Value of Energy Efficiency from Water/Wastewater

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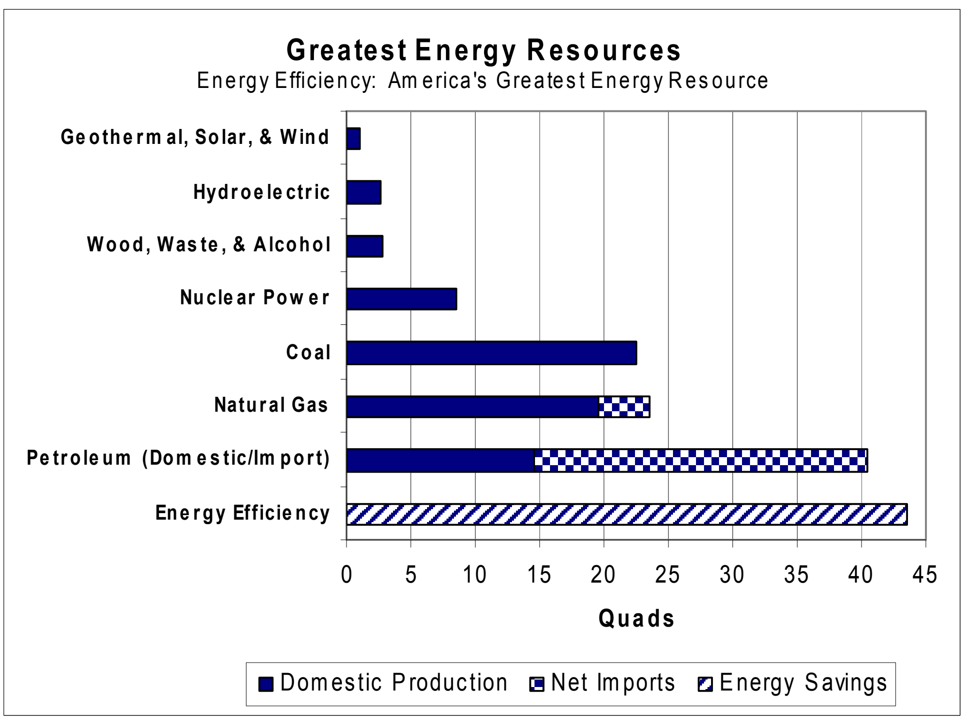
ABSTRACT

In recent years, energy efficiency has become a popular topic amongst communities in the United States and abroad. This has come to the forefront due to an overall focus on the environment and to be as efficient and environmentally focused as possible. By incorporating modifications into a wastewater facility, a community can not only accomplish energy efficiency, but also save their community money, and become a model that other communities can follow on a path to becoming energy-efficient and moving toward sustainability.

Introduction

Energy efficiency is an attribute a community needs to achieve sustainability. Interest in energy efficiency is growing. In itself, energy efficiency is an abundant fuel that, if identified, assessed and implemented, can be far less costly than other fuels.[1]

Figure 1. Greatest Energy Resources



[1] Erhard, Ray. Water and Energy Interdependence. WEF/WERF: Sustainable Energy Management Approaches in Wastewater Treatment Facilities. San Diego Convention Center. San Diego, CA October 13, 2007.

Existing Conditions

Interest in achieving energy efficiency in wastewater is growing.[2] Many facilities have recognized the value associated with implemented energy-efficient modifications.[3] An identified result of implementing energy-efficient modifications at wastewater treatment facilities in the United States' is that their energy consumption then becomes similar to European energy consumption rates.[4] The challenge associated with energy efficiency implementation is that presently there has not been a state or federal regulatory agency identified that has energy efficiency in its design code.[5] This causes all actions associated with energy efficiency to be voluntary, proactive and more environmentally conscious. Further, by not having design codes that include energy efficiency requirements, we simply continue to design and construct wastewater systems that meet effluent limits but are not necessarily energy-efficient throughout their life span.

Actions Taken

To move towards energy efficiency, wastewater treatment energy-efficient best practices are becoming more available.[6,7] Also, the Water Environment Federation's "Energy Conservation in Wastewater Treatment Plants" Manual of Practice (MOP) is under revision. These documents are the tools wastewater superintendents should utilize to ensure the design they receive is energy-efficient. The documents should also be utilized by regulatory agencies, design consultants, management and decision makers to ensure that all entities know what needs to be done for the design to be energy-efficient. Having all groups utilize these documents, will ensure that all designs will be energy-efficient.

The best practices that are primarily being implemented to produce energy efficiency are:

1. Flexible membrane diffusers
2. Fine-bubble aeration systems
3. Dissolved oxygen control
4. Variable speed drives
5. Energy use meters installed on all major process systems
6. Variable capacity blowers
7. Design requirements to treat existing flows effectively and efficiently
8. Proactive planning, involving operations, management, administration, designers and utility representatives

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[2] Fok, Stephen. PG&E Municipal Water & Wastewater Baseline Study. Consortium for Energy Efficiency Program Meeting. Boston, MA. June 14-16, 2006

[3] Morrow, Patrick, and Scott Halbrucker. Owner Implementation of Fine-Bubble Lagoon Aeration Equipment. Wisconsin Wastewater Operator's Association 41st Annual Conference. LaCrosse Civic Center and Radisson Hotel. LaCrosse, WI. October 24, 2007.

[4] Morrow, Patrick, and Scott Halbrucker. Owner Implementation of Fine-Bubble Lagoon Aeration Equipment. Wisconsin Wastewater Operator's Association 41st Annual Conference. LaCrosse Civic Center and Radisson Hotel. LaCrosse, WI. October 24, 2007.

[5] Erhard, Ray. Water and Energy Interdependence. WEF/WERF: Sustainable Energy Management Approaches in Wastewater Treatment Facilities. San Diego Convention Center. San Diego, CA October 13, 2007.

[6] FOE Best Practices

[7] EPA Sustainability – Best Practices

9. More knowledgeable equipment selection to efficiently meet existing and future design flow conditions

These best practices provide the insight necessary to make designs and system operations energy-efficient from existing loading conditions to design conditions.

Implementation

Implementation of energy-efficient modifications has been enabled through the Focus on Energy program as the result of site assessments and incentive grants. The Focus implementation approach for the water/wastewater programs has been to provide site surveys, develop assessment reports and provide incentive grants for implementation.

Site surveys are performed to learn the site, its operation and obtain data. This data and information is then used to develop an assessment of the facility to identify where energy efficiency opportunities exist. Upon identification of the opportunities, a forecast of the savings is developed, an estimate of the cost of the modification and the payback period are provided. This program approach has resulted in a number of energy-efficient modifications to be implemented. This has resulted in reducing the energy consumption of wastewater treatment facilities. Following are examples of implemented projects that have been successfully reducing facility energy consumption.

Northern Moraine Wastewater Treatment Facility

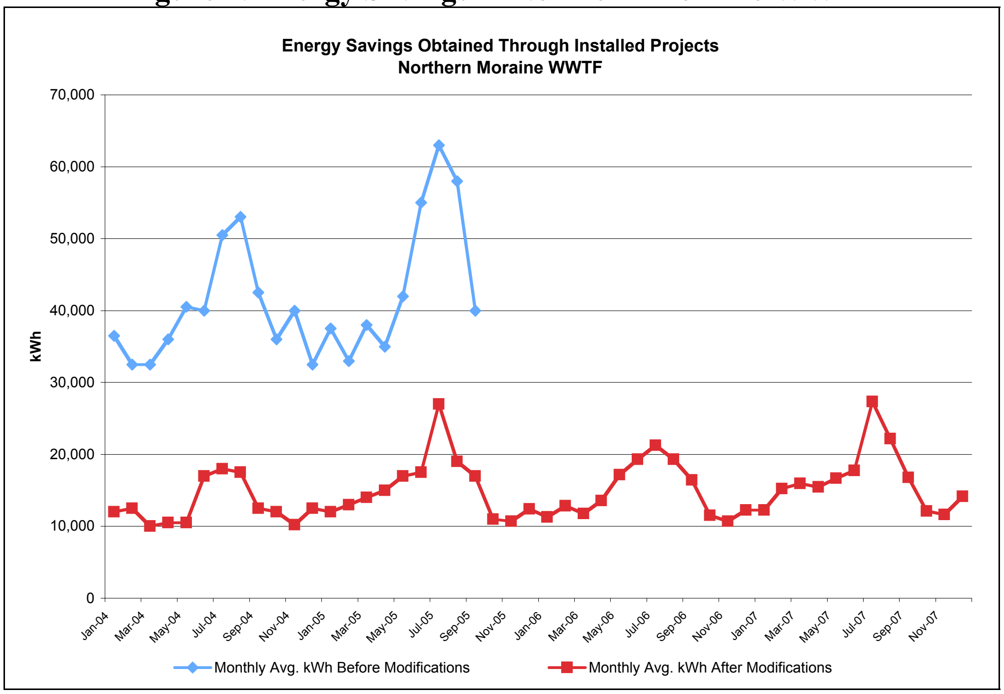
The Northern Moraine Utility Commission Wastewater Treatment Facility was constructed in 1976 and has had no major modifications. The facility is a dual package activated sludge treatment system with a design flow of 0.6 million gallons per day (MGD). The present flow to the facility is 0.3 MGD; therefore, it is 50 percent hydraulically loaded. In the package facilities, the wastewater was aerated with coarse-bubble diffusers before flowing onto a secondary clarifier. The solids from the treatment process are conveyed to an aerobic digester aerated and mixed with a coarse bubble aeration system. The effluent from the clarifier passes into a distribution box and then is discharged into seepage cells for final disposal. The annual electric consumption for the facility is 474,590 kWh, relating to an energy use of 4,334 kWh/million gallons for the entire facility.

The energy assessment identified an energy-efficient opportunity changing the existing coarse bubble aeration system in the aeration tank and aerobic digester in coordination with a reduction in blower capacity would lead to a significant energy savings. The modification was to install a fine-bubble aeration system in both package facilities and provide smaller capacity blowers. The existing forecasted aeration energy consumption was 523,000 kWh/year this was forecasted to be reduced to 196,000 kWh, resulting in a savings of 326,700 kWh/year.

This savings was also coordinated with a change to a dissolved oxygen (DO) monitoring and control system. The automatic DO system controls the blowers' operation to provide only the air flow rate necessary to achieve treatment requirements and mixing conditions. Further, the facility superintendent took a step to save energy in their aerobic digester by providing controls to limit the number of hours of operation of the digester blower. The operations personnel modified the digester to the point that the digester blowers operate only seven to eight hours per day as compared to their previous mode of operating continually. By applying best practices to the wastewater treatment facility, a nearly 70 percent reduction has been realized at the facility.

The graph below, presents years of energy use. It can be observed that the system continues to save 70 percent continually over a number of years of operation.

Figure 2. Energy Savings at Northern Moraine WWTF



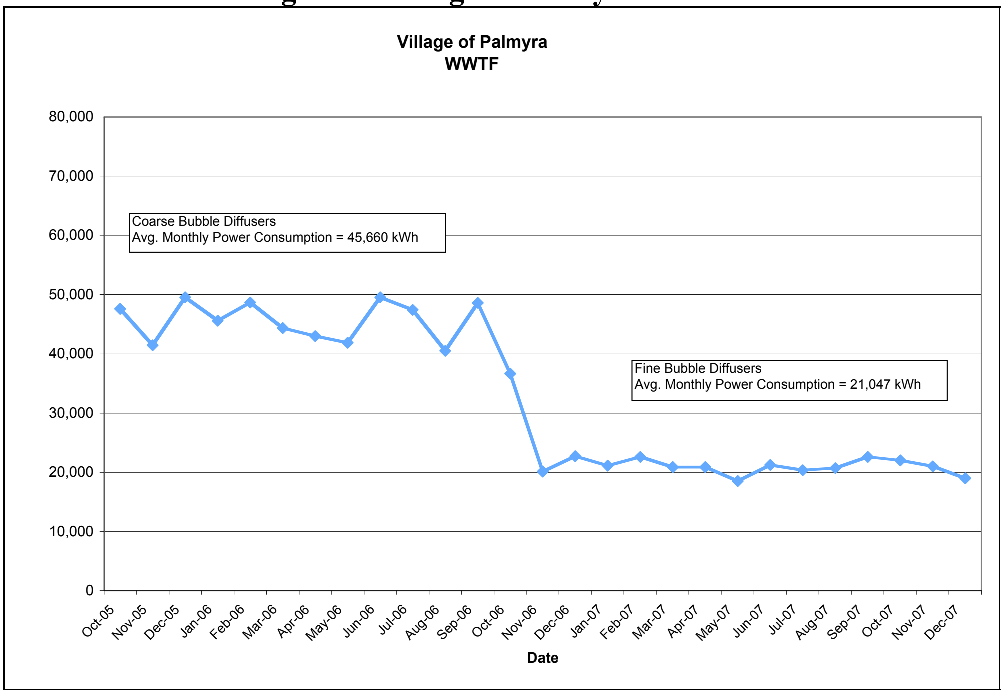
Palmyra Wastewater Treatment Facility

The Village of Palmyra has an aerated lagoon wastewater treatment facility. The lagoon system consists of three lagoons, two aerated and one settling. The two aerated lagoons have a combined volume of 3.94 million gallons. Each lagoon is aerated through helixor aerators with three 40 hp blowers supplying the air. The design conditions for the lagoon system are 0.233 MGD and an influent of 335 mg/l (650 pounds per day (ppd) biological oxygen demand (BOD). However, the present loading is only 0.184 MGD with a BOD of 232 mg/l (355 ppd BOD). The WWTF is 79 percent liquid loaded and 55 percent organic loaded. The annual electric consumption identified during the assessment was 494,710 kWh/yr, relating to an energy use of 7,340 kWh/million gallons for the entire facility.

The energy assessment of the facility found that the aeration system could be made more energy-efficient by converting it to a fine-bubble aeration system. The initial modifications were to install a fine-bubble aeration system as well as new blowers. This modification forecasted a savings of 214,600 kWh/yr, resulting in an annual savings of $11,600. However, the village chose to install only the new fine-bubble diffusion system resulting in a reduction in savings to an estimated 136,700 kWh/yr. The village did reduce the speed of the existing blowers as much as they could to obtain the maximum savings from their blowers.

The actual overall reduction is presented on the Palmyra electric usage graph below. As the figure shows, they reduced their electric consumption by nearly 50 percent by applying the best practice of utilizing a fine-bubble aeration system. In fact, the village received a letter from their energy supplier asking them if anything at the wastewater treatment facility was turned off, since their bill reflected the immediate reduction in consumption as soon as the revised aeration system was installed. This does present the value a facility can realize when utilizing a best practice technology.

Figure 3. Village of Palmyra WWTF



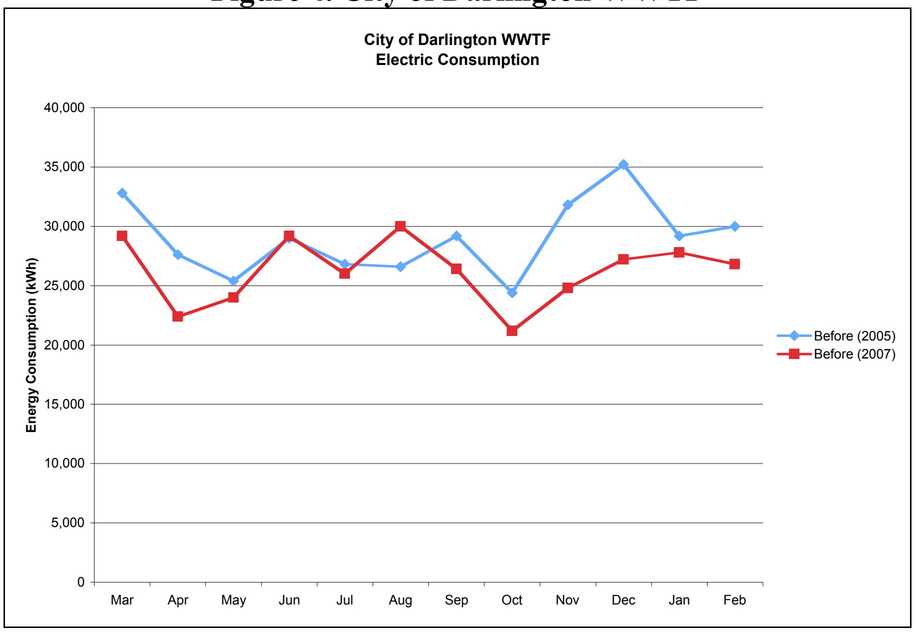
Darlington Wastewater Treatment Facility

The City of Darlington has an activated sludge, oxidation ditch, wastewater treatment facility. The facility has a design capacity of 0.58 million gallons per day and an organic capacity of 612 ppd BOD. It is presently treating 0.201 million gallons per day and 917 ppd BOD. This results in the facility being 35 percent hydraulically loaded while being 150 percent BOD loaded. The influent is treated to a secondary level and then discharged to a receiving stream. Despite the high organic loading, the facility has not had a problem in meeting its discharge-permitted effluent limits. The annual electric consumption for the facility is 388,800 kWh relating to an energy use of 5,298 kWh/million gallons.

The energy assessment developed for the facility identified a number of opportunities where energy could be saved. However the best opportunity was to address its secondary treatment process, installing variable frequency drives on its aeration equipment operating its oxidation ditch. It was identified during the survey that the dissolved oxygen concentrations in the ditch ranged from 2.4 mg/l to 6.0 mg/l DO. This range represents an opportunity where energy could be saved, because a DO concentration greater than 2.0 is not necessary to provide treatment. Therefore, the assessment focused on the amount of savings that could be obtained if the DO concentrations could be controlled. The assessment forecasted that a savings of nearly 28 percent of the aeration system energy consumption should be saved or nearly 60,000 kWh/yr.

The proposed modification of installing an automatic DO system was implemented and now the facility is realizing a savings of 15 to 20 percent as presented on the following graph showing the energy consumption prior to the modification and then afterward. This is an example of how the application of a best practice, DO control, can reduce energy consumption while continually saving energy for the facility.

Figure 4. City of Darlington WWTF



Oconto Water System

The City of Oconto Water Department identified an energy efficiency opportunity: controlling pump discharge flow rate by throttling discharge valves. The water department was throttling three of its municipal water supply pumps to make its wells work properly. The problem the water department was experiencing was that the drawdown of the wells was increasing, responsive to reduced recharge of the well. Therefore, to maintain supply and quality, the wells were throttled to lower their flow rate, maintain drawdown and retain water quality. The water department knew valve throttling was an effective operational approach, but they also knew it was not energy-efficient. Therefore, they utilized the Focus program to purchase variable frequency drives to control the output of the pump by controlling its speed and reducing the energy consumed by the wells. The variable speed drives also provided the correct tools for the utility to better manage the drawdown and the recharge of the wells. The water department is experiencing the following energy savings at the wells:

Table 1. Oconto Water Department Well Operation Summary

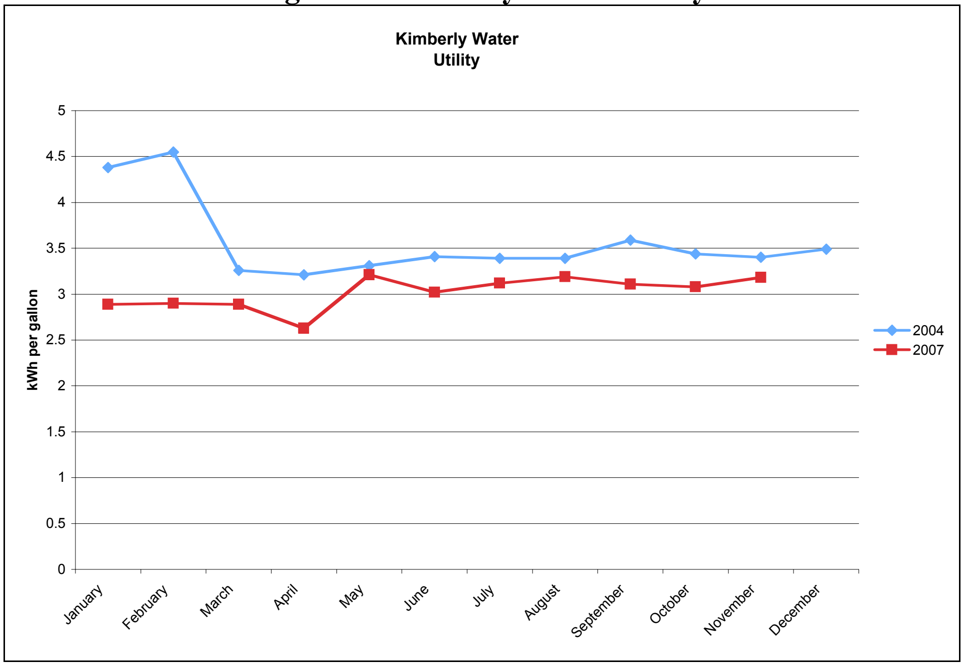
Well Number	Throttled		Amp Draw		Savings
	From (GPM)	To (GPM)	From	To	%
5	900	700	150	99	33
7	1,200	870	170	98	42
8	1,600	1,100	170	125	26

The Oconto Water Department has experienced the value of best practice application of variable speed drives to control the energy consumed to do the work done needed to meet the water demands of the community.

Kimberly Water System

The Kimberly Water Utility implemented an energy efficiency modification at its John Street water facility. The energy efficiency opportunity that was identified and implemented called for the present operation of pumping from a deep well into a ground reservoir, from the ground reservoir through a softening process, and then into their distribution system to be modified. The modification called for a larger premium efficient motor and a variable frequency drive to be installed on the facility's deep well pump. With the modifications the system then had the ability to pump directly from the deep well through the softening system, directly into their distribution system and to vary the pumping flow rate. This energy-efficient modification was an application of a best practice to minimize pumping energy, particularly a double pumping operation, as was the case with the John Street facilities. The modification allowed the system to pump water one time, rather than pump, discharge and then pump again. The modification installed reduced the electric consumption for the deep well at John Street, from an average of 3.57 kWh/gallon to 3.02 kWh/gallon or a reduction of approximately 15 percent. The variable speed drive provided additional flexibility for operation. The variable frequency drive provided a tool for the flow rate to be adjusted as the water quality adjusted to meet the capability of the softening system. It also allowed the operators to vary flow rate to better manage electric demand during peak demand periods. The application of this best practice at John Street has lead to the assessment of using the same best practice in other locations in the distribution system.

Figure 5. Kimberly Water Utility



The application of energy efficiency best practices can readily occur at a water system as well as at a wastewater treatment facility. Therefore, public utilities should become aware of the level of savings achievable at both utilities.

Sheboygan Regional Wastewater Treatment Facility (WWTF)

The Sheboygan Regional WWTF serves the City of Sheboygan and six neighboring communities, totaling approximately 85,000 people. The WWTF has a present average daily flow of 11.0 MGD, with a design capacity of 18.4 MGD.

The facility has the following general treatment processes, screening and grit removal, followed by primary clarification, followed by activated sludge for secondary treatment, final clarification, disinfection with discharge to receiving waters. The biosolids produced are processed using a combination of eight anaerobic digesters, two large biosolids storage tanks and a belt thickener. The annual electric consumption at the facility is 5,973,500 kWh, relating to an energy use of 1,330 kWh/million gallons.

The energy assessment for the WWTF identified a number of potential energy efficiency opportunities including: change to high-efficiency lighting, installing premium efficient motors, refurbishing and placing back into operation a pressure tank and control system on its final effluent recycle water system, assessing its compressed air system, addressing its HVAC systems throughout the WWTF, and evaluating its raw sewage pumping system for application of variable frequency drives.

The Sheboygan Regional Facility reviewed these identified energy efficiency opportunities and became very interested in the savings it could realize by doing the same work but using less energy and reducing the cost of energy. The result of this was an extremely proactive reaction, to the extent that the facility superintendent took the survey and moved forward to an audit approach. He reviewed his facility to determine where he could save energy and he reviewed his more active collection system pump stations to identify where energy could be saved in operation and/or through improved retrofit approaches. The following is a listing of the energy efficiency modifications the facility has implemented during the program years. The facility has normally been implementing a project or two per year, with the goal to become energy self sustaining.

Pump Station Projects:

- *North Avenue Pump Station* – Installed three 60 hp premium efficient motors and variable frequency drives of the pumps. These modifications resulted in a 20 percent reduction in yearly kWh consumption.
- *Kentucky Avenue Pump Station* **-** Removed five eddy current drives and replaced them with three soft starts, two variable frequency drives, two premium efficient motors and improved control system. These modifications resulted in a 30 percent reduction in yearly kWh consumption.

Wastewater Treatment Facility Projects:

- *Influent Pump Station (on-site)* – Removed one eddy current drive and one direct connected motor. Installed two variable frequency drives, two soft starts, two premium efficient motors, three new drive controllers and updated controls and monitoring system. The modifications resulted in a 20 percent reduction in yearly kWh consumption.
- *Aeration Blower* – Existing blowers were failing and would require total rebuilding. Removed two 250 hp positive displacement blowers and replaced with two high-efficiency single-stage blowers and updated dissolved oxygen monitoring and control system. The modifications resulted in a 20 percent reduction in kWh/yr consumption.
- *Sludge Boiler Replacement* – One existing boiler had failed with two other units in similar condition. Therefore, the facility decided to change the boilers prior to more units failing. Removed existing boilers and replaced with two 3.8 million BTU fire tube boilers, installed new piping and controls to interconnect the sludge system heat loop with the building heat loop, and included monitoring and control system to optimize the sludge boiler heat to heat the building. The modifications resulted in a 46 percent reduction in the facilities natural gas usage for building heat.
- *Cogeneration Project* – The facility was flaring off excess biogas. The site has been utilizing biogas to operate a raw sewage pump and to augment its heating system. However, to better utilize the biogas generated at the facility, the facility moved forward and installed 10 microturbines for producing electricity and then utilizing the heat produced by the generation of electricity to supplement the heat needed for its anaerobic digesters. Also, to improve the benefit of utilizing the biogas, the superintendent searched for and located a high strength waste that is now trucked to the site and metered into the digestion system in such a control scheme that the volume of gas production is nearly constant to maintain operating all of the microturbines. Therefore, utilization of a renewable source of energy is a positive for the Sheboygan Regional Facility.

In 2007, these energy efficiency modifications produced the following savings shown in Table 2.

Table 2. Energy Efficiency Modifications

Electricity	**kWh**	**Dollars**
North Avenue Pump Station	55,680	5,658
Kentucky Avenue Pump Station	178,600	16,206
Influent Pump Station	180,000	12,510
Aeration System Blowers	358,560	24,920
Cogeneration (payment from Power Company)		27,118
Total Electricy Savings	772,840	86,412
Natural Gas	**Therms**	**Dollars**
Sludge Boilers	61,125	52,418
TOTAL 2007 ENERGY SAVINGS		**$138,830**

Source: Energy Reduction Projects Sheboygan Regional WWTP presentation delivered at UW Madison Managing Energy in Water and Wastewater Facilities, April 2008.

Therefore, it can be recognized that the Sheboygan Regional WWTF is proactive in implementing energy efficiency projects. Presently, the facility is investigating the potential value of a microhydro turbine to produce electricity from the facility's final effluent discharge.

Conclusion

Implementation of energy efficiency modifications can lead to a savings of 20 percent to 70 percent at public water/wastewater utilities. Additional value that can be attained by communities through implementation of energy efficiency modifications are:

- Reduced energy consumption
- Reduced utility bills
- Reduced maintenance on equipment
- Improved discharge quality
- Increased treatment capacity
- Doing the "right thing"
- Leading by example

A valuable result of energy efficiency is that the community's utility will lead by example. If the commercial, residential and industrial sectors within a community see that the public utility has made energy efficiency a goal, and that goal has been achieved, they will most likely note the success, relate it to their operations, identify the value it would bring them, and proactively proceed to identify the "low-hanging fruit" to initiate energy efficiency in their own operations. Having implemented the easy to do energy efficiency opportunities, they will proceed to develop a continuous process to assess energy efficiency to assure all facets of their work will become and remain energy-efficient.