An Integrated Program Approach to Saving Energy in the Municipal Water and Wastewater Sector

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ABSTRACT

There are substantial opportunities for municipalities to improve the energy-efficiency of their water and wastewater facilities. This paper summarizes the potential for energy savings in this sector and describes how energy-efficiency programs are currently addressing this opportunity. Using PG&E as an example, the paper describes how energy-efficiency program administrators are developing an integrated approach to address major areas of energy consumption, such as pumping and secondary treatment systems, as well as operations management and power generation opportunities. It provides information on several important energy-efficiency developments, including a new municipal water and wastewater facility program initiative and an industry-led research project to establish a facility-level energy performance benchmarking metric.

Introduction

Public facilities that treat and distribute drinking water and those that collect and treat wastewater are widespread and energy-intensive, accounting for approximately 3 percent of U.S. electricity use.[1] At this level of consumption, water and wastewater facilities are one of the largest and most energy intensive loads owned and operated by local governments, representing up to 35 percent of municipal energy use.

Energy-efficiency programs can provide substantial value to municipal water and wastewater utilities and their customers. The potential benefits to municipalities include lower energy costs as well as non-energy benefits, such as reducing the need for chemical additives, reducing solids accumulation and the deferral/reduction of capital expenses. The following sections provide an overview of the water sector which includes treatment and distribution and wastewater sector which emphasizes treatment, as well as a discussion of energy-efficiency program offerings and recent program developments at the national level. Implications of these developments are also discussed.

Wastewater Collection and Treatment

There are approximately 15,000 wastewater treatment plants operating in the United States. More than 70 percent of the U.S. population is served by these publicly-owned treatment works – relatively few in number are operated privately (less than 10%). According to EPRI,

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[1] EPRI, Water and Wastewater Industries: Characteristics and Energy Management Opportunities, 1996. This 3 percent figure does not include energy usage to treat or transport water in the industrial and agricultural sectors, or large water transmission systems like the California Aqueduct which transmits raw water from Northern California to Southern California.

over 75 percent of wastewater plants are small (1.0 million gallon per day (mgd) or less in capacity), serving 7 percent of the US population. Approximately 4 percent are large (10.0 mgd or greater in capacity) and serve over 70 percent of the population.[2]

Wastewater systems generally consist of three principal components: Collection systems (sewers and pumping stations), treatment facilities (primary, secondary, advanced), and effluent disposal. Primary treatment methods are usually similar across facilities. All wastewater plants, for example, need to collect, filter and remove solid matter from incoming streams.

Secondary treatment types vary widely, although most employ bacterial cultures to remove organic materials still remaining after primary treatment. These bacteria require oxygen to function via aeration.[3] The most common types of aeration processes are activated sludge, lagoon, oxidation ditch/extended air plant, and trickling filter. Among these treatment types, activated sludge with aeration powered by fans and motors, is generally the most energy-intensive. For example in a typical activated sludge treatment plant the aeration system typically represents 60 percent of a plant's electricity use; pumping represents an additional 15 percent.

Water Treatment and Distribution

There are roughly 200,000 municipal water treatment systems in the country, of which approximately 60,000 are community water systems that serve year-around residents, e.g., residents served by municipal, county, and private water utilities as well as mobile home parks, subdivisions and apartments with their own supply systems. Most of the water in the United States is provided by community water systems. Nearly 80 percent of the U.S. population is supplied by about 5 percent of these systems. The remaining 95 percent include a large number of small and very small systems serving populations of 3,300 or less. Approximately two-thirds of the systems are supplied by surface water; the balance is served by groundwater. Public agencies (municipalities, counties, water districts or authorities, and townships) own and operate most community water systems and use a similar decision-making process. A small number are privately operated.

Since approximately 80 percent of the electricity used at these facilities is for pumping it is no wonder that most of energy saving opportunities within the sector relate to pumping equipment and operational control systems. On the process side, many municipal water and wastewater treatment plants are shifting from chlorine-based disinfection to ultraviolet (UV) disinfection to eliminate the risk of storage and handling of toxic chemicals. Although UV disinfection is energy intensive, it adds no chemical residue. This feature is important for discharge to sensitive aquatic environments (and for wastewater reuse). In general, low pressure UV systems are substantially more efficient than medium pressure systems.

While pumping and aeration systems appear to offer significant opportunities for energy savings within water and wastewater plants, energy-efficiency is a fairly low priority among managers and operators of municipal water and wastewater facilities and their suppliers. The section below describes a few of these market barriers.

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[2] EPRI, Water and Wastewater Industries: Characteristics and Energy Management Opportunities, 1996. (2-16)

[3] Aeration may be defined as the introduction of air into secondary treatment tanks to facilitate the decomposition of organic mater in wastewater.

Customer Barriers to Energy Efficiency

For both water and wastewater managers and operators, successfully supplying demand, meeting all permitting requirements, and staying within budget are the most important drivers in this market.[4] There is also the desire among both operators and design/engineering firms to maintain or improve the reliability of their facilities. Energy-efficiency opportunities must be framed with these factors in mind. Particularly important to water operators are decisions to implement new regulations under the Safe Water Drinking Act such as implementing portions on arsenic and radon control, required filtration and groundwater disinfection. For wastewater operators, critical issues, such as meeting new and more stringent Total Maximum Daily Loads (TMDLs) for effluent components, pose significant challenges.

Since water and wastewater facilities are most often owned and operated by municipal governments, procurement, planning and budgeting must be done in conjunction with local government policies and procedures. Water and wastewater department managers must compete for resources with other municipal departments which can constrain opportunities to implement energy-efficiency projects. Upper-level decision-makers within municipalities do not necessarily understand the value in these projects and will not always support them, especially if they are more costly (first cost).

Market Barriers to Energy Efficiency

While most engineering firms have the capability to conduct facility energy audits, propose energy-efficiency projects and offer process optimization services, only a few actively promote these services to their water and wastewater customers. Apparently energy-efficiency is a departure from their standard business model which is centered on customer expectations for facilities to meet permitting requirements, be reliable and minimize capital costs. A lack of support from senior-level municipal leaders compounds the problem. After many years of promoting the benefits of energy-efficiency in the Northwest, the NW Energy-Efficiency Alliance found that 40 percent of operators said energy-efficiency projects were not supported by the city. While the majority of consulting engineers in the region have noted greater awareness of energy efficiency over time, it has not altered their business model significantly.[5]

Potential Energy Savings and Other Benefits

Despite energy efficiency's relatively low priority among water facility personnel and suppliers, there is a significant opportunity for savings in the water and wastewater sector. Energy is the second highest budget item for municipal water and wastewater facilities after labor costs. It is also one of the highest costs that municipalities face overall.

[4] PG&E Municipal Wastewater Treatment Plant Energy Baseline Study, 2003.
[5] NW Energy Efficiency Alliance, BacGen: Market Progress Evaluation Report, No. 3, Oct. 2004.

Drinking Water Systems

According to EPRI, public water systems consumed approximately 30 billion kWh of electricity in 2000.[6] Surface water supply systems typically consume between 1,400 and 1,500 kWh per million gallons of water supplied. Groundwater systems tend to consume more energy averaging 1,824 kWh per million gallons of water.[7] In both cases, pumping represents the vast majority of energy consumed, including pumping to deliver untreated water to a treatment plant, pumping water through the treatment process, and delivering treated water to storage facilities, reservoirs and customers. In groundwater systems, pumping can account for up to 99 percent of the electricity consumed with the water treatment process requiring less than 1 percent.[8]

Most methods to improve water treatment efficiency and reduce energy costs focus on pump system efficiency, including: 1) improved maintenance, operations and control, and 2) more efficient equipment. For instance, it is estimated that drinking water facilities can achieve 5-15 percent energy savings through the installation of adjustable speed drives (ASDs) and high efficiency motors on pumps.

High-efficiency motors, meeting NEMA PREMIUM™ specifications, enable pumps to move the same amount of water to and from water treatment facilities while using less energy than standard-efficiency motors. In applications with variable loads, ASDs enable pumps to vary speed according to flow rates resulting in substantial energy savings.

Improved scheduling and more efficient operations is another opportunity for water treatment facilities to reduce high energy costs. It has been estimated that electronic control technologies, such as Supervisory Control and Data Acquisition (SCADA) systems, can help facilities reduce energy costs by 10-20 percent. SCADA systems can help enhance energy management overall by providing the capability to more efficiently manage operations, such scheduling energy-intensive operations during off-peak periods, making efficient use of available storage and operating emergency generators for peak clipping.[9]

Wastewater Systems

According to EPRI, public wastewater systems consumed approximately 21 billion kWh of electricity in 2000, or about 1,800 kWh per million gallons of water treated.[10] This energy intensity reflects an average across the various treatment types and plant sizes. While each treatment facility is unique, in general aeration and pumping are the two most prominent areas for energy savings. At plants that include activated sludge treatment (which are 70 percent of the plants with flows exceeding 2.5 mgd), aeration typically dominants electricity use and offers the greatest potential for energy savings.

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[6] EPRI, 2000. Managing the 21st Century: Water and Sustainability – Electricity Use. Electric Power Research Institute, Palo Alto, CA. 2000, Product ID#044739-02, pgs. 2-4.

[7] EPRI, Water and Wastewater Industries: Characteristics and Energy Management Opportunities, 1996. (3-30)

[8] It should be noted that energy requirements can vary with local circumstances such as deep wells and higher elevations.

[9] Estimates based on audit process developed by EPRI and HDR Engineering, presented by Keith Carnes at the ACEEE Water and Wastewater Energy Roadmap Workshop, July 29, 2004. Also see EPRI, Water and Wastewater Industries: Characteristics and Energy Management Opportunities, 1996. (3-30)

[10] EPRI, 2000. Managing the 21st Century: Water and Sustainability – Electricity Use. Electric Power Research Institute, Palo Alto, CA. 2000, Product ID#044739-02, pgs. 3-8.

Because wastewater flows and biochemical oxygen demand (BOD) concentrations vary over time, many aeration systems are not optimized for the operating conditions encountered. Aeration systems can frequently be reconfigured and controlled to improve energy efficiency. EPRI estimates that 10-20 percent energy savings are available through improved process control systems such as installing dissolved oxygen monitoring systems on digesters and installing ASDs on aeration equipment. Another 10-20 percent energy savings are available through the selection of more energy-efficient processes and equipment, such as specifying fine bubble diffusers rather than course bubble diffusers, or rotary press sludge dewatering systems rather than the more commonly specified centrifuge dewatering system.[11]

Pumps system efficiency and use of waste digester gas represent two additional opportunities to address rising energy costs within wastewater treatment. There are approximately 42,000 wastewater pumping stations across the country operating around-the-clock to meet continuous and varying wastewater flows. Opportunities to reduce pump system energy costs are similar to those described for drinking water systems above (e.g., high-efficiency motors, ASDs, and scheduling).

Finally, many wastewater treatment facilities are recovering digester gas to help improve process efficiency or to generate electricity on-site. Interest in this area has grown over time along with increasing energy prices.

Load Management and Demand Response

In addition to helping address rising energy costs, energy-efficiency projects can help address load management and demand response issues. In wastewater plants, peak flow rates and peak organic loads, which require increased pumping and treatment capacity, occur during the midday and afternoon hours, coincident with the summer peak demand periods of many electric utilities. Peak demand for electricity at treatment plants is mainly for operation of aeration systems used in treating organic loads (typically accounting for over 50 percent of plant process use). Process control, scheduling, and storage offer significant peak load reduction opportunities.

Many of the peak demands for water, and the energy requirements to process and transport water, coincide with the peak seasonal demands experienced by electric utilities. Energy management mainly relates to pumping systems. Therefore, using high-efficiency equipment, utilizing effective instrumentation and control, managing pumping operation by efficient use of available storage, and operating emergency generators for peak clipping, offer the greatest demand reduction opportunities.

During the energy crisis in California, the California Energy Commission specifically targeted water and wastewater facilities to reduce loads on the grid. As of December 31, 2002, the program achieved approximately 60 MW of verified peak load reduction capability. These programs were originally designed to encourage generation at these facilities. Opening the

[11] Estimates based on audit process developed by EPRI and HDR Engineering, presented by Keith Carnes at the ACEEE Water and Wastewater Energy Roadmap Workshop, July 29, 2004. For more information on savings potential see case studies from California Process Optimization Program (CalPOP). See CalPOP 2004. Future Investment in Drinking Water and Wastewater Infrastructure. Congressional Budget Office. Washington, DC. November 2002.

program to load shifting and efficiency projects doubled enrollment and nearly doubled expected savings. "Load shifting project account for one-third of the expected savings and had a levelized cost on par with generation. The efficiency projects accounted for a much smaller amount of overall savings, about 8 percent, but these projects were more cost effective with levelized costs 33 percent less than either generation or load shifting."[12]

Non-Energy Benefits

Energy-efficiency projects also typically provide non-energy benefits to customers, such as lower maintenance costs, longer equipment life and better control. Although these benefits are frequently not measured or attributed to energy-efficiency projects within water facilities, it is likely that city managers and water facility operators will find them as compelling (if not more so) than the energy cost savings. A recent evaluation conducted by the Northwest Energy Efficiency Alliance estimated quantifiable non-energy benefits of $35,000 per year per facility in solids removal, deferral/reduction of capital expenses and reduced odor liability. In addition, the operators themselves benefited from energy-efficiency projects and facility energy management, due to the ability to monitor their plants and safely treat water, especially since stable effluent meant a reduced risk of permit violation.[13]

The Role of Energy Efficiency Programs

The high cost of energy and the opportunities for energy savings often lead water and wastewater treatment plants to participate in local energy-efficiency programs. The administrators of these programs, such as electric and gas utilities, state energy offices and regional groups, typically offer a variety of services that can help water and wastewater plants save energy, reduce their electric bills and increase productivity – while also meeting capacity and environmental requirements.

Typically these programs focus on the energy-efficiency of specific types of equipment or on a series of specific projects that are short-term in nature with very little follow-up or inter-connection. Common program offerings applicable to water and wastewater agencies include energy assessments (audits), education and training, project analysis and design assistance (retrofit, expansion/new construction), project financing and incentives for highly efficient equipment (motors, pumps, drives, lighting, etc.). Unfortunately these "one-off" projects do not address water and wastewater industry needs or trends as they relate to energy efficiency and energy management on a continuous improvement basis.

In August 2002, the Consortium for Energy Efficiency (CEE) established a committee of program administrators to explore opportunities to accelerate the demand for energy efficiency within the water and wastewater sector nationally and to identify common program objectives.

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[12] See CEC Peak Load Reduction Programs, Fourth Quarter 2002 Report – Final 06-11-03, Section 8 Water Agency Program Elements. Reporting on AB 970 Water/Wastewater Program Element and SB 5X Water Agency Generation Program Element. Pg. 8-39

[13] Quantec. *BacGen Market Progress Evaluation Report. No. 3.* Portland, Oregon: Northwest Energy Efficiency Alliance, 2004.

The committee explored how programs currently serve water and wastewater customers and found a mix of program approaches across the country. The committee found that most programs serve water and wastewater facilities through custom programs and/or prescriptive rebate programs (e.g., motors, drives, lighting, etc.). Others administer programs focusing on process optimization, such as NYSERDA, the Northwest Energy Efficiency Alliance, Bonneville Power Administration, the California Energy Commission, Wisconsin Department of Administration, TVA and Efficiency Vermont. There are also new construction programs, such as those administered by NYSERDA and the California investor owned utilities (SCE, SDG&E and PG&E). Finally, there are a number of organizations that have researched the water-energy connection and contributed to the committee's thinking about the opportunity, such as non-profit groups and national laboratories.

An Integrated Program Approach for Energy Efficiency

Based on committee member experience and secondary research, CEE's Water and Wastewater Committee identified model approaches to help guide future program development. Highlighted below is one example of a successful energy-efficiency program administered by Pacific Gas and Electric Company (PG&E). Their experience with the San Jose Water Pollution Control Plant (SJWPCP) demonstrates the value of a longer-term, integrated program approach that focuses on continuous improvement.

The SJWPCP (Figure 1) serves a population of over one million people, with a service area of about 300 square miles. Treatment process consists of primary treatment to remove solids, secondary treatment using an air activated sludge process with biological nitrification, followed by effluent filtering and disinfection. A multi-year expansion was launched several years ago to increase the wet weather treatment capacity from 270 to 400 mgd.

Figure 1: San Jose Water Pollution Control Plant

The PG&E integrated program approach began in 1996, when PG&E conducted a Process and Energy Study for the SJWPCP. Subsequent multi-year process evaluation and pilot testing of aeration technologies, oxygen recovery system and the use of premium efficiency motors and variable speed drives have produced valuable results for implementing energy-efficient and cost-effective wastewater treatment designs. In 2001, PG&E conducted an Energy Benchmarking Study for Wastewater Treatment Facilities followed by a Municipal Wastewater Treatment Energy Baseline Study in 2003. These studies contributed to the implementation of an incentive program for new construction projects. By participating in the incentive program, the

SJWPCP worked with PG&E and its consultant on energy efficiency projects, such as fine bubble aeration improvement and oxygen recovery system, resulting in approximately 11 million kWh of electricity savings and 1 million therms in natural gas savings annually. Based on approximately $1,000,000.00 of incremental capital costs, PG&E provided an incentive totaling more than $300,000.00. Together with the projected annual electricity savings, a simple pay-back period of less than three months was estimated.

A National Municipal Water and Wastewater Initiative

Based on the experience of PG&E and other successful programs, the CEE Committee developed the basis for a new national initiative to help local and regional energy-efficiency programs address the energy savings in this sector on a national basis. By supporting a common national approach participating programs hope to increase the demand for improved facility energy performance nationally and to encourage suppliers to the industry to adopt energy-efficiency as a standard business practice. The Committee believes this goal can be realized through greater coordination among energy-efficiency programs and through industry partnerships. CEE plans to pursue the following activities in support of this goal:

1. Raising awareness among senior-level decision-makers at municipalities of the benefits of energy-efficient water facilities
2. Focusing member energy-efficiency programs on key motor system and process opportunities as a means to demonstrate the benefits of facility energy management
3. Supporting the development of an industry-wide metric to describe the energy-performance of water and wastewater facilities, allowing comparisons within water and wastewater facilities over time as well as across similar facilities (normalizing for differences in size, age, regulation, etc.).
4. Developing cooperative relationships with the water and wastewater industry and their suppliers via trade, industry and professional associations.

A national initiative targeting municipal water supply and wastewater treatment facilities is well timed in light of current trends in the industry, including new, mandated water quality requirements, continued population growth (especially in urban areas), aging national water infrastructure, and rising energy costs.[14] Non-regulatory issues can also increase energy consumption levels, such as improving drinking water taste and color. Given the need for major investment in our nation's water infrastructure,[15] this Initiative is intended to provide a consistent national approach for programs to shape the expected increase in demand for water treatment technologies, equipment and services toward greater energy-efficiency.

National Energy Performance Metric for Water and Wastewater Utilities

To support the new initiative (and local efficiency programs) the CEE committee identified the need for a consistent, industry-recognized method to determine facility energy

[14] Many municipal facilities are 30 or more years old and in need of major repair, upgrade and replacement.
[15] The Congressional Budget Office, the General Accounting Office and the U. S. Environmental Protection Agency all agree there is a national funding gap estimated to be as high as $1 trillion for water infrastructure over the next 20 years.

performance that takes into account variations in water and wastewater facility type, input requirements, output requirements and operating conditions.

The committee's interest was sparked by a study conducted by the Iowa Association of Municipal Utilities on the energy consumption and costs to treat water and wastewater in Iowa, and by an RFP from AWWARF to develop a water utility energy index to assist in energy benchmarking. The CEE committee was particularly interested in the potential benefits that a common, nationally-recognized, water utility energy index might provide to their programs.

Rather than pursuing the development of a water facility benchmarking metric, the committee is providing input on an industry-led research effort. AWWARF, the California Energy Commission and NYSERDA are funding the project called, "Development of a Utility Energy Index to Assist on Benchmarking of Energy Management for Water and Wastewater Utilities." The objective of this two-year project is to produce an industry-wide energy performance metric to describe the performance of water and wastewater utilities. The resulting metric could then be incorporated into a comparison framework (benchmarking tool) to facilitate internal and external comparisons within and between utilities.

This project should have several outcomes that can help energy-efficiency programs demonstrate the value of energy-efficiency and motivate greater support among municipal senior-level decision-makers as well as facility operators and managers, including: a process for benchmarking internally over time within an individual facility, a process for benchmarking across a group of utilities, a process for benchmarking different facilities across the utility.

Conclusion

A national initiative is well timed in light of current trends in the industry, including new, mandated water quality requirements, continued population growth (especially in urban areas), aging national water infrastructure, and rising energy costs. The Congressional Budget Office, the General Accounting Office and the U. S. Environmental Protection Agency all agree on the need for major investment in our nation's water infrastructure - on the order of $1 trillion over the next 20 years. In light of these trends, there is an unprecedented opportunity for energy-efficiency programs to help shape the expected infusion of capital for new plant and equipment toward greater energy-efficiency through greater coordination of state and local energy efficiency programs.

References

AWWA. *Water and Wastewater Industry Energy Efficiency: A Research Roadmap.* Denver, Colorado: AWWA, 2004.

Burton, Franklin and Electric Power Research Institiute. *Water and Wastewater Industries: Characteristics and Energy Management Opportunities.* St Louis, Missouri: EPRI, 1996.

CH2M Hill Inc. *On-line Process Monitoring and Electric Submetering at Six Municipal Wastewater Treatment Plants.* New York: NYSERDA, 1998.

Cohen, Ronnie, Barry Nelson and Gary Wolff. *Energy Down the Drain.* NRDC, 2004.

Energy Conservation Task Force of the Water Environment Federation. *Energy Conservation in Wastewater Treatment Facilities.* Alexandria, VA: Water Environment Federation, 1997.

EPRI. *Municipal Water and Wastewater Program.* St. Louis, Missouri: EPRI, 2001.

EPRI. *Energy Audit Manual for Water/Wastewater Facilities.* Palo Alto, California: EPRI, 1994.

EPRI. *Community Environmental Center.* Palo Alto, California: EPRI, 1996.

EPRI. *Quality Energy Efficiency Retrofits for Water Systems.* Palo Alto, California: EPRI, 1997.

EPRI. *Quality Energy Efficiency Retrofits for Wastewater Systems.* Palo Alto, California: EPRI, 1998.

ICF Consulting: *Water and Energy: Leveraging Energy Efficiency Initiatives to Improve Water Use Efficiency.* Washington, D.C.: Climate Protection Partnership Division. U.S. EPA, 2004.

Iowa Association of Municipal Utilities. *Energy Consumption and Wastewater in Iowa*. Iowa: IAMU, 2002.

Jacobs, John, Thomas A. Kerestes and W.F. Riddle. *Best Practices for Energy Management.* St. Paul, Minnesota: AWWA Research Foundation, 2003.

M/J Industrial Solutions. *Municipal Wastewater Treatment Plant Energy Baseline Study.* San Francisco, California: Pacific Gas and Electric Company, 2003.

NYSERDA. *Wastewater Treatment and Sludge Management*. New York: NYSERDA, 1995.

Nexant. "Section 8: Water Agency Program Elements." California Energy Commission Peak Load Reduction Programs Fourth Quarter 2002 Report. California: California Energy Comission, 2003. 8-1—8-40.

Quantec. *BacGen Market Progress Evaluation Report. No. 3.* Portland, Oregon: Northwest Energy Efficiency Alliance, 2004.

Quantum Consulting Inc. *Market Research Report-Executive Summary: Pacific Northwest Water and Wastewater Market Assessment.* Quantum Consulting Inc., Berkeley, California: 2001.

SBW Consulting, Inc. *Energy Benchmarking Secondary Wastewater Treatment and Ultraviolet Disinfection Processes at Various Municipal Wastewater Treatment Facilities.* San Francisco, California: Pacific Gas and Electric Company, 2002.

State of Wisconsin. *Roadmap for the Wisconsin Municipal Water and Wastewater Industry.* Madison, WI: State of Wisconsin, 2002.