

## Four steps to energy self-sufficiency

### A road map for U.S. wastewater treatment plants

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**W**ith increasing operating costs and concerns regarding climate change, most wastewater treatment plants (WWTPs) are under pressure to reduce the net energy used to treat a gallon of wastewater. WWTPs can pursue the goal of energy self-sufficiency by operating more efficiently, as well as producing energy via digestion and power generation, through a combination of alternative philosophical approaches and innovations.

#### The road to self-sufficiency

Wastewater treatment tends to be energy-intensive. It requires pumping millions of gallons of water against high heads, as well as providing aeration to reduce carbonaceous and nitrogenous biochemical oxygen demand (BOD). Typical WWTPs use 500 to 3000 kWh of electricity for every 3.8 million L (1 million gal) of treated wastewater, depending on what unit operations are included and how efficiently they are operated.

If a facility uses anaerobic digestion to stabilize primary and secondary sludge, the biogas generated can be used to maintain heat in the digester and, in many cases, to produce electricity at the plant. Any energy reduction directly saves money for the local ratepayers while reducing the carbon footprint of the facility. The ultimate goal would be for the wastewater plant to become entirely energy self-sufficient by reducing electricity use and by producing sufficient solids to generate all the electrical needs of the facility.

Energy self-sufficiency has been attained at the wastewater plant in Strass, Austria (see Figure 1, right). The plant features two-stage aerobic treatment with innovative controls. Biosolids are thickened and anaerobically digested, followed by gas recovery and power generation.

The centrate from the dewatering operation is treated in a sequencing batch reactor, using a deammonification process to



A dual-vane control blower can increase turndown capability. Tetra Tech

reduce the recirculation of nutrients to the head of the plant. The average power usage is approximately 1000 kWh for every 3.8 million L (1 million gal) of treated wastewater, slightly less than the approximate electricity generation from the solids. Therefore, the plant produces a net surplus of power (see Figure 2, below).

The Strass plant has a number of advantages, compared to a U.S. facility, including the fact that it is processing a European wastewater. While its potential energy from gas generation is similar to European wastewater, U.S. wastewater is typically more dilute, resulting in higher pumping and aeration costs per million gallons of treated wastewater than an equivalent European wastewater with a similar BOD mass loading per capita.

While total energy self-sufficiency might not be possible for every U.S. wastewater plant, just moving in this direction can yield great payoffs, including cost reductions, reduced energy use, energy recovery from biogas, and more efficient and effective plant operations. Four steps to get there are described below.

### Step 1: Commitment to the process

As with any major undertaking, the entire management team – from the civic leaders to the plant superintendent to and the operations and maintenance staff – must be committed to moving to self-sufficiency. Some of the best plans for reducing energy use can be sabotaged by inadvertently leaving things turned on. In addition, trustees and other administrators will have to be committed, because while certain steps constitute “low-hanging fruit” that is easily reached for little or no expense, others will require some capital expenditure with payback in some years.

### Step 2: Energy generation

**Gas generation and use.** The two prongs of attaining energy self-sufficiency are undertaking an energy savings program and installing anaerobic digestion for energy generation. Plants that have had trouble with anaerobic digestion in the past should consider improvements to aid operation, such as ensuring a thick feed of biosolids, increasing mixing in the digester, and improving heating to ensure the right temperature for microorganisms.

**Sludge thickening.** Thickening sludge enhances digester performance. In one example, for a 378,500-m<sup>3</sup>/d (100-mgd) plant where feed sludge was thickened from 2% to 4% solids, the energy costs for heating the sludge were reduced by \$657,000, while destruction of volatile suspended solids increased 10% for additional gas worth \$275,000, yielding total annual energy savings of \$932,000. Such savings readily pay for the capital to increase thickening on a simple present-worth basis.

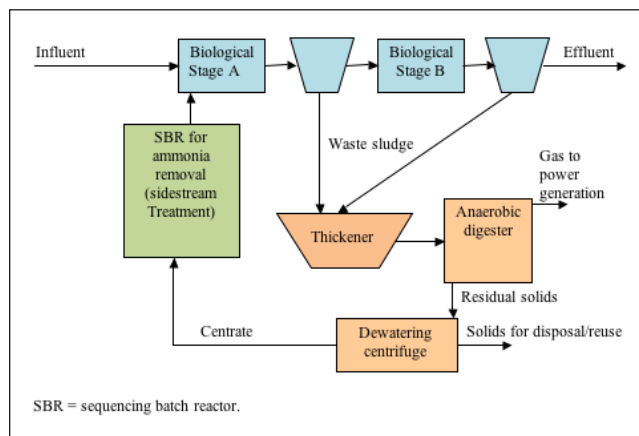
**Advanced digestion technologies.** Conventional digesters are single-stage mesophilic digesters. Advances have been made in multistage digestion, such as using a thermophilic digester followed by a mesophilic digester. Organic load rates for this multistage combination can be higher than those of a conventional digester. Another recent advancement is using mechanical milling machines to condition the feed sludge.

**Codigestion.** Plants can achieve an increase in gas production by feeding high-strength organic wastes to the digester. These could include fats, oils, and grease (FOG), such as brown grease or other oils from offsite sources. Other possible digestible wastes come from the food industry, including food scraps and brewery wastes. In 2007, Biogas Energy Inc. (Halifax, Nova Scotia, Canada) indicated that FOG, food scraps, and brewery wastes can generate 1060 m<sup>3</sup>, 290 m<sup>3</sup>, and 130 m<sup>3</sup> of biogas per Mg, respectively. By comparison, digesting municipal solids will generate at most 110 to 130 m<sup>3</sup> of biogas per Mg. Other possibilities for codigestion feed include waste airplane deicing fluids from cold-climate airports, soft drink bottling wastes, dairy wastes, bakery wastes, and other food industry wastes.

### Step 3: Process energy conservation

The two processes that consume the most energy in a WWTP are aeration and pumping. Pumping needs are difficult to avoid, since the water must get to a desired location and topography must be overcome. However, plants should ensure that pumps are in proper operating condition and use variable-frequency drives in lieu of throttling or other variable-speed devices when possible.

Figure 1. Strass, Austria plant process



Source: Wett, Bernhard, Konrad Buchauer, and C. Fimml (2007). “Energy Self-Sufficiency as a Feasible Concept for Wastewater Treatment Systems,” *Asian Water* (September), pp. 21–24.

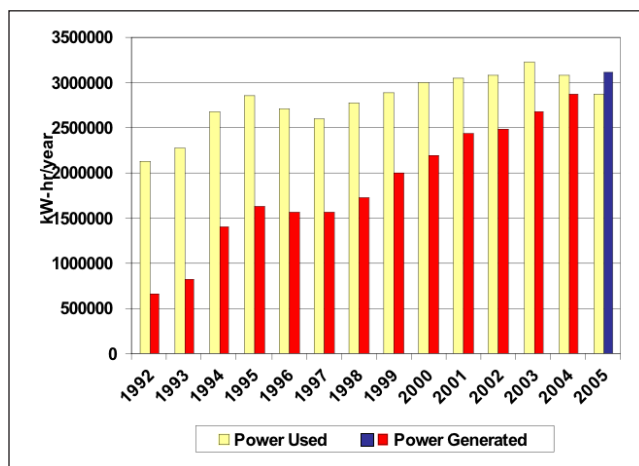
There are a number of opportunities for energy savings in aeration processes.

**Reduce activated sludge age.** The first area of process energy savings is optimizing the aeration process. In many activated sludge facilities, the traditional approach has been to maintain the mean cell residence time (MCRT) at a relatively high value to ensure good nitrification and minimize the generation of waste activated sludge. This results in both increased oxygen use and a decreased amount of sludge that is available to be converted to biogas.

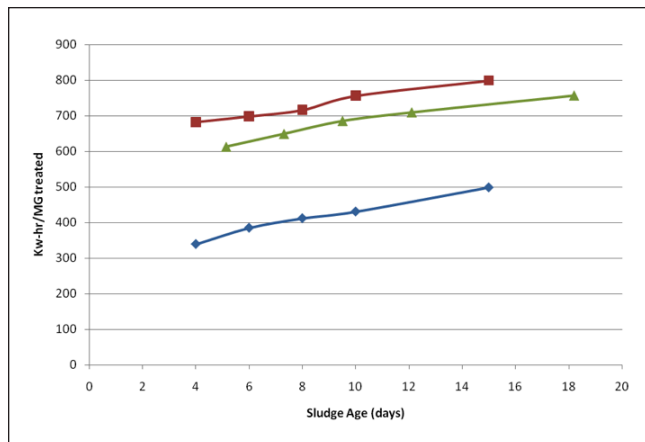
An alternative approach is to shorten the MCRT so that effluent limits are still met but with the maximum possible sludge produced to maximize biogas generation during digestion. Operating to minimize nitrification if it is not required for permit compliance is an energy-efficient strategy. This is demonstrated in Figure 3 (above) and Figure 4 (below), in which all curves show decreased energy use with decreased MCRT.

**Primary settling.** Another strategy for getting more sludge to the digester is using a primary settler where none is present, adding chemicals to enhance the performance of primary tanks,

Figure 2. Road to energy self-sufficiency: Strass, Austria plant



**Figure 3. Model results: energy use for different levels of nitrification–denitrification**



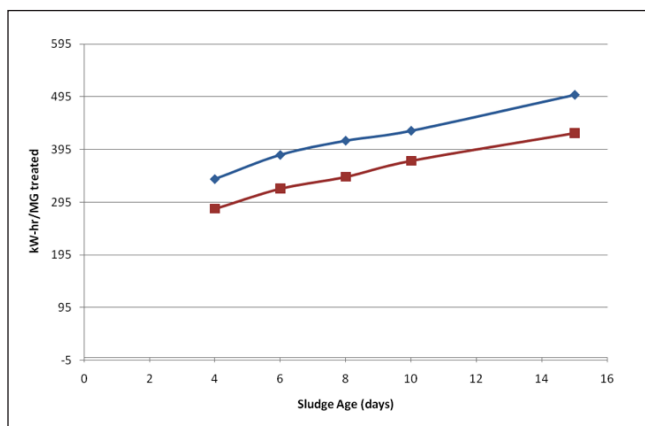
and thickening and digesting the primary sludge. To the extent that primary sludge includes BOD, all that is removed by the primaries will not be aerated and thus can generate more gas.

**Oxygen recovery from nitrate.** The recovery of oxygen from nitrate has been well-documented. Using a denitrification process, such as the modified Ludzack–Ettinger (MLE) process or a sequencing batch reactor, can reduce the overall oxygen requirements of a system and therefore reduce energy costs. For example, an MLE system obtained a net energy use between full nitrification and no nitrification (see Figure 3, left). More complete denitrification would recover even more oxygen and therefore reduce costs further.

**Increase equipment turndown capabilities.** In many instances, plant personnel may determine that aeration airflow could be reduced easily with no decline in performance, but they cannot do so because the aeration blower is too large and lacking adequate turndown capabilities to scale back operation. Large equipment (blowers, pumps, etc.) is sized to treat the ultimate design flows and loadings in the design year. Therefore, it may not be sized for the flows and loadings during the startup years or the ensuing years before the flow and loadings approach those of the design.

Such equipment may be retrofitted or replaced with multiple, smaller units so that only what is needed may be turned on.

**Figure 4. Model results: energy use is different target dissolved oxygen levels**



Alternatively, units can be modified to give them the capability of being turned down to meet the current flow and loadings, thus saving energy. For example, in a recent retrofit case at a 174,000-m<sup>3</sup>/d (46-mgd [design flow]) facility that currently is treating only 79,000 to 83,000 m<sup>3</sup>/d (21 to 22 mgd) of wastewater, an existing single-stage centrifugal blower was retrofitted with a smaller impeller to match the current loadings. The resulting energy savings paid for this retrofit within a year.

In another case, a smaller blower was installed to replace a larger one; the large one remains available to be brought back on-line when flow and load conditions approach the design capacity. An alternative to physically changing or replacing blowers is to equip major pieces of equipment with variable-frequency drives, when feasible.

**On-line sensors and automatic controls.** With improved reliability and easy maintenance of sensors and control devices, more plants are optimizing energy based on the approach of matching the actual demand with the energy supply. A wide variety of acceptable sensors is now available for dissolved oxygen, ammonia, nitrate, and oxidation–reduction potential. In addition, in many full-scale operations, efficient control strategies have been accepted and proven successful for both feed-forward and feedback controls applied through supervisory control and data acquisition systems.

One such strategy is the adoption of a lower dissolved-oxygen (DO) setpoint in the aeration basin. In the past, 2 mg/L was used as the setpoint because the controls were not available to reliably hold the dissolved oxygen at 1 mg/L, so there would have been a risk of the basin turning anaerobic. With new controls and sensors, it is possible to hold DO at 1 mg/L, which is acceptable for aerobic microbial growth. This reduced oxygen need means an energy savings of 15% to 20% at lower sludge ages, as shown in Figure 4 (p. 48). The operating staff may need to gain confidence in the strategy and devices, but with that confidence and good plant performance, the operating staff can adjust the setpoint up and down and maximize the benefit.

In Strass, ammonia sensors were used as the basis for automatically adjusting the aeration. If the BOD remains acceptable, using ammonia–nitrogen levels to adjust oxygen will ensure that oxygen efficiency is maximized. More examples of using automation with sensors are expected in the future.

**Create swing zones.** In many nutrient removal plants, the size of the anoxic and aerobic zones is not ideal when the plant is underloaded below the design flow. A new approach is to retrofit the basin with both mixers and aeration devices so that the energy use can be minimized during the less-than-design loading conditions that may prevail in a particular month or season. WWTPs can create a swing zone that can run as an anoxic zone by turning mixers on or as an aerobic zone when diffusers are turned on.

Another example of a successful swing-zone retrofit is an oxidation ditch, in which a small mixer is installed at the corner of the carousel so that the brush aerator can be operated as an aeration device at a lower power level under the current flow and loading conditions. For example, a retrofit in North Cary, N.C., will have some initial capital costs for the mixers, but payback time will be short because of the resulting energy savings. The size and the

number of the swing zones will depend upon the site conditions and loadings.

**Sidestream treatment.** Deciding whether to provide sidestream treatment has been a long-term challenge for WWTPs. Centrate from dewatering accounts for 15% to 25% of nitrogen loadings in many plants, with more plants processing solids from other plants owned by the same municipalities. As energy costs have increased, more attention has been focused on sidestream treatment.

For example, New York City is implementing an ammonia removal and recovery process at its 26th Ward Water Pollution Control Plant. This is a physical-chemical process with ammonia stripping and recovery to produce ammonium sulfate fertilizer.

Plants in Strass and in Rotterdam, Netherlands, use biological processes with a novel genus of microorganism that requires less oxygen to remove ammonia-nitrogen.

Both physical-chemical and biological processes are promising and should be considered for retrofit. The decision to provide any of these sidestream treatment processes depends on the current loadings, the permit limit, the plant site, the costs, and other factors that have to be evaluated on a site-specific basis.

**Shortcut: Team up with a landfill, airport, or food manufacturer.** As an adjunct to developing gas generation from biosolids, plants should consider teaming up with a local landfill that is producing methane gas. This gas typically would be flared, but if it is collected and piped to the wastewater treatment plant, it could support power generation even when the biosolids flow may not warrant it, such as early in the life of a design. Such an approach has provided a shortcut to energy self-sufficiency for certain plants in Wisconsin, Ohio, and Texas.

Codigestion of deicing fluid or organic feed from food and beverage manufacturers is another shortcut.

**Cash-back incentive for biogas generation.** Beyond the technical reasons for implementing biogas generation and use, many states offer financial incentives for alternative energy generation in order to meet their targets for such generation, such as 15% of power coming from biogas by 2015. The incentives vary by state, and they generally are higher than the cost of generation, such as \$0.10/kWh, compared to \$0.03 to \$0.04/kWh. These incentives will shorten the payback period for implementation.



**With new controls and sensors, it is possible to hold dissolved oxygen at 1 mg/L, yielding energy savings of 15% to 20%. Tetra Tech**

#### **Step 4: Assessment and map-checking**

As the journey down the road to energy self-sufficiency continues, the energy team should periodically review progress and assess how well the employed strategies and technologies have worked for the facility. If some technologies could save money but are difficult to carry out on a daily basis, the team should consider alternatives. Beyond the process savings, additional energy projects around the facility could have a rapid payback, such as installing energy-efficient and motion-activated lighting.

As the journey continues, projects will have less of an effect on the energy bottom line as the easiest and most effective ones are completed. Economics might prevent the plant from making it all the way on the long road toward total energy self-sufficiency. However, any steps taken on this road will bring major benefits to both ratepayers and the environment.

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