Energy Optimization

THE CHALLENGE

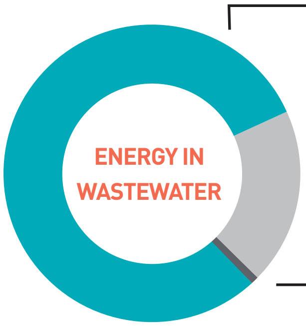
For most water facilities, energy is one of the highest operating costs. The pumping, aerating, heating, and cooling needed to treat and move water add up to a significant bottom line. Stricter regulations are pushing facilities to use even more advanced—and energy-intensive—treatment technologies. Optimizing energy use can provide huge cost savings and numerous additional benefits, including improved air quality, environmental protection, and energy security.

THE RESEARCH

WRF has a robust energy research program, with more than 100 projects that explore ways to not only optimize current energy use, but to generate power as well—setting the course for a self-sufficient water sector. Topics include best practices for energy management, using and producing renewable energy, optimizing treatment processes and equipment design, integrated planning for water and energy, balancing energy efficiency with water quality protection, reaching energy neutrality, and finding creative ways to fund energy projects.

WRF has partnered with key organizations on this work, including a 25-year collaboration with the U.S. Department of Energy to help guide a unified energy-water research agenda. A partnership with the New York State Energy Research Development Authority also resulted in over 15 projects that further advanced energy efficiency and onsite electricity generation. Other key partners include the Global Water Research Coalition, the Consortium for Energy Efficiency, the California Energy Commission, the National Science Foundation, the Electric Power Research Institute, and the World Bank.

Wastewater contains 5 to10 times the amount of energy needed for the wastewater treatment process—the majority in the untapped area of thermal energy.



80% Thermal: Heat energy contained in wastewater, governed by the specific heat capacity of water.

20% Chemical: Energy content stored in various organic chemicals in wastewater.

>1% Hydraulic: (two types) Potential energy is energy created by water elevation, while kinetic energy is energy from moving water.

Renewable Energy

In the early 1990s, WRF was among the first organizations to research ways to improve energy efficiency in water facilities, and the first step was incorporating renewable energy. From wind turbines to solar panels and the battery systems to store power, these options reduce the reliance on a single form of energy as well as a facility's carbon footprint.

In 2016, WRF released *GELCAT: The Green Energy Life Cycle Assessment Tool* (OWSO6R07c/1559), a tool that helps water facilities weigh the costs and benefits of promising renewable energy technologies. Originally featuring just solar, wind, and hydropower, an expanded tool (GELCAT 2.0) now includes micro-hydropower and geothermal heat pumps.

The rise of these renewable resources is changing the energy landscape—and WRF is providing the science for facilities to keep up as we move from a single-grid model to one that includes smaller, locally generated units connected to the grid. The project *Opportunities and Barriers for Renewable and Distributed Energy Resource Development at Drinking Water and Wastewater Utilities* (ENER17C15/4625) evaluates various programs that help utilities implement renewables and identifies associated roadblocks. The resulting guidebook contains resources to help utilities implement distributed energy resource solutions. A follow-up workshop (5062) connected research, industry, and policy by engaging local, state, and national water and energy professionals. They discussed opportunities for distributed energy resource (DER) implementation, the regulations and policies impacting these opportunities, recommendations for future actions, and the need for policies addressing DER and renewable energy.

Reducing Energy Demand

To further reduce plant energy demand, WRF is exploring treatment processes that require less energy, as well as ways to optimize equipment efficiency. More than half of the energy used at wastewater facilities goes into providing oxygen for secondary treatment processes. Because reducing the amount of oxygen needed for biological treatment can significantly shrink energy use, WRF is working to advance the science of anaerobic or anoxic processes. Anaerobic ammonia oxidizing bacteria (anammox) have the potential to provide low-energy treatment, as well as innovative fixed film and membrane processes.

WRF is also investigating new approaches to utilize microorganisms to decrease oxygen demand. *Advancing the Oxygenic Photogranule Process for Energy Positive Wastewater Treatment* (TIRR4C15/4865) developed a new granular bioprocess known as oxygenic photogranules (OPGs). OPGs are made up of phototrophic and non-phototrophic microbes that can treat wastewater without aeration. OPGs also enable effective biomass separation, which can further reduce operational costs and capital investment.

Intercepting sidestream flows to remove nutrients instead of returning these waste loads to the main wastewater process is another way to reduce energy use in the secondary process. By facilitating pilots and collaboration among facilities, WRF is helping to advance the use of innovative biological nutrient removal technologies, which require less carbon and energy. As a result of these efforts, WRF collaborated with the Water Environment Federation to publish the 2015 guidebook, *Shortcut Nitrogen Removal—Nitrite Shunt and Deammonification* (WEF P150003TOC), a necessary resource for facilities considering shortcut nitrogen removal and examining available technologies.

Because system design elements also factor into energy consumption, WRF continues to offer solutions to improve the equipment and design efficiency at various water treatment facilities—from drinking water, to wastewater, to desalination plants. In 2015, WRF released *Drinking Water Pump Station Design and Operation for Energy Efficiency* (4308), a guidebook and software to help facilities assess design and operation options based on energy use.

Energy Recovery and Generation

The treatment and transport of water also present a huge opportunity for energy generation. From energy embedded in biosolids and wastewater to pressure in piping systems, WRF is finding ways to capture that energy and use it as a viable power source to create enough power to offset (or possibly exceed) a utility's energy needs.

At wastewater treatment plants, biosolids are an excellent resource to recover energy and WRF has significantly advanced this science, particularly around anaerobic digestion (see WRF's Biosolids research synthesis for more details). When coupled with combined heat and power (CHP) facilities, anaerobic digestion is regarded as one of the more successful approaches for increasing onsite electricity generation, a key step in self-sufficiency.

Another avenue for energy recovery at water resource recovery facilities (WRRFs) is carbon capture, which aims to harvest carbon compounds before oxidation during the aeration stages in a typical activated sludge process. Instead of using electrical energy (to run the energy-demanding blowers for the aeration process) to remove and destroy the chemical energy contained in the influent carbon, some can be harvested in the primary sludge instead to produce energy using anaerobic processes. *Carbon Capture and Management Strategies for Energy Harvest from Wastewater* (U3R14/4879) examined the impact of wastewater characteristics on the performance and operation of high-rate carbon removal processes. Process and environmental conditions promoting carbon capture were identified to provide a roadmap to reach energy neutrality.

In addition, WRF is helping to expand energy production opportunities. S*tate of the Science and Issues Related* *to Heat Recovery from Wastewater* (ENER10C13/4788) explores the feasibility of recovering thermal energy from sewage. The research team reviewed over 350 peer-reviewed sources on resource recovery and interviewed more than 30 industry leaders. The team gathered experience from 13 North American facilities, six vendors, and multiple international installations to further explain sewage thermal energy use (STEU). As a follow on, WRF is currently developing a detailed research agenda for STEU at water utilities through *Integrating Sewage Thermal Energy Use (STEU) and Other Emerging Water-Energy-Waste Technologies into Decentralized/Distributed Systems* (SIWM-17-16/4843).

Excess pressure in piping at water facilities is another source for harvesting clean, renewable power. WRF partnered with Halifax Water to design and install a recovery turbine, making Halifax the first Canadian utility to use an inline microturbine in a closed distribution system. The resulting report, *Energy Recovery from Pressure-Reducing Valve Stations Using In-Line Hydrokinetic Turbines* (4447), details key planning and design considerations, economics, and risk mitigation, which can be used as a guide by other utilities considering energy recovery from a turbine generator.

Integrated Planning

Because energy and water are so intertwined, WRF is taking important steps to help water facilities and electric utilities develop a more unified approach—including understanding how electricity is used in different plant configurations. *WaterWatts: A Modern Look at Wastewater Power-Metering Data* (ENER15C15/1403) compares energy consumption in individual processes, breaking out pieces that are typically looked at as a whole, to get a clearer picture of energy performance.

Water and Electric Utility Integrated Planning (4469) helps identify approaches to get electric and water utilities working together in mutually beneficial ways and to advance strategic planning initiatives. The project was based on a unique tournament concept, where representatives from electric and water utilities were given hypothetical scenarios and tasked with jointly developing strategic solutions, which were later assigned scores. The tournament, funded by a partnership between WRF, EPRI, and DOE, is set to be the first of many, prompting efforts with broader perspectives, involving stakeholders like federal agencies, regulators, and policy makers.

Data Utilization

Utilities are increasingly implementing innovative data management solutions based on big data to attain operational sustainability, target cost/energy savings, and strive toward a net-zero energy balance. Despite the improvements made around the management, accessibility, interpretation, and visualization of energy data, the application of big data concepts for energy management is still in its infancy. *Application of Big Data for Energy Management in*

SOLUTIONS IN THE FIELD: METRO VANCOUVER

Hydrothermal processing (HTP) offers the ability to turn solids into renewable energy, using the same components that have long formed fossil fuels in nature (water, heat, and pressure), and speeding up the process so it takes place in about an hour, rather than several millions of years.

WRF recognized the technology's potential early on and partnered with the U.S. Department of Energy's Pacific Northwest National Laboratory to fast track research on this innovative technology. The collaboration also engaged a group of about 10 wastewater facilities that came on board to share the cost of testing the technology.

One of the collaborating facilities, Metro Vancouver, a partnership of 23 local authorities in British Columbia, then signed on to lead the development of a demonstration plant. Construction of the HTP unit began in 2019. When operational, it will significantly reduce solids disposal costs and produce biocrude oil, which could be used for things like fueling vehicles

As more facilities move toward energy neutrality, WRF is providing the research to help optimize current energy use and boost onsite power production.

Water Utilities (4978) provides utilities with knowledge on advanced big data analytics for automated data collection and achieving energy-efficient, cost-effective operations. This research also provides an approach for the development of a comprehensive data management and analytics strategy at a reference utility, which can become a model for future pilot studies.

Providing further guidance in this area, *Managing Water and Wastewater Utility Data to Reduce Energy Consumption and Cost* (4668) provides a comprehensive knowledge base for implementing effective strategies for energy data management at water and wastewater utilities. The report emphasizes the importance of conducting a data needs assessment that addresses types of data, frequency of collection, collection priorities, data use, available funding, and types of resources to be allocated. The report also provides a set of clearly defined key performance indicators, connecting energy and non-energy data, that can be identified for energy optimization.

INNOVATION

WRF's Innovation Program is pursuing pilot projects on various topics to evaluate promising technologies and processes beyond the bench scale. One such topic is energy efficiency at water resource recovery facilities. A new project, *Nitrogen Reduction Technology* (5117), recruited three universities to pilot four novel nitrogen reduction technologies: hydrogel and membrane reactors, partial nitrification/denitrification/anammox (PANDA) using suspended and fixed film biomass, and integration of anammox and partial denitrification (PDN) for mainstream nitrogen management.

WHAT'S NEXT?

In September 2021, WRF was awarded a $2.2 million grant from the U.S. Department of Energy to lead a project, *Data-Driven Process Control for Maximizing Resource Efficiency* (5141). This project will develop and demonstrate data-driven process controls in full-scale facilities for five promising process technologies that provide a whole-plant approach and offer substantial energy and resource recovery benefits. The five applications that will be investigated are:

- Carbon Diversion: High-rate contact stabilization
- Biological Nutrient Removal: ammonia-based aeration control/ammonia vs. NOx control + mainstream partial denitrification with anammox
- Disinfection with Peracetic Acid
- Phosphorus Recovery: MagPrex™
- Holistic Biosolids Optimization

One project funded under this grant is *Transforming Aeration Energy in Water Resource Recovery Facilities (WRRFs) through Suboxic Nitrogen Removal* (5148), which will examine strategies to achieve biological acclimation to very low dissolved oxygen concentrations (at or below 0.5 mg/L, called suboxic), while also achieving reliable and improved nutrient removal, compared to conventional high dissolved oxygen biological nutrient removal systems.

Energy projects within the water sector are often discretionary and are initiated based on projected annual energy savings metrics. The water sector lacks standard energy savings estimation procedures, as well as measurement and verification approaches and procedures that adhere to the Efficiency Valuation Organization's 2012 International Performance Measurement and Verification Protocol. *Developing a Framework for Quantifying Energy Optimization Reporting* (5091) seeks to fill this gap by assessing economic feasibility and energy reduction impact analyses currently used by drinking water and wastewater utilities. This investigation will inform the development of an improved and standardized framework for future economic feasibility evaluations and post-construction measurement and verification of energy performance.

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