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	Water Microgrids
	A Primer for Facility Managers
	December 2021
	C Cejudo K Stoughton A Piazza P Gunderson J Yoon R Ekre B Pamintuan
	U.S. DEPARTMENT OF Prepared for the U.S. Department of Energy under Contract DE-AC05-76RL01830

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Water Microgrids

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Pacific Northwest National Laboratory Richland, Washington 99354

Acronyms and Abbreviations

EPA	Environmental Protection Agency
FEMP	Federal Energy Management Program
TRN	Technical Resilience Navigator

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1.0 Introduction

A water microgrid is similar in concept to an <u>energy microgrid</u>, which the U.S. Department of Energy defines as "a local energy grid with control capability, which means it can disconnect from the traditional grid and operate autonomously." Similarly, a <u>water microgrid</u> is a local water system that supplies, treats, and distributes water, with the primary objective to meet mission <u>critical water demands</u> during a disruption of the primary supply. A water microgrid has the capability to operate independently of an existing primary water system and includes a layer of sensing capability that provides the necessary monitoring and controls to operate the water microgrid (Figure 1, Figure 4).





A water microgrid may offer a viable solution for a site to address resilience gaps identified through the resilience planning process. For example, a site may not have adequate and redundant water supply to meet mission critical demands with vulnerabilities in the operating systems. A water microgrid provides the ability to <u>island</u> the water system from the <u>primary</u> water supply to satisfy water demand requirements throughout an outage or disruption.

1.1 Required Characteristics of a Water Microgrid

The main function of a water microgrid is to provide redundant on-site water for critical demands during a disruption. Critical water demands are required to enable the site's mission critical functions, operations, and activities. A water microgrid has the capability to treat the on-site water supply (primary and/or redundant) to appropriate quality standards and distribute it for consumption. For a water microgrid to function properly, it must have the required characteristics of being self-sufficient, reliable, and automated (Figure 2).



Figure 2. Water Microgrid Characteristics

1.2 Scale of the System

Water microgrids can function at differing scales, ranging from simple to complex, which are highly dependent on local conditions such as water uses, site size, and potential natural hazards that could impact the site. The mission critical water demands and access to on-site water sources will drive the water microgrid system scale and infrastructure options. There are two basic concepts of a water microgrid: self-contained and microgrid islands (Figure 3). A self-contained water microgrid has on-site water sources, treatment, distribution, and wastewater treatment, which are independent from the primary provider. Conversely, a microgrid island has an agreement with the off-site primary provider to operate the site's water microgrid independently if needed via valves and controls to enable this independent operation under close coordination with the off-site utilities. In both cases, the site will have on-site redundant water supply.



Figure 3. Water Microgrid Scales

1.3 Water-Energy-Climate Nexus

Water microgrids require energy to operate and are therefore at the intersection between water, energy, and climate. Water networks and treatment use about 10% to 15% of national power production.¹ Energy is necessary for pumping, treating, and distributing water. Climate change imposes additional pressures on water systems, including deeper and more frequent droughts, highly variable precipitation patterns, and rising temperatures. These climate change impacts lead to increased competition of water demands, and more frequent – and more severe – weather events that threaten sanitary supply and critical infrastructure.²



Figure 4. Water-Energy-Climate Nexus

Implementing a water microgrid shifts energy use of pumping, treating, and distributing water from the local utility to the site. Increased electricity demand due to water microgrid infrastructure will likely not be significant, but sites should consider the energy use intensity of different water supply, treatment, and distribution options, particularly if systems need to function on backup power.

¹ The International Water Association. 2016. *Water Utility Pathways in a Circular Economy*. London, UK. <u>https://www.iwa-network.org/wp-content/uploads/2016/07/IWA_Circular_Economy_screen-1.pdf</u> ² U.S. Department of Energy. 2014. *The Water-Energy Nexus: Challenges and Opportunities*. Washington, D.C. <u>https://www.energy.gov/sites/default/files/2014/07/f17/Water%20Energy%20Nexus%20Full%20Report%2</u> <u>0July%202014.pdf</u> Additionally, decarbonization is an increasing priority for federal facilities.¹ Sites should consider how water microgrid components may affect plans to reduce energy use or achieve net zero carbon. On-site water sourcing and treatment may be more or less energy intensive than existing methods, but does shift the burden and cost to the site. Water scarcity due to climate change means water may have to be pumped further distances or from deeper in the groundwater table, or from saltwater or brackish water, which require energy-intensive desalination process to remove salts and minerals.^{2,3,4} Section 2.5 provides an overview of reliable power systems required for a water microgrid.

https://www.energy.gov/sites/default/files/2014/07/f17/Water%20Energy%20Nexus%20Full%20Report%2 0July%202014.pdf

¹ The White House. 2021. *Fact Sheet: President Biden Sets 2030 Greenhouse Gas Pollution Reduction Target Aimed at Creating Good-Paying Union Jobs and Securing U.S. Leadership on Clean Energy Technologies.* Washington, D.C.

² The Pacific Institute. 2021. *The Future of California's Water-Energy-Climate Nexus*. Seattle, WA. <u>https://pacinst.org/wp-content/uploads/2021/09/Water-Energy-Report_Sept-2021.pdf</u>

³ San Diego County Water Authority. *Seawater Desalination*. <u>https://www.sdcwa.org/your-water/local-water-supplies/seawater-desalination/</u>

⁴ Sisson, P. 2021. "Facing Severe Droughts, Developers Seek to Reuse the Water They Have." *The New York Times*, 8/3/2021. <u>https://www.nytimes.com/2021/08/03/business/drought-water-reuse-development.html</u>

2.0 Water Microgrid Technical Components

A water microgrid is composed of supply, storage, treatment, distribution, backup power, and automated controls. Water microgrids collect appropriate sources of alternative water, treat it, and distribute it for use in secondary applications, or return it to the environment. Figure 5 provides an example illustrating the major components of water microgrid island.



Figure 5. Example Components of a Water Microgrid Island

ී 2.1 Supply

Water microgrids commonly have on-site independent water supply to provide reliable backup water to mission critical demands in time of disruption. There are two general types of water supply:

- <u>Freshwater</u>: Surface water and groundwater found naturally in the environment, possibly developed to improve volume or availability. Examples include underground aquifers; perennial or ephemeral springs, creeks, and streams; rivers and lakes; and reservoirs.
- <u>Alternative water</u>: Water supplied from non-freshwater sources, typically diverted from waste streams or captured, then treated and re-used. Examples include harvested rainwater from building roofs and other hard surfaces, diverted storm water, reclaimed wastewater,

greywater, captured condensate, atmospheric water generation, water purification concentrate, foundation water, blowdown water, and process reuse.

Both freshwater and alternative water can be treated to either potable or non-potable standards. Potable water is tested, permitted, and approved for human consumption. Non-potable water is not approved for human consumption, even with some degree of treatment to reduce particulates, microorganisms, and impurities. Section 2.3 provides more information on treatment as a component in water microgrids.



Water storage systems are critical components of a reliable water microgrid at any scale because they play a significant role in ensuring adequate water supply throughout outage durations (of varying critical time periods) to preserve mission capability. Similar to batteries in an electric microgrid, on-site water storage tanks can supplement or replace the primary water supplies when they are partially or completely disrupted. And in the case of water supply from on-site freshwater or alternative water, storage tanks may be helpful in buying time for those redundant supplies to come online.

Water microgrids may include water storage at the supply, before treatment, as well as posttreatment before distribution. There are several options available for water storage. Atmospheric tanks store water at ambient pressure and rely on booster pumps or elevated towers using gravity's potential energy to provide the water pressure for use. Hydropneumatic tanks pressurize the water with an air chamber, where a bladder or diaphragm compresses the air as water is stored in the tank. This compression provides the delivered water pressure as the water is withdrawn. Underground tanks provide storage below grade and rely on booster pumps to lift and pressurize the water for distribution.



2.3 Treatment

Water microgrids have the ability to treat water supply to either potable or non-potable quality, depending on the application requirements. Potable water is tested, permitted, and approved for human consumption directly and thus carries a higher quality burden. Water that is not of sufficient quality for human consumption is considered non-potable. Each type carries unique considerations for the water microgrid design and operation. A water microgrid must match mission critical water demand and consider the most appropriate water quality by end-use type and minimum treatment standards.

Basic water treatment elements include collection, screening of large particles, settling of sediments, filtration of smaller particles, and disinfection to kill harmful pathogens. A variety of available technologies can serve these functions. These treatment components, both engineered and off-the-shelf, should be carefully designed based on the size of the system and specific requirements of the application. If the water microgrid is serving potable demands, the treatment system should ensure it is meeting the requirements of the Safe Drinking Water Act.

2.4 Distribution

The water distribution system is the circulatory system of the water microgrid. Water supply is conveyed through a series of pipelines, valves, and pumps. The system carries the treated water through trunk mains, distribution mains, and domestic lines sized for proper velocity based on flow volume to distribute water to individual buildings. A water microgrid's distribution system should be well maintained and tested at regular intervals to ensure that the lines have minimal losses. Designs should prioritize energy and water efficiency to minimize wear and tear on components.

4→ 2.5 Backup Power

A critical component of water microgrids is backup power. Many of the water microgrid components, including treatment, pumping, and mission critical demand isolation, require energy to function and may be energy intensive. For the water microgrid to be self-sufficient, it must include a localized independent power source to be fully islandable from the primary offsite water supply and main power grid. Some hazards will threaten water and energy supplies simultaneously. For the water microgrid to be resilient to these threats, it must include a reliable backup power source in case of a main power grid failure; otherwise, water microgrid infrastructure becomes incapable of fully functioning. The facility's reliable backup power must be sized to accommodate the water microgrid energy demands, in either a combined or dedicated energy microgrid system or a dedicated generator. In addition, the design of the backup power system should take into account any natural hazards that may cause an outage of both energy systems and water and be designed to withstand those hazards.

Distributed energy resources, such as an energy microgrid or standalone power generation, can diversify energy supply and provide redundancy and resiliency to the energy system that supports the water microgrid.



2.6 Automated Controls

Water microgrids have an overarching automation infrastructure providing real-time system monitoring that enables and disables system components during an outage to meet mission critical water demands. This includes hardware, software, and logic protocols to carry out predetermined operation regimes through fully or semi-autonomous operations during islanding from, and subsequent reconnection to, off-site primary water supply networks. Data acquisition and communications elements of water microgrids may also provide early warning of natural disasters to contain damage.¹ To do so, valves and sensors are dispersed throughout a standard distribution system to isolate supply paths in the event of infrastructure failures, in accordance with the design of the distribution lines. In addition, distributed sensing/control technologies monitor the system with real-time flow meters, pressure gauges, and water quality monitoring equipment deployed throughout the network to gather vital data for the water microgrid operation. With the proper control logic, the master controller coordinates through an

¹ Adeyeye K, A Bairi, S Emmitt, and K Hyde. 2018. "Socially-integrated resilience in building-level water networks using smart microgrid+ net." *Procedia Engineering* 212:39-46.

interface with these valves and sensors, and then shuts off non-critical mains such that mission critical water demands can be isolated.

Sites include water infrastructure that distributes water to end-uses, though they may not include advanced controls or be configured to isolate critical water demands. Individual assessment of a particular site is required to establish what additional infrastructure is needed to provide a complete automated control infrastructure that meets the required characteristics of a water microgrid, especially at smaller distribution pipes or locations.

3.0 Key Considerations

There are many factors to consider when implementing water microgrids, which will be vital to the successful deployment of the system. These include the following:

Operation and maintenance: Water microgrids have a complex set of system components that require proper operation and maintenance by system operators. These operators will need the appropriate training and the system will require regular testing to ensure it is operating as designed.

Current system conditions: Existing water infrastructure such as water distribution, storage, and treatment systems should be evaluated to determine its viability as part of a water microgrid. Hydraulic modeling can be used to examine these systems, simulating pressure zones, changing conditions, and revealing weak points within the system. The result of the hydraulic model can provide essential information to properly design the microgrid components, controllers, and supporting equipment.

Regulatory approvals: Water supplied and treated on-site will likely require regulatory approvals at the local, state, and federal levels. Careful consideration is needed ensure that the necessary approvals are initiated at the beginning of the process and maintained through the operation.

Utility restoration agreements: Some sites may consider working with their local water utility to have a restoration agreement in place that gives them high priority for regaining water supply after an emergency disruption. This can help to ensure water supply is restored to normal operation as quickly as possible. For these types of agreements, water treatment systems and standards must be defined in coordination with utilities to ensure water quality and sanitation are maintained through resumption of service.

Curtailment plans: A site considering a water microgrid should have a curtailment plan in place that provides specific procedures on curtailing non-critical water demands during time of disruption. A curtailment plan specifies the applications that are suspended and designates the roles and responsibilities of installation personnel responsible for executing the plan.

Emergency planning: Along with curtailment planning, emergency planning is an important function at an installation with a water microgrid. An emergency plan provides the installation with the procedures and personnel that are in place to respond to a water emergency. A comprehensive emergency plan includes identification of essential functions, roles and responsibilities, delegation of authority, and testing and training program. Emergency drills should be conducted regularly to ensure that personnel are well trained to respond to an event.

Community outreach: Communicating with the site's personnel is important to inform them of the water microgrid and its functions.

4.0 Technical Resources

The following are technical resources that may prove useful when considering the implementation of a water microgrid:

4.1 Federal Energy Management Program Technical Resources

Federal Energy Management Program (FEMP) Water Management: Learn about a variety of technical topics and gain access to resources and tools on federal water management including comprehensive evaluations, water efficiency, and alternative water. Specific FEMP water webpages include:

- <u>Comprehensive Evaluation Resources and Tools</u>
- Water Metering
- Water Efficiency Best Management Practices
- <u>Alternative Water Resources</u>
- Water Treatment Overview

FEMP Technical Resilience Navigator (TRN): Access the TRN, a risk-informed resilience planning tool, which provides is a systematic approach to identifying energy and water resiliency gaps and developing and prioritizing solutions that reduce risk. The TRN enables organizations to be proactive in identifying and addressing vulnerabilities to their critical energy and water infrastructure to reduce outage impacts and support continuous mission operations.

FEMP Cybersecurity: Access information and tools to learn about cybersecurity of federal facilities and how to facilitate the implementation of Executive Order 13800, *Strengthening the Cybersecurity of Federal Networks and Critical Infrastructure*.

4.2 Other Resources

Environmental Protection Agency (EPA) <u>Water Sense at Work</u>: Explore a compilation of water-efficiency best management practices, aimed at helping commercial and institutional facility owners and managers understand and better manage their water use.

<u>EPA Drinking Water Resilience</u>: Explore a variety of topics around water resilience, including water emergency planning and community relations.

Whole Building Design Guide Training Courses: Explore this site's comprehensive trainings targeted at specific topics. Use the search function to find resilience and water-related trainings.

5.0 Glossary

alternative water: Supplied from sustainable sources and is NOT freshwater. Alternative water examples include harvested rainwater, reclaimed wastewater, and process reuse.

critical water demand: The water end-uses required to enable the installation's critical operations.

energy microgrid: A local energy grid with control capability, which means it can disconnect from the traditional grid and operate autonomously.

freshwater: Water supplied from surface or groundwater sources that has a total dissolved solids concentration of less than 1,000 milligrams per liter (1,000 ppm)¹. Surface water includes reservoirs, lakes, rivers, streams, and wetlands. Groundwater is found underground in cracks and spaces in soil and rock.

island or islandable: The ability to disconnect and operate independently from a local utility.

primary water supply: Main water supply for an installation that provides water necessary to maintain all water requirements. Primary water supply may be produced off-site or on-site.

redundant water supply: A secondary water supply that provides backup water to support specific water requirements. For the purposes of a water microgrid, redundant water supply is on-site and serves critical water demand.

water microgrid: A local water system that supplies, treats, and distributes water, with the capability to operate independently of an existing primary water system, and includes a layer of sensing capability that provides the necessary monitoring and controls to operate the water microgrid.

¹ Freshwater definition accessed December 2021 from the U.S. Geological Service. *Saline Water and Salinity*: <u>https://www.usgs.gov/special-topics/water-science-school/science/saline-water-and-salinity</u>

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