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Joint Modeling of Water and Energy for Resilience and Flexibility

January 2026

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U.S. DEPARTMENT of ENERGY

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Title: Joint modeling of water and energy for resilience and flexibility

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Focal Area: This white paper addresses the intersection of energy and potable water resources , considering energy-for-water through joint systems modeling. Specifically, we focus on the opportunities to promote joint resilience in water and power systems through coupled modeling to inform decision-makers.

Existing Challenge:

Managing interconnected energy and water systems is a persistent challenge as design and planning tools for studying the operation and interaction between the two systems are lacking. The lack of integrated energy and water models for these systems is a significant limiting factor for decision makers in their ability to manage water systems as a flexible load and to recover post disaster. While each utility has tools available to model their systems, limited technology exists to anticipate and prepare for the operations and interactions with the other. Power system models that include flexible water system loads often represent them as single nodes or highly simplified networks, failing to capture the full range of water system components. This simplification limits the models' usefulness for combined power-water system optimization studies (Shmaya and Ostfeld, 2024). Conversely, research on configuring water systems to provide demand response and flexibility to power system operations, often rely on simplified representations of complex, dynamic energy pricing mechanisms making them less efficient and realistic (Sowby, 2021). Energy prices vary by energy source mix, time of day, and grid consumption, all of which are often omitted in these simplified models.

Winter Storm Uri in Texas (2021) highlighted the particular vulnerability of water systems to sustained power outages with up to 14 million residents under boil water orders (Glazer *et al.*, 2021). These potable water outages occurred across the state with smaller water systems sustaining significantly longer outages than larger water systems (Glazer *et al.*, 2021). Similarly, water system resilience can be tested through hurricanes with analysis of Hurricanes Katrina and Rita highlighting the need for energy system integration in resilience assessments (Matthews, 2016). Enhanced joint modeling of water and energy infrastructure can identify the benefits and opportunities of joint management in disaster scenarios, potentially reducing recovery time, especially in smaller communities.

Electric power utilities have a wide range of approaches available to maintain grid reliability, such as energy storage, smart grid technology, transmission system expansions, and demand-side management. The lack of a consistent technological approach to coordinate energy and water systems results in minimal capacity for optimization and support between these interconnected systems. For example, water treatment facilities often include back-up generators installed as a means of achieving resilience to grid perturbations. Water systems have other components and features that could be leveraged to provide demand side flexibility (Rao, Bolorinos, *et al.*, 2024). Large pumping loads within distribution systems could be deferred to a time when the grid is less stressed (reduction of peak loads) or when electricity prices are lower. Alternatively, in cases where the power grid is in a surplus, pumping loads could be turned on to alleviate overproduction. Without a joint model, these generators are not optimized to be coordinated with grid operations. Under certain operational conditions, a utility could feasibly dispatch a water system's backup generators to remove large water system loads from the power grid, especially if demand side reduction is required to reduce the threat of rolling blackout or brownouts.

Near-Term Opportunity:

As water resilience efforts turn to alternative strategies such as membrane filtration technologies, such as desalination, or water reuse, these energy intensive processes increase the opportunities for flexibility in joint modeling ventures (Rao, Atia, *et al.*, 2024). Incorporation of diverse and non-traditional water supply strategies to enable switching between sources, supply/demand curtailment, and flexible pumping are potential levers for co-optimization of systems (Zohrabian *et al.*, 2021). However, any flexible dispatch of these assets needs to be aligned with the provision of safe, potable water. Delaying operation of these units or shifting the length of time storage tanks are full could produce water quality issues.

Addressing these concerns requires the development of integrated models that bridge the traditional silos between water and power systems to develop a unified framework capable of revealing the interdependencies between the two sectors. Through advanced modeling techniques, this holistic energy–water framework can be applied both spatially, across both small and large regional systems, and temporally, across timescales from real-time operations to long-term planning. With such a framework, utilities can better balance multiple objectives and constraints, optimize operations, and strengthen disaster preparedness and response. By capturing key power system variables, such as load and pricing, integrated models could inform water system operations such as water treatment plant scheduling and pumping on sub-daily scales, while ensuring that consumer water demands are met and allowing utilities to meet budgetary constraints.

Historical data and model outputs from both systems could also support near-term forecasts, for instance on weekly scales, to inform proactive operational decisions. Such forecasts could help maintain reliability by minimizing the load on power systems, ensuring tanks remain sufficiently full for emergency response and supply, and maintaining water quality by preventing stagnation. For longer time horizons, integrated models could be used to evaluate system expansion scenarios, such as adding new energy or water sources, expanding water treatment capacity, or accommodating large industrial customers (e.g., data centers), and subsequently assessing their combined impact on water and power systems.

Beyond routine operations, integrated models would provide significant value for coordinated response, recovery, and rehabilitation efforts during emergencies and disasters, critical aspects of system resiliency. For example, they could help to optimize trade-offs of competing objectives such as de-energizing power lines at risk during wildfires while keeping pumps online to supply adequate water for fire suppression. Similarly, in the case of combined power-water outages, integrated modeling could guide the sequence of power and water restoration across cities, ensuring that power is restored first to locations where water service has resumed and avoiding prioritization of unoccupied buildings.

Realizing these opportunities will require close collaboration among power and water utilities across communities of various sizes to share data, exchange operating practices, and co-develop strategies for real-time operations and planning. National laboratories, universities, and utility/industry collaborations could lead the development of advanced modeling and optimization tools needed to reflect utilities' diverse objectives and integrate best practices for disaster management and resilience.

Success Measure:

Success can be evaluated by tracking improvements across the following areas:

1. ***Grid reliability and flexibility***: modeling of water systems and increase in number of MOUs or mutual aid agreements between water and power utilities. Reduced outages of water treatment facilities over time.
2. ***Water system operations and efficiency***: increased visibility into power system loads for operation optimization to lower energy costs. Improved water quality during emergencies through modeled coordination, especially during emergencies.
3. ***Disaster response and recovery***: streamlined coordination and support through variable loads between utilities during outages. Improved identification of critical facilities and modeled action responses to reduce downtime to high priority customers.

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