Capturing the Energy Efficiency and Renewable Energy Opportunity in the Wastewater Treatment Sector

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ABSTRACT

The wastewater treatment sector buys an estimated $2 billion worth of electricity each year and is often the biggest contributor to a given municipality's energy bill. While large today, energy needs in this sector, and associated carbon emissions, are projected to grow over time driven by population growth and more stringent water quality regulations. Significant energy efficiency and renewable energy opportunities exist in this sector to help reduce costs and improve the resiliency of these systems, but plant operators face market barriers that prevent them from fully capturing these opportunities. For example, plant operators are primarily focused on meeting water quality permit limits; new operating practices and technologies that save energy are therefore a lower priority, and plant operators often lack the expertise to implement them. Relatedly, available capital tends to flow to projects that keep core operations running, with little left over for innovative energy projects.

This paper will describe programs the U.S. Department of Energy has developed in partnership with industry to overcome these barriers and accelerate clean energy progress that reduces costs, improves environmental performance, and enhances resiliency in the wastewater treatment sector. Couched within the context of the Department's broader efforts to address the energy-water nexus, this paper will highlight real world success stories covering both energy efficiency and renewable energy, including the generation of biogas-derived electricity from on-site combined heat and power systems. The paper will also discuss unmet needs and suggest future approaches to capture energy efficiency and renewable energy opportunities within the sector.

Introduction

Wastewater treatment plants provide critical services. They produce clean water that protects public health and improves the environment. The technologies and processes needed to treat and pump wastewater require significant energy to operate, which results in environmental and economic costs for the treatment plants themselves, the municipalities they operate in, and the public they serve. There are a little over 15,000 wastewater treatment plants across the country according to data collected by the U.S. Environmental Protection Agency (EPA 2012) through its Clean Watershed Needs Survey (CWNS). Through the CWNS, the EPA collects information every four years on capital needs to meet the water quality goals of the Clean Water Act, as well as additional data on wastewater treatment facilities, such as plant size, location, and treatment technologies used. Collectively, these plants consume an estimated 30.2 terawatt hours per year of electricity (Arzbaecher et al. 2013, 5-15), which equates to about $2 billion in annual electric costs.[1] While on a national level, wastewater treatment plants make up less than 1% of total electric consumption, they are often the single largest energy users within a community,

[1] Assumes 7 cents per kilowatt hour (kWh) average electric costs, equivalent to the rounded 2015 average industrial electric rate reported by the U.S. Energy Information Administration.

and, when coupled with potable water systems, can make up a third or more of a municipality's energy bill (EPA 2016). These energy needs are expected to grow over time, driven by population growth and increasingly stringent water quality requirements, which tend to drive the adoption of more energy intensive treatment technologies and processes (Arzbaecher et al. 2013, 9-1).

While the sector's energy needs are large and growing, the opportunities for improving energy efficiency and increasing the use of renewable energy are also significant. Exploiting these opportunities can have large benefits for communities. Energy costs make up 25 to 40% of total operating costs for wastewater treatment plants (EPA 2011, 1). Reducing energy bills can free up funds for other investments and keep costs down for ratepayers. Relatively common energy efficiency measures have helped some plants cut energy costs by up to 50% (EPA 2013, 35), and others are using renewable forms of energy, such as solar, to power close to 20% of their operations. The Washington Suburban Sanitary Commission, for example, has installed solar panels at two plants that are projected to save ratepayers about $3.5 million over the life of the projects (WSSC 2013). Additionally, this sector has the unique opportunity to recover energy from the wastewater it processes, usually by capturing methane-rich biogas produced through anaerobic digesters and converting it to electricity through on-site combined heat and power (CHP) systems. The EPA (2011, v) has estimated that each million gallons per day (mgd) of wastewater flow can produce enough biogas in an anaerobic digester to produce 26 kilowatts of electric capacity through a CHP system.[2] Several plants across the United States, including East Bay Municipal Utility District, are pairing aggressive energy efficiency measures with biogas utilization to become "energy neutral," meaning they produce as much energy onsite as they consume in a given year (Shen et al. 2015). In addition to improved environmental performance, biogas-powered CHP can help plants reduce reliance on the electric grid and continue to operate when power supplies are disrupted. For example, the CHP system at New Jersey's Bergen County wastewater treatment facility allowed the plant to stay operational in the face of widespread power outages following Superstorm Sandy in 2012 (Hampson et al. 2013, 27). Independent of its resiliency benefits, the CHP system is delivering financial benefits to the plant and its ratepayers, generating about $3.5 million in electric bill savings per year (Hampson et al. 2013, 28).

Over the last few years, the Department of Energy has launched an integrated set of efforts focused on energy management, energy performance data, project identification, and financing to help wastewater treatment plants overcome the barriers preventing them from capturing more of these energy efficiency and renewable energy opportunities. DOE's efforts advance a common vision for the sector in which wastewater treatment plants are providing critical services with improved resiliency and low energy and carbon footprints, while recovering energy and/or other resources for use in their own facilities and communities. More specifically, DOE's goals in support of this vision are to demonstrate and drive market-relevant model approaches for achieving 30% or greater improvements in energy, carbon, cost reductions, and recovered waste energy for a variety of wastewater treatment plants, utilizing a range of technical and financing options. This paper will discuss the barriers wastewater treatment plants face as they seek to advance energy efficiency and renewable energy, give an overview of DOE's programs and the types of treatment plants it is working with, and describe how DOE's

[2] For context, the average electricity use at a wastewater treatment plant is about 5,400 kwh per day. This number is derived by dividing the sector's estimated national electricity use (30.2 TWh from Arzbaecher et al. 2013, 5-15) by total number of plants (15,312 from EPA 2012).

programs are helping these plants overcome the barriers. These programs and their goals are consistent with DOE's broader efforts to more intelligently address issues at the energy-water nexus through a balanced portfolio of data modeling and analysis; technology research development, demonstration, and deployment; policy analysis; and outreach and stakeholder engagement (DOE 2014).

Barriers

DOE's efforts are targeted at helping the sector overcome key barriers that stand in the way of greater progress on energy efficiency and renewable energy. DOE's understanding of these barriers is informed by interactions with its wastewater treatment sector partners as well as comprehensive reports from the Water Environment & Reuse Foundation (Willis et al. 2012; Willis et al. 2015). Some of the barriers the wastewater treatment sector faces are common to all or most sectors. The inability to fully engage senior leadership on energy efficiency, or inadequate staff level resources, for example, are two barriers common to almost all sectors. Other barriers, though, are more specific to wastewater treatment plants. Wastewater treatment plant operators are primarily concerned with maintaining reliability and complying with water quality permits at the lowest possible cost to ratepayers. This can lead to conservative attitudes toward operational practices and new technologies that improve energy efficiency, impeding their adoption out of concern they may impact water quality permits. Strategic energy management (SEM) approaches can help overcome this barrier. Plants that adopt SEM approaches manage energy with the same rigor and sophistication as they do other critical aspects of their operations, such as labor and safety. With SEM, energy efficiency becomes an organizational priority that is less likely to be overlooked as plants seek to maintain compliance with permit limits. DOE programs, discussed further in this paper, are advancing SEM within the wastewater treatment sector. Importantly, DOE is documenting success stories to demonstrate significant energy savings are possible in the sector without negatively impacting costs or performance.

The second major barrier relates to financing. While many organizations across sectors struggle to find the money to pay for energy efficiency upgrades, the wastewater treatment sector faces financing challenges that are unique and sometimes more severe than those confronting other organizations. The wastewater treatment sector faces an estimated $270 billion in capital investment needs to meet the water quality goals of the Clean Water Act (EPA 2012). These core infrastructure upgrades tend to take priority over energy projects and soak up most if not all the capital available to these plants. External forms of financing are available, but treatment plant operators and municipal leaders are often wary of authorizing new spending that could lead to rate increases. Energy Savings Performance Contracting (ESPC) is one financing approach that can address this barrier. Through this mechanism, the upfront costs of energy upgrades are paid for over time through a stream of guaranteed energy savings, obviating the need to increase rates to fund projects. Additionally, some wastewater treatment operators are reluctant to invest in energy projects with payback periods longer than the lives of their discharge permits, which typically run three to five years. The fear is that new permit conditions may kick in that change operations to such an extent that they render recently purchased energy efficiency equipment obsolete. Careful planning and project evaluation can, however, identify many energy efficiency opportunities, even capital-intensive ones, that pay for themselves in five years or less.

DOE Programs Driving Energy Efficiency in the Wastewater Treatment Sector

DOE offers a mix of partnerships and technical assistance resources to help the wastewater treatment sector overcome these barriers. Briefly, these programs include:

- The State Energy Program, which has provided about $1.7 million in competitively awarded funds to the states of Florida, Nebraska, New Hampshire, New Mexico, Tennessee (with Alabama), and Minnesota, to work with hundreds of wastewater treatment plants and provide them with technical assistance in the form of benchmarking, energy audits, and energy management training. Most of these funds were awarded in 2015, with success stories and other results expected to be published in late 2017 and early 2018.
- The Better Buildings Sustainable Wastewater Infrastructure of the Future Accelerator (SWIFt), which is working with 27 state, regional, and local agencies to advance energy efficiency in wastewater treatment plants in their jurisdictions. Specifically, SWIFt partners are working to improve the energy efficiency of their more than 100 participating facilities by at least 30 percent and integrate at least one resource recovery measure. Through the three-year Accelerator, DOE will work with partners to develop road-tested tools and other resources to drive energy efficiency across the sector.
- Better Buildings, Better Plants, through which about 20 wastewater treatment agencies have committed to improving the energy efficiency of all their plants by 25% over ten years. Together, this covers about 50 plants of varying sizes and treatment technologies. Several of these agencies have made additional commitments to openly share their energy performance data and energy saving solutions. Additionally, through the Better Buildings Challenge, ten municipalities have included their wastewater treatment operations in the scope of their city-wide commitments to improving energy efficiency by 20% over ten years.
- Five plants are developing advanced energy management systems through DOE's Superior Energy Performance Program. To achieve Superior Energy Performance certification, these facilities implement the ISO 50001 energy management standard and demonstrate third-party verified energy savings. About forty manufacturing plants have already achieved Superior Energy Performance certification, recording energy savings of up to 30%. Results from the wastewater treatment plants are expected upon certification, which should occur in late 2017 and early 2018.
- DOE's Industrial Assessment Centers (IACs) have multiple decades of experience providing free energy audits to small and medium-sized manufacturers, uncovering average energy savings of about 8% of total facility-wide energy use. Recently, the IACs have increased their engagement with the wastewater treatment sector, conducting more than 40 audits for these facilities since 2014. Among the most commonly identified recommendations include installing variable frequency drives on motors and pumps, right-sizing equipment, and installing combined heat and power (CHP) systems.

- DOE's CHP Deployment Program has also increased its focus on wastewater treatment plants in recent years. Since 2014, DOE's regional Technical Assistance Partnerships (TAPs) have helped about 40 wastewater treatment plants evaluate the costs and benefits of installing CHP at their facilities. DOE estimates that more than 200 sites across the country already have CHP systems in place, totaling more than 700 megawatts (MW) of capacity, with another 200 MW of potential at over 1,300 sites. In recognition of CHP's abilities to keep power flowing when the electric grid is disrupted, DOE launched the CHP for Resiliency Accelerator in 2016 to help state and local decision makers factor resiliency benefits when considering CHP projects to power their critical infrastructure, including, though not limited to wastewater treatment plants.

Collectively, since 2014, these programs have partnered with or provided technical assistance to more than 400 plants, representing about 15% of both the nation's population and total wastewater treatment flows. More than 100 of these plants, representing close to 13% of the nation's population and 14% of its wastewater flow, have set energy savings goals ranging from 20 to 30%.[3] If all these plants meet their targets, they would save an estimated $55 to $80 million on their electric bills.[4]

Characterizing DOE's Wastewater Treatment Plant Partners

Relative to the national population, DOE tends to work with larger wastewater treatment plants that consume more energy. The average U.S. wastewater treatment plant processes about 2.3 mgd and serves about 16,000 people; for DOE programs, average flow is about 29 mgd and 219,000 people served. The pie charts below illustrate the drivers behind the differences in the averages. Almost 40% of the nation's wastewater treatment plants are smaller than 0.1 mgd. While these plants represent less than 1% of the participants in DOE's programs, many of the resources developed through these programs will still be relevant and helpful to these smaller plants. Consistent with DOE's goals of influencing large energy users, close to 60% of the participants in DOE's programs are over 10 mgd, while these plants make up 4% of the national total. All national-level statistics in this section are taken from EPA's CWNS.

[3] This includes the plants participating in DOE partnership programs that require goal-setting: Better Buildings Challenge (20% savings goal), Better Plants (25%), and SWIFt (30%).

[4] This number is calculated by first estimating total electric consumption of those 100 plants using their flow rates, which are taken from EPA's Clean Watersheds Needs Survey (CWNS) and multiplying those against published estimated energy intensity values (Arzrbaecher et al. 2013, 5-15). Savings rates, between 20 and 30%, depending on the program, are applied to arrive at estimated kilowatt hour savings. A 7 cents per kWh electricity rate is applied to arrive at total estimated cost savings.

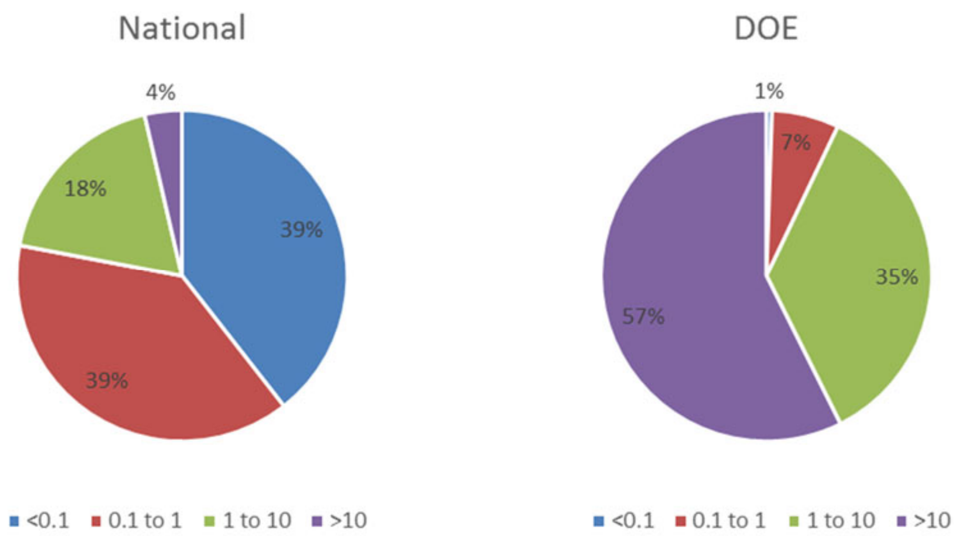

Figure 1: Size breakdowns for wastewater treatment plants: national and DOE participants

While few very small plants are directly partnering with DOE, guidance documents, tools, and reference sheets the Department is developing will be applicable to these plants. Even though they use relatively less energy, smaller plants should not be neglected as they make up such a large share of the national total and hold some advantages in pursuing energy efficiency projects. They often have a more streamlined decision-making process involving just one or two key people, rather than the multi-layered approval process common at larger facilities. Additionally, smaller plants tend to operate with smaller financial cushions. Because of this, energy efficiency projects can be more consequential since they will have a larger impact on the overall financial health of the small plants.

DOE is also working with relatively more plants that utilize advanced treatment technologies, rather than secondary treatment. A stronger focus on advanced treatment plants makes sense for a couple of reasons: 1) they are the more energy intensive plants, with an average estimated energy intensity of about 2,690 kWh/mgd for advanced treatment facilities and 2,080 kWh/mgd for secondary facilities (Azerbaecher et al. 2013, 5-15); and 2) over time, as water quality standards are strengthened, more plants are expected to upgrade to advanced treatment technologies. Advanced treatment technologies, such as membrane bioreactors and biological nutrient removal, are often used to remove pollutants, such as nitrogen and phosphorous, that are not usually addressed by secondary treatment systems. As shown below, the split within DOE's programs between advanced and secondary is about 60% to 40%, while the national ratio is the reverse.

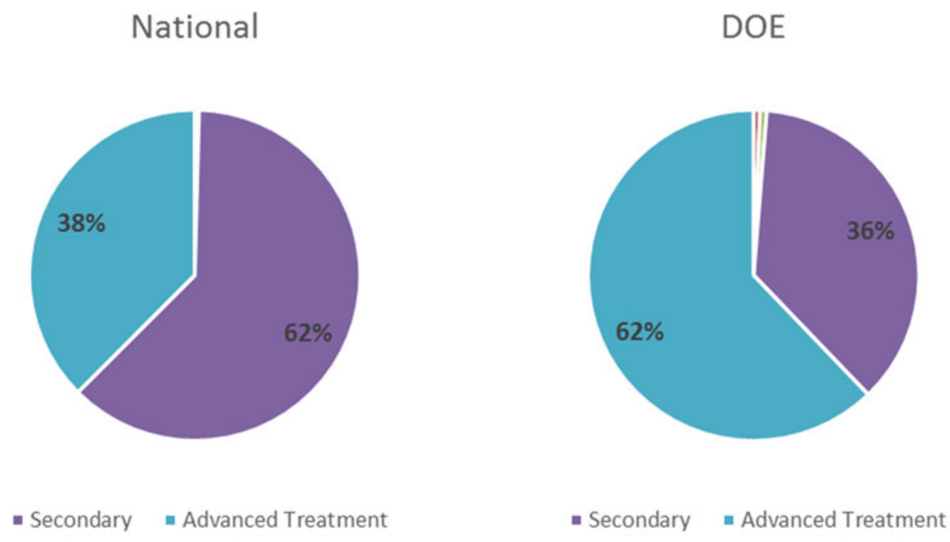

Figure 2: Treatment type breakdowns for wastewater treatment plants: national and DOE participants

Table 1 below shows participation levels in DOE programs on a geographic basis, broken out by EPA region. DOE participants tend to be better represented in the Northeast and West (regions 1 and 2), but currently less well represented in the Great Plains states covering regions 6, 7 and 8. As DOE grows its programs, it will seek to expand in those states where it presently has a lighter presence.

Table 1: Geographic breakdown of wastewater treatment plants in DOE programs

EPA Region	# plants	Total flow
1	23	587
2	17	1,492
3	14	116
4	25	729
5	31	661
6	2	145
7	4	40
8	7	31
9	24	767
10	9	141

Working with Partners to Address Key Barriers

DOE's programs offer an integrated and coordinated set of activities to help wastewater treatment plants overcome the organizational and financial barriers impeding greater progress on energy efficiency. To overcome these barriers, DOE's programs emphasize facility strategies that can be organized into four categories: energy management; energy performance data; project identification; and financing. Table 2 below describes how these facility strategies help to overcome the two primary barriers and the specific programmatic activities DOE has launched to advance those strategies.

Table 2: DOE Activities Addressing Key Barriers

Facility Strategy	Barriers Addressed	DOE Activities that Advance the Strategy
Energy Management Systems	Companies that adopt strong energy management systems commit to managing energy with the same care and importance they give to other issues critical to their organization, such as safety and product quality. By elevating the importance of energy efficiency and developing a systematic approach to energy management, these systems help counter the conservatism that limits the adoption of new energy-saving technologies and practices in wastewater treatment plants.	DOE anticipates publishing over the next 12 to 18 months case studies on the five wastewater treatment plants seeking certification to Superior Energy Performance to demonstrate the benefits advanced energy management systems hold for this sector. For plants not prepared to seek full certification, DOE is developing tools and resources that walk them through the steps of developing energy management systems consistent with ISO 50001. Better Plants partners have been among the early adopters of SEP and ISO 50001, recognizing that these systems help drive plant-level progress toward their corporate-wide energy saving commitments.
Energy Performance Data	Strong energy performance data allows plant operators to more accurately assess the impact and benefits of their energy-saving efforts. Reliable, quantitative data on benefits can help overcome some of the conservatism that keep plant operators from implementing energy efficiency projects. By accurately quantifying the returns on energy efficiency investments, strong energy performance data can also help address financing barriers.	Through SWIFt, DOE is creating a data guide that will describe the pros and cons of various energy efficiency metrics and commonly utilized tools available to help wastewater treatment plants quantify their energy performance. An accompanying 1-page matrix that compares four key publically available data tracking tools will also be published. DOE has also developed a new tool to help plants quickly quantify energy performance, normalized for key variables that affect energy consumption, such as weather, flow volumes, and pollutant concentrations. These resources will be applicable to wastewater treatment plants participating in all DOE partnership programs and should be especially helpful to those in Better Plants, which report energy performance data to DOE annually.

Facility Strategy	Barriers Addressed	DOE Activities that Advance the Strategy
Project Identification	A list of feasible, cost-effective, and easy-to-implement energy-saving projects can generate quick wins for plant operators and generate enthusiasm for greater progress on energy efficiency. Opportunities backed by strong analysis can also ease the flow of financing to projects by building greater confidence in the energy-saving returns.	SWIFt plans to leverage the IAC database, expertise from the centers, as well as audits being conducted through the State Energy Program to develop scorecards to help plants consider and prioritize low- and no-cost energy conservation measures. Meanwhile, the CHP TAPs are ramping up assistance to the sector, coordinating with other DOE programs in the process. The TAPs have conducted CHP feasibility studies at all 14 of New York City's treatment plants, a service facilitated by the city's participation in Better Plants.
Financing	Information on new sources of financing, and examples of how other plants have successfully utilized those sources, can expand the pool of available dollars plant operators can draw from to fund energy projects. Additionally, guidance on appropriately valuing the benefits of energy projects, including their non-energy benefits, can impact return on investment calculations and lead to more projects being funded.	Two guidance documents are under development or planned to help treatment plants navigate financing options: 1) a guide for implementing energy saving performance contracting; and 2) a more general guide evaluating a range of financing options for wastewater treatment plants. The CHP for Resiliency Accelerator will also help partners better understand the value of resiliency as they consider CHP projects at critical infrastructure facilities, including wastewater treatment plants. Additionally, the Better Plants Challenge is showcasing financing success stories from its partners, including a third-party financing agreement the Victor Valley Wastewater Reclamation Authority entered into to develop a new energy recovery project and the Orange Water & Sewer Authority's use of public loan funds to implement a major plant modernization effort expected to reduce electricity use by 20%.

DOE will continue to publish case studies on the Better Buildings Solutions Center that describe replicable models for overcoming these barriers. By recognizing success, DOE aims to show that significant energy savings are possible while advancing, or at least not conflicting with, other organizational priorities such as permit compliance and financial health.

Partnering with Key Stakeholders

Collaborating with other government agencies and non-governmental organizations that have long been active in this space is key to advancing clean energy progress in the wastewater treatment sector. EPA's Office of Water, for example, played an important role in the development of SWIFt as well as the State Energy Program awards, and has partnered with DOE to leverage the IAC and CHP TAP resources. The Water Environment Federation entered into a formal memorandum of understanding with DOE to promote SWIFt, facilitate peer exchange opportunities, and encourage innovative approaches to improve energy efficiency. DOE has also collaborated with organizations such as the Water Environment & Reuse Foundation and Water Research Foundation on specific research projects. These and other groups have also helped DOE engage wastewater treatment agencies to participate in DOE initiatives, and have agreed to promote DOE-developed solutions and resources to their members.

Conclusion

The wastewater treatment sector is at an important turning point as it seeks to modernize its operations and move to a future that includes lower energy consumption and greater reliance on renewable sources of power, which holds important benefits for communities, such as reduced costs, improved environmental performance, and enhanced resiliency of critical infrastructure. Most agencies are broadly aware of these benefits, but have yet to fully prioritize energy efficiency and renewable energy. By recognizing success, DOE is seeking to elevate the importance of clean energy in the wastewater treatment sector, and induce more plants to pursue energy efficiency and renewable energy on their own. At the same time, DOE is working with its industry partners to develop replicable models that will make it easier for plants to follow the leaders in adopting energy-saving technologies and practices. DOE is also funding research and development projects to, among other things, bring new, more efficient treatment technologies to market and expand the range of available, cost-effective energy recovery options. As the market and technologies evolve, DOE will adapt its programs to most effectively accelerate the adoption of clean energy innovation in the wastewater treatment sector.

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