities rather than taking a systems approach.
- **Belief that "Infrastructure is a hard sell"** – There is a belief that making systems improvements is too expensive and that infrastructure is a hard sell to the public.
- **Belief that "Everything can be modeled"** – There is a belief that everything can be modeled. This is not always the case. Most people do not comprehend the nature of climate non-stationarity (i.e., aspects of climate that are unpredictable that cannot be modeled or forecast). There is not widespread public understanding of water and climate challenges that are facing us soon.

- **Belief that "Water is unlimited and is a human right"** – There is a belief that water is unlimited and will never run out for a particular community or place. There is also a belief that clean water should be free and available to all and that water is a human right rather than a product. In addition, there is a belief by some that reliable power should be available to all and there is a reluctance to look at electricity as a commodity.
- **Belief that "Sustainability hurts reliability and the financial bottom line (i.e., income and revenue)"** – There is a belief that addressing sustainability and the environment hurts the bottom line. There is also an underlying belief that addressing sustainability and the environment makes things less reliable.
- **Ideas about the "Proper role of utilities"** – There are various underlying beliefs about the proper role of utilities. These include the following:
  - Sustainability and the environment are not concerns of utilities
  - Utility projects are or should be big rather than small and distributed
  - Investor-owned utilities are only responsible to their shareholders
  - The public should not be involved in utility decision-making
  - There is risk aversion to public-private partnerships and beliefs about the role of government versus the role of private industry in delivering clean water services.
- **Belief that "Future value should be discounted relative to the present or near-term"** – There is a belief that the future does not matter as much as the present. There is a long history of discounting the future in planning and investments through discount rates.

5.5 Summary

Visible challenges that water and electric utilities are facing today have been influenced by patterns and trends that have existed over time. Patterns and trends have been shaped by underlying structures, which have been shaped by mental models and beliefs. As researchers, utilities, and policymakers move forward to support water and power systems resilience, they can address opportunities and challenges at multiple levels, rather than just focusing on the visible challenges, which can be just the tip of the iceberg. Addressing patterns, structures, and mental models can lead to longer lasting and more robust solutions.

6.0 Specific Resilience Strategies

This section answers the question: "What are specific resilience strategies that would benefit from coordination across water and energy sectors?" Section 6.1 addresses operational and planning strategies and Section 6.2 addresses structural or regulatory strategies. Operational and planning strategies are considered together because they are two areas that can be addressed by utilities, whereas structural and regulatory strategies are more likely to be addressed by regulators and policymakers at different levels.

6.1 Operational and Planning Resilience Strategies

The following suggestions were made for ways to increase operational coordination and resilience between water and electric utilities:

- Identify and designate a champion at each utility as a point of coordination.
- Work together to determine top two to three hazard scenarios and plan together for outages and black sky events.
- Have designated cross-disciplinary sessions at conferences where water and wastewater conferences invite electricity abstracts and vice versa.
- Use third-party conveners as a way to overcome barriers in trust in structured engagements.
- Use flexible pumping loads. Water utilities can use flexible pumping loads to respond to grid and price signals.
- Share data for mutual system benefits. Water utilities can share information about energy use, water and energy conservation programs and potential, flexible energy use potential, and energy generation opportunities. Electric utilities can share information about peak system times and needs, low energy cost times, distributed generation circuit hosting capacity, demand response programs and incentives, energy and water efficiency incentives and program support, NWA solicitations, distributed generation interconnection requirements and process, and system needs by location.
- Expand energy knowledge base among water operations staff and management; do the same thing with energy utilities. For water operators, develop tools and techniques for aligning operator efforts with power costs. Develop shared cybersecurity protocols and trainings for water and electric utilities.
- Hold social networking opportunities between water and electric utility operators.
- Work together to increase water and energy efficiency through energy audits and incentive funding.
- Coordinate use of dispatchable emergency generation sources.
- Have efficient and smart equipment on hand that can be installed when needed rather than replacing like for like when things break.

The following suggestions were made for ways to increase planning coordination and resilience between water and electric utilities:

- **Work together to plan for climate change** – Water and electric utilities can develop and share access to climate scenario modeling data to support planning. Both utilities can work together to plan for drought contingency conditions and develop and strategize alternative water supply and service opportunities in cases where both utilities may be impacted by reduced water availability. In electricity integrated resource planning, electric utilities can include water availability risks and climate variability when identifying generation and transmission investments.

- **Coordinate capital improvement planning (CIP) and plan for shared infrastructure** – Water and electric utilities can coordinate capital improvement planning by sharing system needs and infrastructure options, identifying critical sites for water and wastewater service delivery, and prioritizing hardening power lines to key water sites for water and community resilience. Water and electric utilities can identify projects that can be performed in the same area at the same time, consider shared land use solutions, and explore shared infrastructure for reliability and resilience, such as energy storage systems or microgrids that support both water and energy.
- **Plan together for renewable energy and flexible demand** - Electric utilities can consider the distributed generation and flexible demand potential at water and wastewater facilities in system planning and planning for non-wires solutions.[1] Water utilities would benefit from improved clarity and transparency around distributed generation interconnection requirements. Some workshop participants indicated that electric utilities require sizable investments by water utilities to provide backup power capacity for all renewable energy implementations and interconnection requirements are significant barriers to all but the largest water and wastewater utilities developing renewable energy.
- **Conduct joint stakeholder engagement** - Water and electric utilities can work together to find effective ways to bring customers and other local stakeholders to the planning table. Many utilities are beginning to sharpen their focus on equity and inclusion and community engagement. Through stakeholder engagement, community benefits can be planned and identified. Electric distribution resource planning is an emerging utility activity, which in many cases requires significant local stakeholder input. This stakeholder input process could be leveraged by water and wastewater utilities. Water and electric utilities can coordinate in engaging and supporting small rural water and electric coops.

6.2 Policy and Regulatory Resilience Strategies

This section summarizes policy and regulatory resilience opportunities and strategies that were identified by workshop participants.

An important thing that policymakers, including municipalities, PUCs, governor's offices, or other community or state agencies, can do is establish resilience goals and convene energy-water **stakeholder working groups** to address threat scenarios, needs, and priorities.

Engagement with PUCs is important for overcoming barriers and realizing benefits of water-power resilience. PUCs can require utilities to hold stakeholder workshops as part of integrated resource planning or other planning or resilience dockets that include water and electric utilities as members of a working group. Where necessary, state legislatures can provide guidance around PUC statutory authority to encourage regulatory prioritization of water and energy collaboration. At the same time, water and wastewater utilities can become more actively engaged in docketed PUC proceedings on electricity issues that affect them, such as utility rate

[1] Non-wires solutions are non-traditional alternatives to traditional electric utility poles and wires solutions to meeting an electric system need. Non-wires solutions typically include energy storage, demand response, and distributed generation.

cases, planning proceedings, and demand response and interconnection-related dockets. The National Association of Regulatory Utility Commissions (NARUC) can be engaged as a means to explore and address pressing regulatory needs and opportunities.

PUCs can also consider **regulatory incentives** for water-power coordination for resilience, including favorable ratemaking treatment for integrated and proactive investments that minimize the impact of disasters across sectors and customer classes. PUCs can work with utilities to determine how cross-sectoral benefits will be determined and costs allocated for integrated resilience investments. PUCs can also use **performance-based regulation** (PBR) to build in energy efficiency targets specific to water utilities in the same way that some state decarbonization goals target specific sectors. PBR targets can also include cross-sector carbon reduction and/or resilience targets that encourage cross-sector collaboration.

Water regulators or municipal boards can consider revenue **decoupling mechanisms** for water utilities to decouple revenues from sales to incentivize water utilities to implement water conservation. Decoupling has effectively been used with electric utilities to remove disincentives to pursuing energy conservation.[1]

State and federal policymakers can proactively develop a clear path to **no-cost audits and assessments** for water and energy conservation, flexible demand potential, and renewable energy tied to financing mechanisms and grant funding. The Massachusetts Gap Funding program instituted by the Massachusetts Department of Environmental Protection is a successful model to follow.[2]

State policymakers can institute requirements or incentives for water and wastewater utilities to **track and report energy use**. Funding or support programs can be considered to help buy and implement water and energy metering and communications systems and regulators can encourage or require appropriate data sharing and safeguards.

6.3 Summary

Workshop participants identified operations, planning, and policy/regulatory strategies that support water and power system coordination and resilience. Strategies include identifying champions at each utility, bringing plant operators together to network and socialize, sharing capital improvements plans, and co-locating or sharing equipment. Another strategy is planning together for climate change and extreme weather. Regulatory strategies include forming cross-sector working groups to perform preparedness activities, implementing revenue decoupling to promote conservations, requiring energy use tracking and reporting, and making available energy audits and grant funding.

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[1] For more on decoupling: http://www.raponline.org/wp-content/uploads/2016/11/rap-revenue-regulation-decoupling-guide-second-printing-2016-november.pdf

[2] https://www.mass.gov/doc/massachusetts-return-on-investment-a-gap-funding-model-for-success/download

7.0 Federal-Level Support and Research Opportunities

Workshop participants were asked to identify specific federal-level research or other support activities that would advance water and power system integration and resilience. Recommendations include the following:

- Implement a national-level initiative to develop a **national roadmap** for water energy resilience.
- Establish a federal **department of water** to host data and information, collect and distribute water-power resilience examples and best practices, and foster new ideas.
- Continue to **facilitate conversations and collaborations**.
- Support **technology research and development** on the following:
  - Gasification of wastewater sludge and its efficiency, application, and destruction potential of perfluoroalkyl and polyfluoroalkyl substances (PFAS)
  - Wastewater as a heat sink/source similar to geothermal
  - Tradeoffs between energy management and water quality and impacts of energy management on water transients
  - Packaging a solar photovoltaic (PV)/battery solution for small treatment facilities
  - Wastewater plants as epicenter of microgrids
  - Alternative feedstocks, such as agricultural wastes, to anaerobic digestion as an energy source and impacts on the grid
  - Guidance on pressure management in water distribution systems to minimize energy use while achieving water needs.
- Support **policy and economics research** on the following:
  - Assessing financial environmental risks to water and electric utilities and identifying options for risk pooling and other risk mitigation strategies
  - Quantifying the costs and co-benefits of joint/shared water and power resilience projects
  - Using performance-based ratemaking for resilience
  - Removing barriers to water and wastewater utilities interconnecting distributed generation to the electric system
  - Creating standard methods for assessing energy efficiency potential of water and wastewater efficiency projects.

Workshop participants suggested that a good role for the federal government is to develop **tools for modeling climate change and extreme events** that utilities can use. It was noted that many water utilities use state-developed intensity-duration-frequency (IDF) rainfall curves to plan stormwater and water treatment systems, but most IDF curves are based on historical weather, not climate projections, and improvements are needed. It was recommended that a federal initiative could support updating climate change informed IDF curves. A federal initiative could also develop **severe event damage and impact prediction models** to help guide and justify prudent investment in hardening and resilience.

Workshop participants identified the need for **federal-level funding and project support actions**. These include providing federal infrastructure dollars to support water-power resilience. Grants (or stimulus funds) could be made contingent upon the use of energy efficient and smart equipment for water and wastewater utilities, data sharing, and/or cross-sector engagement and planning.

Finally, a federal initiative to help modernize utilities with **power and water flow metering** to support energy intensity trending was also identified as a readily accessible and highly beneficial activity.

8.0 Conclusions

Opportunities exist at the community, utility, state, and federal level to move beyond existing silos and consider interdependencies, cascading impacts, and risks that face water and electric utilities and take action to realize the benefits of energy and water systems collaboration and coordination. The frequency and magnitude of hazards and extreme events are increasing. Water and power utilities are both subject to much of the same hazards and similar risk. As was seen during the February 2021 Texas event, risks can cascade from one sector to the next. Advanced coordination, integrated planning, and co-developed resilience strategies can help.

Innovation, good ideas, and solutions can also cascade from one organization or place to others. This workshop brought together people from diverse backgrounds and perspectives who shared experiences, ideas, stories, and hope for more resilient and integrated communities. Water and electricity are critical to our well-being. Interdependent systems are experiencing unprecedented physical and cyber challenges. Coordination and joint solutions have the potential to reduce costs and improve outcomes. This workshop was a step in the right direction. Action is needed and time is of the essence. Future work includes engaging utilities, regulators, researchers, consultants, and policymakers at all scales to develop solutions and move from talking to exploring to implementation and action.

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Appendix A – Workshop Agenda

Pacific Northwest NATIONAL LABORATORY

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U.S. DEPARTMENT OF ENERGY

Water and power systems – Coordination and planning for resilience

Virtual Workshop April 13-14, 2021 - Registration Link

Tuesday, April 13, 2021	
Noon - 12:25 EDT/ 9:00 - 9:25 PDT	**Welcome Opening Session** • Welcome – Alejandro Moreno, DOE • Remarks – Steve Clark, EPA • Objectives and agenda – Juliet Homer, PNNL • Check-in activity – Jessie Ciulla, Rocky Mountain Institute (RMI)
12:25 - 12:45 EDT/ 9:25 – 9:45 PDT	**Integrated Water-Power Resilience Project Motivation** • Introduction – Steve Conrad, Colorado State University • Presentation and Q&A - Jennie Rice, PNNL
12:45 - 1:25 EDT/ 9:45 - 10:25 PDT	**Working Session - Assessing the Landscape** • Session Lead - Juliet Homer, PNNL
1:25 - 2:10 EDT/ 10:25 - 11:10 PDT	**Keynote Address: Water and Power Interdependencies and Resilience** • Introduction – Juliet Homer, PNNL • Presentation and Q&A - Michael Webber, Engie and University of Texas at Austin
2:10 - 2:25 EDT/ 11:10 - 11:25 PDT	**BREAK**
2:25 - 3:10 EDT/ 11:25 - 12:10 PDT	**Financial Risk Management** • Introduction – Steve Conrad, Colorado State University • Presentation and Q&A - Greg Characklis, University of North Carolina
3:10 - 3:50 EDT/ 12:10 - 12:50 PDT	**Working Session – Areas to Advance** • Session Lead- Jessie Ciulla, RMI
3:50 - 4:00 EDT/ 12:50 - 1:00 PDT	**Optional Homework Assignment and Check-Out** • Session Lead – Juliet Homer, PNNL

Wednesday, April 14, 2021	
12:00 - 12:20 EDT/ 9:00 – 9:20 PDT	**Day 2 Opening Session** • Agenda, objectives, and overview of Day 2 – Juliet Homer, PNNL • Check-in activity – Steve Conrad, CSU
12:20 - 1:20 EDT/ 9:20 – 10:20 PDT	**Keynote Panel - Solutions** • Ted Cooke, Central Arizona Project • Bipin Pathak, DC Water • Wayne Deczynski, Constellation/PEPCO • Michael DiBara, Massachusetts Department of Environmental Protection
1:20 - 2:20 EDT/ 10:20 – 11:20 PDT	**Working Session – Digging Deeper** • Session Lead – Jessie Ciulla, RMI
2:20 - 2:35 EDT/ 11:20 – 11:35 PDT	**BREAK**
2:35 - 3:20 EDT/ 11:35 – 12:20 PDT	**Participant homework present-outs** • Session Lead – Juliet Homer, PNNL
3:20 - 3:55 EDT/ 12:20 – 12:55 PDT	**Research and commitments activity** • Session Lead – Steve Conrad, CSU
3:55 - 4:00 EDT/ 12:55 – 1:00 PDT	**Next steps and wrap-up exercise** • Next steps – Juliet Homer, PNNL • Check-out activity – Jessie Ciulla, RMI

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