United States Environmental Protection Agency

Wastewater Management Fact Sheet

Energy Conservation

INTRODUCTION

Continual increases in energy costs in the United States affect wastewater treatment plants (WWTPs) just as they do other facilities. Energy costs can account for 30 percent of the total operation and maintenance (O&M) costs of WWTPs (Carns 2005), and WWTPs account for approximately 3 percent of the electric load in the United States. Furthermore, as populations grow and environmental requirements become more stringent, demand for electricity at such plants is expected to grow by approximately 20 percent over the next 15 years (Carns 2005). Energy conservation is thus an issue of increasing importance to WWTPs. This fact sheet describes possible practices that can be implemented to conserve energy at a WWTP.

APPLICABILITY

Evaluating a facility for energy efficiencies and adopting an energy conservation plan often result in increased treatment efficiency, along with the potential for increased treatment capacity, an increased ability to meet effluent limitations, reduced O&M requirements, and reduced energy costs.

The main requirement on the part of the WWTP staff is a commitment to spend the initial time needed to evaluate the system, to follow through with the development of an energy conservation plan, and to implement the plan's recommendations.

KEY COMPONENTS OF AN ENERGY CONSERVATION PLAN

A number of U.S. facilities, including the Washington Suburban Sanitary Commission (WSSC) and the East Bay Municipal Utility District (EBMUD) in the San Francisco Bay area, have developed and implemented energy conservation and management plans (Taylor 2005, Cohn 2005). These plans typically have the goal of reducing energy costs by a specified percentage.

The key components of an effective energy management plan are:

- Creating a system to track energy usage and costs
- Performing energy audits of major operations
- Upgrading equipment, systems, and controls, including facility and collection system improvements to increase energy efficiency
- Developing a cost-effective electric supply purchasing strategy
- Optimizing load profiles by shifting operations where possible
- Developing in-house energy management training for operators

These components are explained more fully below.

Tracking and Evaluating Energy Usage and Costs

The first step in evaluating energy usage and costs at a treatment facility is gaining an understanding of where the energy is being used. This information allows the WWTP staff to identify areas for conservation and to determine where energy is being used inefficiently. At many WWTPs the facility's energy use is recorded at a single recording location. The disadvantage of this method is that it does not allow personnel to see the energy used by each individual process, and thus operating inefficiencies in these processes might be overlooked.

For example, the WSSC commissioned the establishment of an Energy Information System (EIS) in fiscal year 2002 (Taylor 2005). A Java Web application replaced the spreadsheets that had been used to track energy data. The EIS database tracks energy consumption, demand, and costs by major processes at the Blue Plains WWTP in Washington, DC. With this information, an energy audit can determine the most energy-intensive operations.

A facility's energy usage can be compared with energy usage at similar facilities to identify areas that should be examined further. Once the efficiencies of different pieces of equipment and process operations are determined, the facility can begin to develop energy conservation measures by answering the following questions for each piece of equipment and process:

- Does the process/equipment need to run at all?
- Is it possible to run the process/equipment for fewer hours?
- Is it possible to shift this activity to off-peak hours (for some auxiliary functions)?
- Are energy efficiency process modifications or equipment upgrades practical and possible while maintaining equipment efficiency?
- What equipment is most energy efficient for this process?
- Is it possible to run more efficient pumps for normal base loads or to use lower-efficiency, larger units for only the peak flows?

The answers to these questions will help determine what processes can be modified or what equipment can be operated more efficiently or replaced to save energy (Carns 2005).

Performing Facility Energy Audits

A comprehensive energy audit allows a facility to determine the largest, most energy-intensive operations. By determining the energy demands of the various processes and equipment at a WWTP, personnel can look at improving the treatment energy efficiency. The objectives at most facilities are lower energy consumption, demand, and costs (Taylor 2005). In some cases, life-cycle cost analyses can be used to help assess and optimize the selection of individual components and systems.

For example, the WSSC developed an energy performance project evaluation process to assist in determining whether to proceed with different opportunities to upgrade or replace various systems (Taylor 2005). Equipment upgrades and maintenance were then funded from the energy savings realized. The WSSC's Energy Performance Project had two phases. Phase I involved detailed engineering feasibility studies with associated evaluation and recommended technical solutions. Preliminary design work was done and the scope of the project, costs, and financing were established.

Phase II involved more detailed design work, including construction, commissioning, and training, along with operation and maintenance. Phase II also included monitoring and verification of the performance of the improved systems and the savings that resulted (Taylor 2005).

Upgrading Equipment, Systems, and Controls

Numerous processes can be upgraded to improve the energy efficiency of WWTPs. Some of these were demonstrated when EBMUD instituted an aggressive energy management program in 2001 (Cohn 2005). EBMUD serves approximately 600,000 people in the San Francisco Bay area of California. Its Energy Management (EM) program included energy demand reduction, on-site energy generation, and modifications to the way electricity was purchased. Energy usage was examined, and a variety of processes were targeted for energy demand reductions. EBMUD modified some traditional processes, and the result was large savings in energy usage. For example, in the initial stage of the activated-sludge process, a 100-horsepower surface aerator was replaced with a 25-horsepower subsurface aerator. In addition, an aerated grit chamber that used approximately 2,900 megawatts per year was replaced with a vortex system, resulting in energy savings of approximately 70 percent per year (Cohn 2005).

EBMUD also implemented additional improvements, including the following:

- Installing high-efficiency influent and effluent pumps, high-efficiency motors, and variable-frequency drives
- Discontinuing second-stage activated-sludge mixing

- Adding plastic balls to prevent heat loss and evaporation losses in the oxygen production vaporizer pit
- Tying in pipes on gas recirculation blowers to allow one blower to service two mixing tanks

These energy-efficient strategies and modifications, along with others, resulted in an estimated annual savings of $2,796,000 (California Energy Commission, EBMUD Case Study, 2003).

In addition to the upgrades and modifications mentioned above, there are numerous other process changes that can contribute to energy savings. High rate diffusers are capable of supplying large quantities of air or oxygen with low pressure drop and small bubble size (approx. 1-4 mm). Fine bubble diffusion is inherently more effective than coarse bubble diffusers in improving oxygen transfer efficiency. Systems can be purchased that incorporate many of the technologies mentioned in this fact sheet into an efficient aeration system. Aeration systems can incorporate high-efficiency motors, variable-frequency drives (VFDs), and dissolved oxygen monitoring. This, in conjunction with energy efficient aeration systems, can provide energy savings of 10 to 25 percent over traditional aeration processes (Pacific Gas and Electric Company, 2006).

VFD motors are becoming increasingly popular. A VFD is an electronic controller that adjusts the speed of an electric motor by modulating the power being delivered (California Energy Commission, Variable Frequency Drive, 2003). For applications involving varying flow requirements, mechanical devices such as valves are often used to control flow. This process uses excessive energy and can create less-than-ideal conditions for the mechanical equipment involved. VFDs enable pumps to accommodate fluctuating demand, resulting in operating at lower speeds and conserving energy while still meeting pumping needs. According to the California Energy Commission, VFDs can result in significant energy savings: a VFD can reduce a pump's energy use by as much as 50 percent. Because the benefit of a VFD is dependent on system variables like pump size, static head, friction, and flow variability, it is imperative to fully examine each application before specifying a VFD. For example, the Onondaga County (NY) Department of Water Environment Protection retrofitted VFDs on the activated sludge pump motors. Combined with other savings from reducing aeration basin blowing and improving the efficiency of some pumps, the plant saved 2.8 million kW-hrs per year, an annual cost savings of over $200,000. Since the cost for implementation of the program was just over $230,000, the project payback period was 13 months for the 80 million gallons per day facility (U.S. DOE, 2005).

Another technology readily available to plants is the use of high-efficiency motors. Since pump and blower motors can account for more than 80 percent of a WWTP's energy costs and high-efficiency motors are up to 8 percent more efficient than standard motors, it is readily apparent that high-efficiency motors can contribute greatly to reducing facility energy costs.

Design improvements and more accurate manufacturing tolerances are keys to the improved efficiencies with these motors. In addition, these motors typically have greater bearing lives, lower heat output, and less vibration than standard motors. While high efficiency motors have a 10-15 percent higher initial cost, with their lower energy consumption and lower failure rates, these motors should be considered for all new purchases and replacements (California Energy Commission, Energy-Efficient Motors, 2003).

An example of an emerging technology with potential application to WWTPs is fuel cells (Figure 1). Like a conventional battery, a fuel cell uses two reacting chemicals separated by an electrolyte to produce an electric current. Unlike a conventional battery, however, a fuel cell is not charged prior to use. The chemical reactants in a fuel cell are fed continuously to the cell to provide constant power output. The reaction involves no combustion and no moving parts, and it produces little pollution. Heat generated in the process can be recovered and used in the facility.

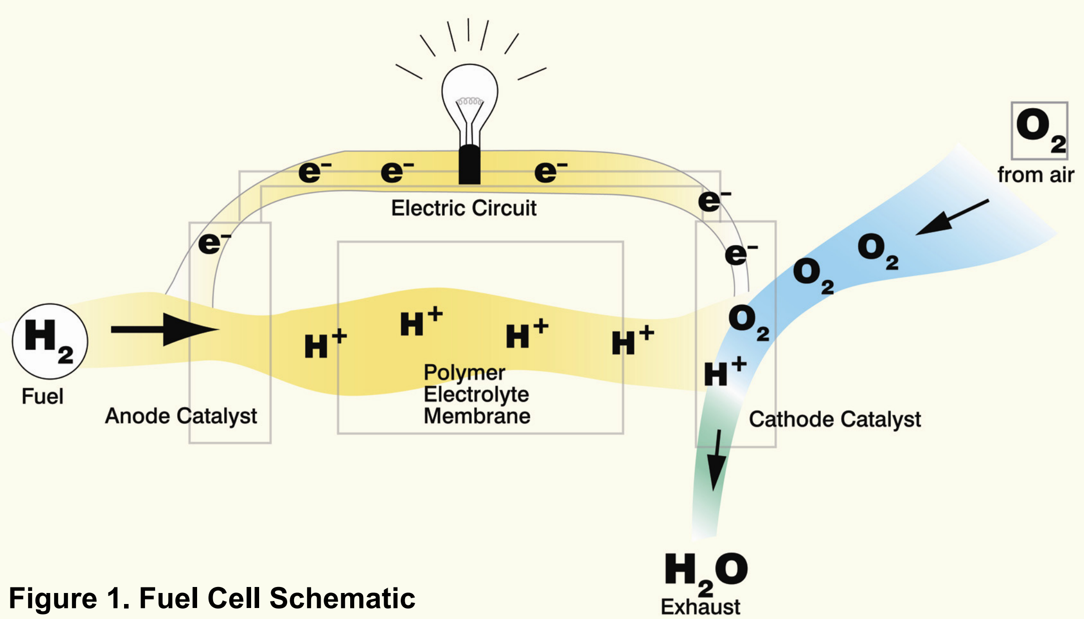

Figure 1. Fuel Cell Schematic

Although fuel cells are costly to install, they have distinct advantages over the combustion power sources at WWTPs, such as diesel generators. One advantage of the fuel cells is lower harmful emissions. Using diesel driven generators, especially for continued use as a supplemental power source, can lead to air quality problems. Many states (including California) have established strict emissions limits on all diesel engines. While most older diesel engines can not meet the new air restrictions, newer high-efficient, low emission engine driven generators are now available.

As a fuel source, fuel cells use hydrogen, which can be derived from methane, natural gas, or anaerobic digester gas. Digester gas must be scrubbed before use to remove compounds that can be problematic for fuel cells (U.S. EPA 1995). Fuel cell emissions are so clean that they are exempt from many Clean Air Act permitting requirements (California Energy Commission, Fuel Cells, 2003).

Energy conservation might also include the investment in Auxiliary and Supplemental Power Sources (ASPS) or energy recovery equipment, which will allow energy to be produced on-site (EPA, 2006). This energy could then be used to run processes or power buildings on-site, partially or fully, or could be sold to other users if there is an appropriate delivery system to the electric grid. Possible ASPS include bio-gas-fueled internal combustion engines, microturbines (Figure 2), wind turbines, fuel cells, and solar cells. Some ASPS available do not conserve energy but replace off-site generation with on-site generation.

The city of Pacifica, California, recently began operating 1,800 solar panels to supply a portion of the Calera Creek Water Recycling Plant's electric needs. The solar panels provide 10 to 15 percent of the treatment plant's energy needs. The facility estimates $100,000 per year in energy savings (Manekin, 2006).

Making improvements to the wastewater treatment plant and the collection system has also been found to result in energy savings. In particular, installation of an equalization basin allows the plant to even out pumping needs, and so allows for "peak shaving" by running pumps during off-peak hours (Fuller, 2003). Reducing infiltration and inflow in the collection system also can pay for itself in energy savings. By rehabilitating damaged or deteriorated sewer lines and eliminating improper connections to the system, the overall flow to the WWTP is reduced, thus reducing the amount of energy required to treat the flows.

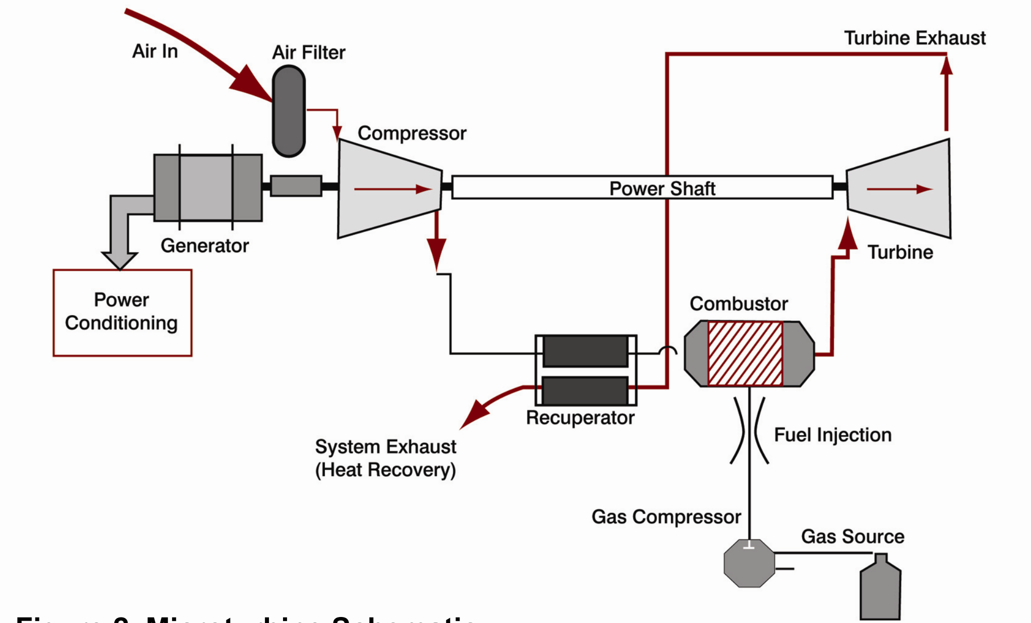

Figure 2. Microturbine Schematic

Another improvement to a wastewater treatment plant that can result in large energy savings is a Supervisory Control and Data Acquisition (SCADA) system. These systems use computers to automate process monitoring and operational control. Because such systems monitor energy usage, cost savings can be realized, along with the savings associated with enhanced process control (Fuller 2003). SCADA systems can monitor and control the activity of wastewater systems from a single location. Immediate detection of problems through diagnostic displays enables quick intervention for fast resolution. Operators can easily compensate for seasonal flow and wet weather by automatically adjusting set points. Centralized control and monitoring of distribution and collection systems provides data for water modeling and energy use optimization, as well as predictive maintenance of distributed equipment.

In addition to monitoring treatment processes, SCADA systems can provide continuous monitoring and control of plant operations such as:

- Wastewater collection systems
- Water distribution systems
- Remote operations
- Programmable logic controllers
- Pump stations
- Sewer diversion
- Wet weather overflow protection

Creating the most efficient electric supply purchasing strategy, optimizing load profiles, and reducing costs

At many facilities, the administrators are unaware of the rate structures of their electric bills. Electricity is typically billed in two ways: (1) by the amount of energy used over a specific period, measured in kilowatt-hours and (2) by demand, the rate of the flow of energy, measured in kilowatts. Electric utilities structure their rates on the basis of the user's required voltage level, the electricity usage at different hours of the day, and the peak demand. A WWTP might be operating equipment when electricity is at peak rates, resulting in unnecessary costs. Plant personnel should become familiar with the energy rate structure to determine whether they can operate equipment at off-peak hours or reduce energy consumption during peak-demand hours.

For example, the WSSC revised its power purchasing to optimize energy costs at WWTPs. The WSSC purchases blocks of power supply (kilowatt-hours) at a wholesale, competitive level. This provides for a predictable baseload cost. The WSSC purchases its remaining kilowatt-hours on the spot market. The WSSC also purchases energy (kilowatt-hours) and capacity (kilowatts) separately. As market prices shift, the electric utility shifts the WWTP's load accordingly (Taylor 2005). An example of shifting loads is the use of system storage to store wastewater during periods of highest load rather than operating pumps. The stored wastewater can then be pumped and treated during periods of low demand.

Another example, EBMUD has also changed the way it purchases electricity. EBMUD used to buy electricity solely from Pacific Gas and Electric at an average cost of $0.11 per kilowatt-hour. Now EBMUD purchases electricity from the Western Area Power Administration, which markets hydroelectric power, at an average cost of $0.06 per kilowatt-hour (Cohn 2005). It should be noted that there are risks associated with purchasing electricity on the spot market. Correct market forecasts are essential, and WWTPs must deal with price volatility in the market.

A technology often used to supplement energy usage at WWTPs is cogenerating electricity and thermal energy on-site, capturing and using anaerobic digester gas (or bio-gas). For example, EBMUD generates enough energy for approximately 50 percent of its energy needs. EBMUD is considering a digester cover that would store gas at night, creating a temporary reserve that could be used during peak-demand periods. The Encina Wastewater Authority also uses digester gas (bio-gas) to generate electricity on-site. Encina has also adopted seasonally adjusted time-of-use rates from its electric company. By shifting treatment process times, Encina has been able to reduce peak-demand rates. By using the time-of-use rates and cogeneration, Encina estimates annual savings of $350,000 per year. At EBMUD, cogeneration of electricity and thermal energy has resulted in cost savings estimated at $1.7 million annually (California Energy Commission, Encina Case Study, 2003).

Energy Management Education

Energy conservation includes monitoring and maintaining each process in the plant. Proper maintenance and upkeep of the equipment and processes in a facility are an integral component of a complete energy conservation plan. Employee training and awareness of the energy plan and procedures need to be continually updated to ensure that the goals and energy savings are targeted.

Training for plant personnel is essential as is educating the public on energy, efficiency and conservation. A good option for conserving energy at a WWTP is the possibility of reducing flows to the plant by reducing water use in the community. As less water flows into the plant, less volume is treated and thus less energy is consumed. An aggressive Infiltration and Inflow program can also reduce flows to the plant.

Ideas for promoting water conservation include

- Educating residents about high-efficiency appliances, plumbing fixtures and water-saving habits
- Educating residents to reduce peak water demands to avoid the extra costs associated with operating additional pumps and equipment during peak-flow periods

COSTS

Many WWTPs are beginning to identify a range of approaches for setting their rate structures based on full-cost recognition. Under full-cost pricing, utilities recognize their actual cost of providing service over the long term and implement pricing structures that recover costs and promote economically efficient and environmentally sound water use decisions by customers. WWTPs are encouraged to factor in the full spectrum of capital and O&M costs, including energy usage (i.e., life cycle costing), in accordance with full cost pricing concepts (U.S. EPA 2006).

Energy conservation costs depend on the equipment purchased and the plans implemented. There are costs associated with tracking energy usage, equipment efficiency, and with gaining knowledge about the distribution of energy usage.

Cost savings are expected as energy use decreases. According to the California Energy Commission's Electric Load Management study (2003), the Encina WWTP (36 mgd) altered the operation of certain processes to off-peak hours and realized cost savings of $50,000 per year. The study also found that the Moulton Niguel Water District, which serves 160,000 people, eliminated peak operations at several pumping stations and reduced costs by $320,000 per year. The study concluded that cost savings from implementing an energy management system to track energy for a WWTP treating an average daily flow of 15 million to 30 million gallons per day is estimated to be up to $25,000 per year.

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