Energy-Positive Water Resource Recovery Workshop Report

Executive Summary

April 28–29, 2015 • Arlington, Virginia

Transitioning from Water Treatment to Resource Recovery

The aging U.S. water infrastructure will require an investment of about $600 billion over the next 20 years if it is to continue reliably transporting and treating wastewater and delivering clean drinking water.[1] This massive investment marks an opportunity to apply new knowledge and technology and rethink the design and functionality of the water management infrastructure. Building on industry's pioneering efforts to reduce energy usage and increase the recovery of valuable resources from wastewater, the United States can seize this opportunity to create a world-class water infrastructure while reducing the costs to run it. Aside from the critical financial benefits, society would benefit from cleaner water, reduced landfilling, increased resilience to climate change, and more sustainable utilization of resources. In pursuit of this vision, stakeholders have outlined potential federal activities to support industry in advancing the state of the art for water resource recovery facilities (WRRFs) while reducing or even eliminating the nearly 1% of U.S. electricity currently used to collect, transport, and treat wastewater.[2]

Water Resource Recovery Facility

The term "water resource recovery facility" (WRRF) is used throughout this document at the behest of the water treatment community to reflect a shift in self-identification; it replaces the term "wastewater treatment plant."

The National Science Foundation (NSF), the U.S. Environmental Protection Agency (EPA), and the U.S. Department of Energy (DOE) jointly hosted the *Energy-Positive Water Resource Recovery* (EPWRR) *Workshop* to envision a transition from the wastewater treatment facilities of today to a new generation of WRRFs nationwide and identify specific opportunities to stimulate and support this transition. The U.S. Department of Agriculture (USDA) and the Department of the Army also participated in this workshop at the NSF headquarters in Arlington, Virginia, on April 28–29, 2015. Participants provided information to federal stakeholders about ongoing industry efforts[3] and how federal activities could best amplify and help realize the industry vision for the *WRRF of the Future*.

WRRF of the Future

As used in this document, "WRRF of the Future" refers to the workshop participants' vision of the facilities that are expected to recover water and other resources by 2035 or before.

Envisioning the Utility of the Future

As envisioned by the workshop participants, the *WRRF of the Future* should continue to assign top priority to wastewater treatment for the protection of human health and the environment but should also expand its slate of services and products in support of healthy, economically vibrant communities.[4] For example, the future WRRF could effectively manage more diverse waste streams, generate fuel, produce water and fertilizer, and help communities recover other valuable resources. To achieve this

[1] U.S. Environmental Protection Agency. "Water Infrastructure and Resiliency Finance Center." Accessed July 27, 2015. http://water.epa.gov/infrastructure/waterfinancecenter.cfm.

[2] 30.2 billion kilowatt hours: Pabi, B., A. Amaranth, R. Goldstein, and L. Reekie. *Electricity Use and Management in the Municipal Water Supply and Wastewater Industries*. Electric Power Research Institute and Water Research Foundation, 2013. www.waterrf.org/PublicReportLibrary/4454.pdf.

[3] For more information, please see: National Association of Clean Water Agencies (NACWA), Water Environment Federation, and Water Environment Research Foundation. *Water Resource Utility of the Future 2015,* Executive Summary. Washington, DC: NACWA, 2015. www.nacwa.org/images/stories/public/2015-07-10wruotf-exs.pdf.

[4] This section identifies the idealized characteristics of a future WRRF.

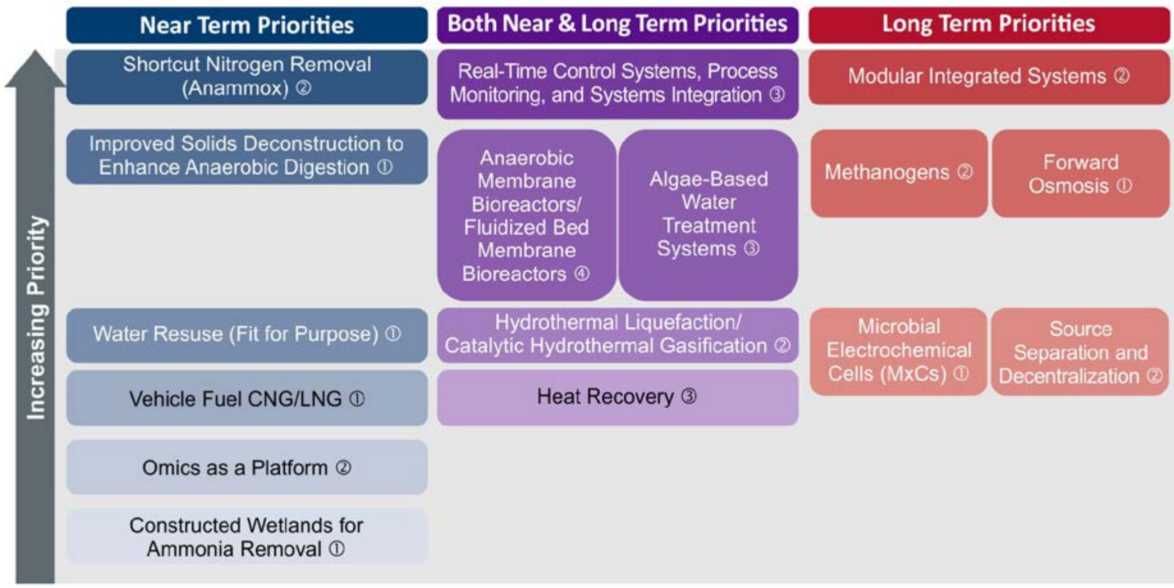
vision, the ideal *WRRF of the Future* should use and recover resources efficiently, coordinate with utilities and other community services, engage customers and the public in new ways, and deploy smart technology and systems.

- **Resource Efficiency and Recovery—**Beyond merely treating wastewater, *WRRFs of the Future* should emphasize the recovery of diverse resources, including water, nutrients, and energy. WRRF systems should effectively and economically safeguard public health and the environment while producing water, power, and products to meet community needs and standards. Success in recovering nutrients, minimizing energy use, and reducing emissions would ultimately transform these facilities from necessary public systems into prized community assets.
- **Integration with Other Utilities—**To meet the growing demand for clean water, WRRFs should continue to treat variable wastewater streams to high standards. *In addition,* WRRFs could produce electricity, lesser water grades, and saleable products that efficiently and economically serve a mix of shifting local priorities. WRRFs could optimize the recovery and tailored treatment of local wastewater and other waste streams to meet the specialized needs of power plants, manufacturing plants, agricultural systems, local governments, health agencies, and other institutions.
- **Engaged and Informed Communities—**To shift current community perceptions of wastewater treatment toward positive associations with resource recovery, WRRFs should actively engage with their customers, elected officials, industry, and the public. Initial outreach efforts should expand public understanding of sustainable water resources and awareness of WRRF goals. Communities may advocate for WRRFs that reduce carbon emissions, support green infrastructure development, and drive economic growth. Customers can contribute to the success of the *WRRFs of the Future* by better managing waste at the source. Ultimately, effective customer engagement could improve public infrastructure and increase local support for net-zero-water buildings and other integrated solutions to water, energy, and food supplies.
- **Smart Systems—**Future WRRFs could use a host of sensors, software, and innovative equipment to track performance and inform plant operations. Smart systems would enable facilities to actively monitor the volume and content of incoming waste streams, supervise plant operations, and verify the safety or quality of outputs to enable real-time adjustments in processing parameters. These facilities could potentially scale up or down as needed to maintain economical operations under shifting conditions. Advanced technologies could support facility integration beyond traditional plant boundaries, e.g., enabling coordination with the local power company to facilitate demand-response activities.

Research Opportunities

Workshop participants prioritized 16 areas in which concerted research is likely to deliver significant progress. Six of these topic areas are for the near term, five are long term, and five span both the near and long term (see Figure ES-1 and Table ES-1). Research, development, and demonstration in these areas could further catalyze industry investment in building the *WRRF of the Future*.

Aeration represents the largest energy-consuming operation at a WRRF. Participants identified a number of research opportunities that could reduce or even eliminate the need for aeration. For example, shortcut nitrogen removal—anaerobic ammonium oxidation (anammox)—would eliminate the



①Research area prioritized by a single breakout group; ②Research area prioritized by two different breakout groups; ③Research area prioritized by three different breakout groups; ④Research area prioritized by all four breakout groups

Figure ES-1: Prioritized Research Opportunities

need to aerate during denitrification, and constructed wetlands might also be used to reduce aeration needs, though throughput remains a challenge in natural systems.

Sludge disposal is one of the largest expenses at WRRFs. Improved solids deconstruction would better break down the biomass, increasing the production of biogas and reducing the remaining digestate. Workshop participants similarly identified anaerobic membrane bioreactors and fluidized bed membrane bioreactors as technologies that could enhance anaerobic digestion (AD) and reduce the volume of sludge for disposal. Together, research on sludge and aeration could significantly reduce energy consumption, increase energy recovery, and minimize the costs of sludge disposal.

Deployment Challenges

In considering potential pathways toward the *WRRF of the Future*, workshop participants identified key challenges to be overcome. These challenges include regulatory, technical, social, and financial barriers.

While compliance with water treatment standards will remain the core mission of future facilities, this long-standing priority has promoted a risk-averse culture. As a result, many facilities today are disinclined to deploy and validate advanced resource recovery technologies that could generate economic value. Pioneering facilities are needed to scale up promising technologies, validate them, and help set the standards for safely integrating resource recovery into existing and future WRRFs.

Financing and social acceptance are pivotal issues in deploying these novel technologies. Financing poses a perpetual challenge for the research, development, demonstration, and deployment (RDD&D) of water resource recovery technology. Many WRRFs operate as regulated utilities in structures that leave little revenue for research or innovation. Without capital improvement budgets, these facilities necessarily focus on maintaining existing services instead of building for the future. A better understanding of environmental sustainability, including the social costs of water and carbon pollution,

Table ES-1: Research Priorities Identified by the Four Parallel Participant Breakout Groups*

Near-Term Priorities	Both Near- and Long-Term Priorities	Long-Term Priorities
1. **Shortcut nitrogen removal (anammox)** eliminates the need to aerate the sludge, sharply reducing energy use for denitrification. *(2 groups)*+ 2. **Improved solids deconstruction** makes nutrients more accessible in anaerobic digesters, increasing biogas production and reducing solids handling.‡ 3. **Water reuse** for targeted potable and non-potable applications could reduce stress on existing drinking water supplies and deliver energy benefits. 4. **Compressed natural gas /liquefied natural gas-**powered vehicles could utilize upgraded biogas. 5. **Using omics as a platform** (combining fields such as genomics, proteomics, transcriptomics, and metabolomics) could improve the biological processes associated with water treatment. *(2 groups)*+ 6. **Constructed wetlands** should be evaluated as an option for nutrient and pollutant remediation.+	1. **Real-time control systems, process monitoring, and systems integration** could provide greater insight into plant operations and improve the reliability and efficiency of WRRFs. *(3 groups)*+ 2. **Anaerobic membrane bioreactors and fluidized bed membrane bioreactors** could increase biogas production; reimagining anaerobic digestion as a continuous process (versus traditional batch flow) would give microbes more time to digest the sludge. *(4 groups)*‡ 3. **Algae-based systems** could leverage existing treatment technologies with photosynthetic resource recovery. *(3 groups)*+‡ 4. **Hydrothermal processes** could be used to convert biomass from wastewater into higher-value products. *(2 groups)*+ 5. **Heat recovery** from wastewater could be used to offset energy demands at the WRRF and throughout the sewage network. *(3 groups)* *Note: Research on topics in this category may need to begin in the near term and continue throughout the long term.*	1. **Modular integrated systems** reduce the physical and environmental footprint of wastewater treatment and enable rapid, distributed deployment. *(2 groups)* 2. **Methanogens** research could improve the resiliency, yields, and throughput of the microbes that digest organic material and produce methane. *(2 groups)*‡ 3. **Forward osmosis** could be used in bioreactors to recover energy and remove pollutants from wastewater streams. 4. **Microbial electrochemical cells** can be used to generate hydrogen, electricity, or higher-value biofuel and bioproduct precursors. 5. **Source separation and decentralization** linked to urban planning could enable systems tailored for specific feedstocks or purposes and reduce dependence on major infrastructure. *(2 groups)*

*Numbering within a time period indicates relative prioritization.
+Priority directly reduces need for aeration, the largest energy-consuming operation at a WRRF.
‡Priority directly reduces costs associated with sludge treatment and disposal, which are among the highest WRRF costs.
Other identified priorities indirectly address costs and energy needs in the operation of a WRRF.

would help justify funding for water resource recovery. Public awareness of the long-term benefits and reliability of these systems could also help attract financing and stimulate adoption of promising water resource recovery technologies.

Moving Forward

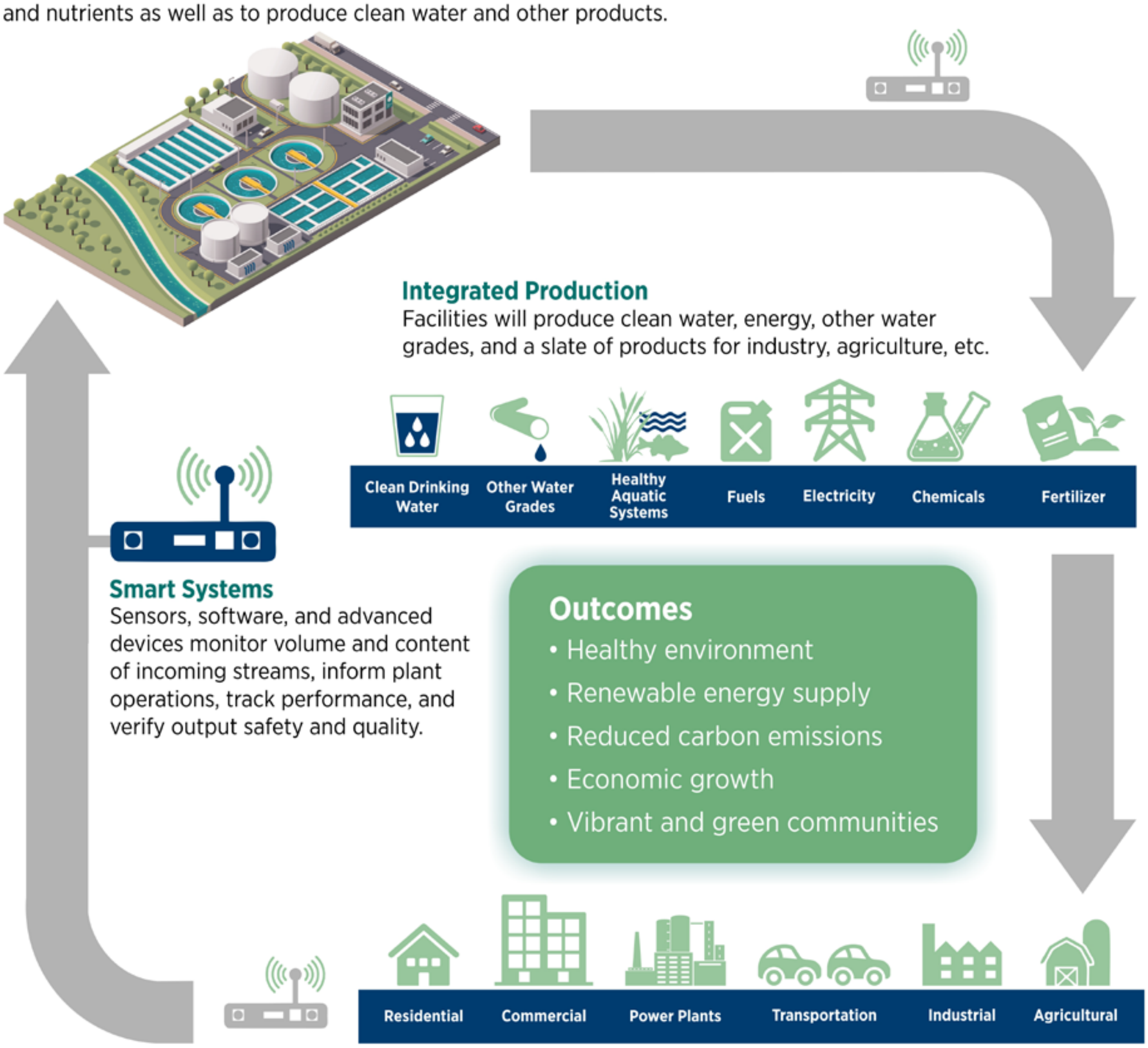
As water treatment facilities, pipes, and related infrastructure in cities around the country approach the end of their expected service life, a unique window of opportunity exists to replace the aging infrastructure with the *WRRF of the Future*—reducing stress on energy systems, decreasing air and water pollution, building resiliency, and driving local economic activity.

Water Resource Recovery Facility of the Future

Energy Positive and Beyond: The Vision for Transforming Wastewater Treatment

Energy Efficiency and Resource Recovery

Facilities will use energy-efficient operations to recover water, energy, and nutrients as well as to produce clean water and other products.



Engaged & Informed Communities

Officials, industry, and the public will manage demand and waste better, support resource recovery goals, and contribute to integrated solutions for water, energy, and food supply.

treatment management
solids infrastructure
integrate regulations education
microbial models utility
technology systems quality
capital enhanced
social design economic market control
source public fuel metrics
methane tech water biosolids
nutrient sensors
products
energy
waste health
heat
resource
potable carbon
performance digestion process test
modular scale cost regulatory
need data recovery demo benefits
federal utilities value
membrane research footprint
technologies collection anaerobic
separation climate facilities
integrated wastewater
mainstream