South Carolina
Economy - Energy - Environment

WASTEWATER TREATMENT ENERGY CONSERVATION REPORT – SAMPLE RECOMMENDATION

UTILIZE BIOGAS TO GENERATE ELECTRICITY BY INSTALLING A MICROTURBINE

Recommended Action

It is recommended that plants using anaerobic digestion utilize the excess biogas being produced in the sludge treatment process on site to generate electricity by installing a microturbine.

Background

Digester gas is a valuable resource formed as a product of the anaerobic sludge treatment process. At this facility, the sludge collected from the primary and secondary clarifier is dewatered and mixed in a partial egg-shaped digester under anaerobic conditions (absence of any terminal electron acceptor) at 35° C. In the digester, complex organic compounds are converted into methane and carbon dioxide and the gas produced is known as biogas. Methane can be recovered and has many applications due to its high calorific value. This plant produces about 36,452,000 standard cubic feet of digester gas in a year. Some of the biogas is used for sludge heating, but most of it is flared without being used. Because the methane produced has the potential to reduce the energy use of the plant, another use for the biogas should be implemented.

There are multiple ways methane can be used, but the recommendation for this plant is to install a micro turbine for power generation. A micro turbine is a miniature industrial gas turbine that can produce energy using the methane gas produced in the anaerobic sludge treatment process. Most micro turbines consist of a compressor, combustor, turbine, alternator, recuperator, and generator and can have outputs from 25 to 500 kW. The conversion efficiency of a micro turbine is generally between 25 and 30 percent and they produce a good amount of heat which can be recovered as hot water for digester heating. Additionally, micro turbines produce the lowest emission of any noncatalyzed fossil fuel combustion system.

Another advantage of using a micro turbine at this plant is the diesel generators are already being used during times of high demand at this plant. This means the plant already has the infrastructure to support the use of a generator integrated into the system and the implementation of a microturbine would be relatively simple.

Anticipated Savings

For the anticipated savings of this recommendation, the average methane production values supplied by the plant were used. On average, the two partial egg anaerobic digesters on site produce 3,037,679 standard cubic feet (scf) of gas per month. The plant is already using some of this gas to heat sludge and are burning off an average of 2,372,646 scf of gas per month as waste. This means the average monthly consumption of gas used to heat the sludge is 663,033 scf.

Assuming the digester gas produced is around 65% methane, the *methane average production quantity* (Q_p) is:

$$Q_p = 3{,}037{,}679 \frac{scf}{month} \times \frac{month}{30\ days} \times 911 \frac{Btu}{scf} \times \frac{MMBtu}{10^6 Btu} \times 0.65$$

$$Q_p = 59.96 \frac{MMBtu}{day}$$

Converting to the same units, the *quantity of heat required to run the boilers to heat the sludge* (Q_b) is:

$$Q_b = \frac{663{,}033 \frac{scf}{month} \times 911 \frac{Btu}{scf}}{30 \frac{days}{month} \times 10^6 \frac{Btu}{MMBtu}}$$

$$Q_b = 20.13 \frac{MMBtu}{day}$$

This means that the available quantity of heat energy per day (Q_a) is

$$Q_a = Q_p - Q_b$$

$$Q_a = 59.96 \frac{MMBtu}{day} - 20.13 \frac{MMBtu}{day}$$

$$Q_a = 39.83 \frac{MMBtu}{day}$$

Assuming the micro turbine has an efficiency of 25%, the *power generated using the methane gas* (P) is:

$$P = \frac{39.83\,\frac{MMBtu}{day} \times 293\,\frac{kWh}{MMBtu} \times 0.25}{24\,\frac{hrs}{day}}$$

$$P = 121.55\ kW$$

The *electricity consumption savings* (ECS) per year with the plant's operation of 8760 hours per year is

$$ECS = 121.55\ kW \times 8760\,\frac{hrs}{year}$$

$$\boldsymbol{ECS = 1,064,795\,\frac{kWh}{year}}$$

At an electricity consumption rate (CR) of $0.075 per kWh, the estimated annual *electrical consumption cost savings* (*ECCS*) would be

$$ECCS = ECS\ \times CR$$

$$ECCS = 1{,}064{,}795\ \frac{kWh}{year} \times \frac{\$0.075}{kWh}$$

$$\boldsymbol{ECCS = \$79,860/year}$$

The *electricity demand savings* (EDS) is

$$EDS = \frac{1{,}064{,}795\ \frac{kWh}{year}}{8760\ \frac{hrs}{year}} \times 12\,\frac{months}{year}$$

$$\boldsymbol{EDS = 1,459\ kW\ /year}$$

With a demand cost (DC) of $8.98 per kW-month/year, the *electricity demand cost savings* (EDCS) is

$$EDCS = EDS\ \times DC$$

$$EDCS = 1{,}459\ \frac{kW}{year} \times \frac{\$8.98}{kW}$$

$$\boldsymbol{EDCS = \$13,098/year}$$

The total annual cost savings (TCS) is

$$TCS = ECCS + EDCS$$

$$TCS = \$79{,}860 + \$13{,}098$$

$$\boldsymbol{TCS = \$92,958}$$

Implementation Cost

It is estimated that the capital cost for a micro turbine range from $700-$1,100/kW. At the estimated 122 kW for the micro turbine at $1,100/kW, capital costs could be estimated at $134,200. It is estimated the installation costs should be 30-50 percent of the total installed cost. The estimate for installing the micro turbine is around $400,000 including the equipment needed for biogas cleaning.

IC = $400,000

Simple Payback Period

Using the estimated $400,000 for implementation, the *simple payback period* (SPP) is calculated below by dividing the *total cost savings* (TCS) by the *implementation cost* (IC). This estimate can be recalculated as a more concrete implementation cost is determined if this recommendation is implemented.

*SPP = IC / TCS * 12*

*SPP = ($400,000/$92,958) * 12 months/yr.*

SPP = 51.6 months

All the calculations performed for this recommendation are very conservative, so it is possible the payback for the implementation of this recommendation could be even shorter and the yearly savings could be much higher. It is not expected the methane use would be able to power the entire plant at this time, but the energy produced could certainly be used to target known energy intensive processes such as aeration.

It is also important to note a larger kW micro turbine will be needed if the less conservative estimate is used or if the amount of methane in the plant increases. This would increase the upfront capital cost, but the payback period should remain relatively the same due to higher yearly energy savings as well.

These calculations also did not take into account using the microturbine's waste heat to heat the sludge at the plant. The plant already has the necessary equipment to heat their sludge by burning biogas, but it may be advantageous to use the micro turbine system to do both as it would allow for the maximum amount of biogas to be combusted for the purpose of generating electricity. Using the waste heat of the micro turbine to heat the sludge would increase the initial cost by an estimated $75–$350/kW.

If power generation is not something the plant is interested in pursuing, the micro turbine could also be used to cut energy use by mechanical means. The generator can be replaced with an air compressor to supply air for aeration equipment. With this option, the current mechanical mixers used for aeration at the plant would need to be replaced with bubble diffusers. It is estimated there is enough biogas produced to completely power the equipment required for aeration in the activated sludge process. Because the biogas produced is so far in excess of what is required for aeration, it is recommended that coarse bubble air diffusers are used rather than fine bubble. Fine bubble aerators are known to be more energy efficient than course bubble, but since they have a higher maintenance and capital cost, coarse bubble aerators are recommended as energy will be produced in excess for running the aerators.

Another important factor to consider is the future expansion of the plant and predicted increased daily flow. With more wastewater being treated, more methane will be produced and other options for using the excess methane that are not currently feasible for the plant could become practical.

References

BTU to scf conversion reference: https://www.enggcyclopedia.com/2011/09/heating-values-natural-gas/, Site accessed 22 July 2019.