THE Water Research FOUNDATION

Energy Optimization

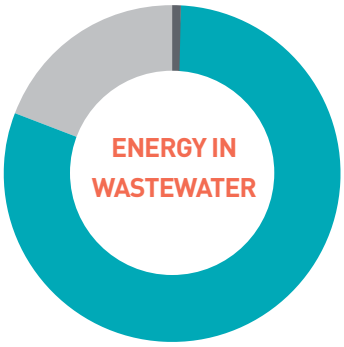
THE CHALLENGE

For most water facilities, energy is one of the highest costs in their operating budget. The pumping, aerating, heating, and cooling needed to treat and move water add up to a significant bottom line. And 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 improving air quality, protecting the environment, and bolstering 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



80% THERMAL

20% CHEMICAL

>1% HYDRAULIC

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

The energy content of wastewater includes:

Thermal Energy: Heat energy contained in wastewater, which is governed by the specific heat capacity of water.

Hydraulic Energy: (two types) Potential energy is the energy created by water elevation, while kinetic energy is the energy from moving water (velocity).

Chemical (Calorific) Energy: The energy content stored in various organic chemicals in wastewater. The organic strength is typically expressed as the chemical oxygen demand (COD) in mg/L.

Energy Research Development Authority also resulted in more than 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.

Renewable Energy

Beginning 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 sustainable 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), a user-friendly tool that helps water facilities weigh the costs and benefits of promising renewable energy technologies. Originally featuring just solar, wind, and hydropower, the recently 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 also involves smaller, locally generated units connected to the grid. The recently completed project *Opportunities and Barriers for Renewable and Distributed Energy Resource Development at Drinking Water and Wastewater Facilities* (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.

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. Aeration and pumping account for the largest amounts of energy used by water facilities, making them the primary targets to tackle.

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.

Intercepting sidestream flows to remove nutrients instead of returning these highly concentrated waste loads to the main wastewater process is another way to reduce energy use in the secondary process. By facilitating piloting opportunities and collaboration among interested facilities, WRF is helping to advance the use of innovative biological nutrient removal technologies, which require less carbon and energy compared to conventional nutrient removal processes. 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 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

Although the treatment and transport of water require a large amount of power, they 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 ultimately create enough power to offset (or possibly exceed) a utility's energy needs.

At wastewater treatment plants, biosolids currently offer the most developed opportunity to recover energy and WRF has significantly advanced this science, particularly in the area of anaerobic digestion. 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.

Ongoing research is finding methods to boost energy recovery from biogas, including emerging technologies that improve solids digestibility, advanced biogas cleaning, and co-digestion. *Co-Digestion of Organic Waste Products with Wastewater Solids* (OWSO5R07) demonstrates important discoveries about organic loading rates and digester stability, zeroing in on the types and amounts of feedstock that have a synergistic effect on biogas production—improving the economic viability of co-digestion, as well as industry confidence in the process.

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

SOLUTIONS IN THE FIELD: METRO VANCOUVER

Hydrothermal processing (HTP) could be a game changer for the wastewater industry, particularly when it comes to solids treatment. The technology 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, part of a LIFT initiative, 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.

how electricity is used in different plant configurations. *WaterWatts: A Modern Look at Wastewater Power-Metering Data* (ENER15C15) compares energy consumption in individual processes, breaking out pieces that are typically looked at as a whole, in order 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.

Creative Funding

WRF is helping facilities overcome one of the biggest challenges involved with energy optimization: funding energy projects. From guidance on building a better business case for projects like CHP to offering a path for identifying effective funding partnerships, WRF provides utilities with the tools to get their energy projects off the ground. *Public-Private Partnership Opportunities for Water and Water Resource Recovery Utility Energy Projects* (ENER18C15/4634) provides a best practice guide to help water and wastewater utilities navigate energy projects, taking into consideration factors such as legal matters, financing, contracting, and risk management practices.

LIFT

The Leaders Innovation Forum for Technology (LIFT) accelerates water innovation and helps move new water technologies and processes to the field quickly and efficiently. Since the initiative began, technologies to reduce energy and chemical demand and capture energy have been a key focus. With dedicated energy-related focus areas, including Energy from Wastewater, Biosolids to Energy, Biological Nutrient Removal, Digestion Enhancements, and Intelligent Water Systems, LIFT has helped advance the use of more than 100 innovative technologies that have beneficial impacts to water utilities.

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

WHAT'S NEXT?

Because many facilities are moving toward energy production, WRF continues to examine the best ways to optimize this energy. In this new paradigm, it is critical to capture and measure accurate information on energy inputs and outputs—and there is a tremendous amount of information to capture. Managing and understanding big data associated with energy and key performance indicators will play an important role in running a water facility and optimizing energy production and efficiency.

As low-energy practices and technologies continue to advance, WRF is also taking a closer look at how these processes impact other parts of the treatment train. Answering questions like how co-digestion affects solids processing will help provide a holistic view of operations and how to improve energy efficiency while meeting clean water goals.

In addition, WRF is helping to expand energy production opportunities. Projects such as *State of the Science and Issues Related to Heat Recovery from Wastewater* (ENER10C13) will examine how this heat can be used, how well current technologies perform, and what impact regulations have on heat recovery potential.

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