Reduce Grid Required Energy to Utilize Your Wastewater Treatment Facility

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ABSTRACT

Communities with wastewater treatment facilities have the opportunity to generate energy from the resource received at their facilities. With approximately 15,000 wastewater systems in the United States, many communities have the opportunity to reduce dependency on grid-provided energy and become more sustainable.

Anaerobic treatment results in the production of biogas that is approximately 65% methane and 35% carbon dioxide. It is a renewable energy source that can be utilized to fuel electric generation, and the heat produced can be captured so both energy sources can be beneficially utilized at the wastewater treatment facility to offset grid-supplied energy sources. This opportunity needs to be assessed by each community to identify the level of benefit it can achieve to offset its dependency on grid-supplied energy.

Introduction

We continually hear such words and phrases as “sustainability,” “green energy,” “green power,” “recycle,” “use less,” “utilize renewable energy,” etc. Now, municipalities and industries have an attractive new opportunity to become sustainable and utilize renewable energy. This opportunity can be found at their wastewater treatment facilities. An energy audit performed at a community’s wastewater treatment facility (WWTF) and an inventory of the WWTF’s assets will likely identify opportunities to reduce and offset a major portion, if not all, of the facility’s energy consumption. This is highly significant since an average community’s water and wastewater facilities consume approximately 35% of their municipality’s energy.

Knowing that sustainability can cut billions of dollars of energy costs and billions of kilowatt hours nationwide, wastewater organizations are presenting a challenge to communities: Become energy-neutral by producing all the energy required to operate their wastewater systems through use of renewable energy sources. That way, wastewater facilities will place no demand on grid-provided energy supplies.

How Can WWTFs Meet the Challenge?

Wastewater treatment facilities have a number of unit treatment processes. Most treatment facilities will consist of primary clarifiers (a unit process that allows initial settling of organic solids); a secondary treatment process (activated sludge requiring air to be supplied constantly to provide oxygen for continual biological activity); and secondary (final) clarification (a unit process to again provide for solids to settle prior to discharge) followed by a method of disinfection. The solids that were removed, both primary and secondary, are then processed through either an aerobic or anaerobic process. The anaerobic process is usually applied to medium- (1 million to 10 million gallons per day, MGD) or larger-size (greater than 10 MGD) facilities. Therefore, most medium- to larger-size facilities need to assess if their anaerobic treatment systems are operating at design conditions so they can maximize their production rate of biogas. Biogas is a key to freeing facilities from the electric grid.

Wastewater treatment facilities consume energy constantly because they have a biological treatment process that continually requires oxygen to stay alive and active. During the treatment process, soluble organics are converted to cell growth (the biological organisms in the wastewater use the soluble waste material as food to grow new cells), which are then removed and can be processed through an anaerobic treatment process that results in the production of biogas. This, in general, is how the organic material in wastewater is converted into an available energy source (biogas).

Anaerobic treatment will reduce the organics in the waste stream, resulting in the production of biogas (usually 65% methane, and 35% carbon dioxide and varying impurities). With biogas, the wastewater treatment facility and community now have a renewable energy source similar to the natural gas that is burned in a boiler. The energy value of biogas is typically 650 Btu/cubic foot, compared to natural gas, which is 1,000 Btu/cubic ft. However, biogas can be directly burned to offset natural gas consumption, or it can be processed through engines (internal combustion or turbines) to generate electricity to offset electric usage. The heat is then captured from the engine, and its exhaust providing heat for process purposes or building heat.

The amount of biogas a wastewater treatment facility can produce will vary greatly depending on the facility's size and the organic loading the wastewater treatment facility receives. Additionally, the wastewater treatment facility can seek to provide an auxiliary food source for the anaerobic digester – usually a high-strength industrial waste that is compatible to anaerobic treatment – to increase biogas production. The strategy is to feed the anaerobic digester at its design condition for its entire life of operation. By doing this, the wastewater treatment facility is maximizing the value of the anaerobic digester. Existing projects have shown that a wastewater treatment facility can typically offset all of its aeration power (usually 50% to 60% of its total electrical usage) and may be able to offset 100% of its entire power consumption, making it energy-neutral. There are even facilities that are able to sell a portion of the electric power they generate back into the grid. These communities now have the power companies paying them!

Who Has Anaerobic Digesters?

Many municipalities have anaerobic digesters; however, most attention has been given to large wastewater treatment facilities greater than 10 MGD. Attention also needs to be given to small- and medium-size wastewater treatment facilities (less than 1 MGD) and (1 to 10 MGD), respectively, with anaerobic digesters. These wastewater treatment facilities have great potential to produce sufficient biogas to become energy-neutral. However, to become energy-neutral, small- and medium-size wastewater treatment facilities should first become energy efficient. Then they should locate an auxiliary feedstock to feed their digester system. The auxiliary feedstock should be a high organic waste that will provide sufficient feedstock for the digester to be at design conditions from startup. This will result in the digester maximizing its biogas production.

Many smaller wastewater treatment facilities with anaerobic digesters have units that are 40 to 60 feet in diameter with side water depths of 20 to 25 feet. Anaerobic digesters within these dimensions have the ability to produce sufficient biogas to fuel a 30 to 65 kW microturbine (or a small internal combustion engine to drive a generator to produce 30 to 65 kW). Thirty to 65 kW is likely sufficient energy to offset 60% or more of the wastewater treatment facility's energy consumption. Further, if the wastewater treatment facility happened to have two digester tanks that were both converted to producing biogas, they would have the ability to produce sufficient power (biogas) to fuel electric generation to meet the energy requirement of the entire wastewater treatment facility – and potentially have sufficient energy to feed the grid.

This described strategy is available to all sizes of wastewater treatment facilities. There is a 10 MGD wastewater treatment facility in Wisconsin that is presently utilizing auxiliary feed stock to improve biogas production to the level that it is producing 85% to 95% of its daily energy requirements. At times, it can produce more than 100% of its onsite power requirements. There is a 5 MGD wastewater treatment facility in Wisconsin that is utilizing the biogas produced from its anaerobic digesters to offset all of the energy required by the aeration system (usually this is 55% to 60% of the wastewater treatment facility's electric consumption). Wisconsin also has a 3 MGD wastewater treatment facility that recently placed in operation its biogas-fueled electric generation system. The 3 MGD system has produced up to 100% of the electric energy needed to operate its entire wastewater treatment facility.

What Needs to be Done to Have a System Meet Its Energy Requirements?

As noted earlier, a wastewater treatment facility must maximize its biogas production. This is usually accomplished by the WWTF providing the digester with enough auxiliary feedstock to maximize its biogas production as fuel for generation purposes.

Biogas quality tests need to be performed on samples (if available) of the biogas proposed to be utilized as a fuel. The tests will identify the need for biogas conditioning or cleaning equipment to provide a clean fuel for continual beneficial utilization. The testing can also identify the fuel value of the specific gas (the percentage of methane in it).

Biogas conditioning is a basic requirement to make biogas utilization a continual as well as sustainable choice. There are troublesome stories about failures of WWTFs utilizing biogas at early stages of the technology. Unfortunately, as a result, many WWTFs are hesitant to trust the technology. However, insufficient biogas cleaning caused many of those failures. Most early conditioning systems were simply moisture traps and iron sponges, not the systems that are available today to condition the biogas. Present-day systems have the technology to refrigerate the biogas to remove sufficient moisture, and then filter it with carbon filters to remove remaining impurities. With these new technologies employed, failures very rarely occur. Biogas can even be cleaned to a concentration nearing that of natural gas, allowing it to be clean enough to burn in natural gas-powered vehicles.

How Much Biogas Might a WWTF Produce?

WWTF biogas production is based on a number of conditions. Initially, the size (volume) of anaerobic digesters limits the volume of biogas produced responsive to required detention time to allow anaerobic organisms to breakdown the volatile solids introduced into the digester. This is followed by the operating temperature of the treatment process, 95 or 135 degrees. The higher the temperature, additional volatile solids will be broken down, resulting in higher biogas production. However, a balance needs to be achieved between the higher temperature and its increase in reducing volatile solids compared to the added energy required by the treatment process to operate at 135 degrees. Another major factor that impacts the volume of biogas produced is the amount of feedstock fed to the digester. To operate an anaerobic digester system to maximize its biogas production, the amount of organic material fed to the digester should be maximized. Throughout the life of the system, it should be fed at its design condition so it operates constantly at maximum biogas production throughout its operational life.

Where Do I Locate Auxiliary Feedstock?

Locating auxiliary feedstock is another requirement to maximize biogas production. Most municipal WWTFs are designed for a 20-year design life. This results in treatment process sizing that will inherently be partially loaded through the majority of years of operation. This is not how an anaerobic system should be operated to maximize its benefit to the community. The community has a sunk cost in the digester system. Therefore, the system should be operated to maximize its benefit to the community during its useful life expectancy. This results in the need to identify auxiliary feedstock to provide the organic material to operate the digester at its design condition throughout its useful life. Auxiliary feedstocks are usually located through surveys of surrounding industries that produce high-strength organic wastes (food and beverage facilities; dairies; fat, oil and grease; ethanol facilities, etc.). This helps identify what waste streams are available to be directly conveyed, usually trucked, to the WWTF and directly fed into the digestion system to maximize biogas production. Through the addition of feedstock, the gap between partial loading and loading at design conditions is filled.

Why is Generation Good?

Electric generation is good because it actually provides two sources of usable renewable energy: electricity and heat. Electric generation can usually be utilized onsite and can offset the majority of electric consumption from the grid. In some locations, usually where auxiliary feedstocks are used, generation systems can generate enough electric energy to meet their needs as well as contribute energy to the grid. Electric generation also allows the various processes at a WWTF to continue to utilize variable speed drives on process equipment, resulting in energy-efficient operation (use only what is necessary based on real-time flows and loads to the WWTF). Associated with electric generation is heat capture. The engine that drives the generator can be an internal combustion engine or a turbine engine. However, in either case, it is a benefit to capture the heat. Capturing the heat usually increases energy recovery to 60% to 70% (Energy recovery breaks down to 30% to 35% from efficient electricity generation, and then heat capture provides another 30% to 35%).

Can Energy Neutrality be Achieved?

Energy neutrality at a WWTF can be achieved. It is a valuable opportunity that should not be overlooked or deemed unachievable. Following are examples of installed projects representing what proactive communities can do and are doing to become green and sustainable, and to have an energy-neutral wastewater treatment facility. Neutrality needs to become a goal presented to the managers of the community’s wastewater treatment facility. Neutrality can be achieved by first making the operations of the WWTF energy efficient. That means minimizing the amount of energy required to meet discharge permit limits. Efficiency should be followed by maximizing the volume of biogas that can be produced from the anaerobic digestion system at the WWTF. When both of these proactive actions are taken, a community will move its wastewater treatment facility to energy neutrality.

Can Energy Neutrality be Achieved at New WWTF's, Retrofitted WWTF's or Both?

Energy neutrality can be achieved at new and older wastewater treatment facilities that can be retrofitted. If a new facility is being designed, the community needs to be proactive and direct the designer to design the treatment system to be energy-neutral. This will take particular effort by the community because present design codes do not incorporate the need to be energy efficient or energy-neutral. The community must direct its designer to incorporate processes that will result in the ability of the system to be energy efficient, followed by applying energy generation (biogas) to move the system to energy-neutral through beneficial utilization of biogas as a renewable energy resource.

Examples of WWTF's Beneficially Utilizing their Biogas.

Wausau, WI. The community has a 5 MGD WWTF with activated sludge and anaerobic digesters. The WWTF is operating and meeting its permitted discharge limits. However, in operating to meet the discharge limits, it was not focused on operating energy efficiently. The community became aware they could become energy efficient and utilize their biogas. The community decided to approach possible modifications on two fronts: first, become energy efficient, and then, utilize its anaerobic digestion system to the best of its ability.

The community first initiated a study to determine what could be modified at the WWTF to make it more energy efficient. The study provided an assessment that identified modifications to the aeration system that could significantly reduce energy consumption. They implemented the energy efficiency modifications to the aeration system, resulting in a reduction from 300 hp to approximately 125 hp. This was followed by a second study to identify the most beneficial modification(s) to utilize the biogas produced from their anaerobic digesters. The study identified the best beneficial utilization was to install a biogas conditioning system, followed by the installation of two 65 kW microturbines.

The WWTF is presently operating the microturbines, which are continually being fueled by the conditioned biogas produced from their digesters. The two microturbines are producing sufficient energy to operate the energy-efficient aeration system. Since the blowers are now operated off the electricity generated from the beneficial utilization of biogas, the implemented modifications have resulted in the WWTF reducing its aeration power consumption from 300 hp to zero. These modifications have resulted in reducing the energy consumption at the facility by more than 50%. Also, the heat from the electric generation system is captured and utilized to meet all process heat requirements (anaerobic digesters are operated at 95 degrees). Any available heat beyond that required for process purposes is being utilized to offset natural gas consumption to heat buildings on site.

Stevens Point, WI. This community has a 5 MGD WWTF activated sludge facility with anaerobic digesters presently operating at 3 MGD. The WWTF has been proactive over the past four to six years and has implemented a variety of energy efficiency projects to minimize the amount of energy required to operate its WWTF. Some of the energy efficiency modifications have included installation of flexible membrane fine bubble diffusers; an automatic, dissolved oxygen control system; new technology for a more energy-efficient aeration blower; and reducing the size of air compressor associated with its air diaphragm sludge pumps.

The WWTF then commissioned a study to identify how it could increase biogas production and beneficially utilize the increased volume of biogas. The WWTF has a higher than average organic load responsive to the types of industries in the community. Also, the community is a college town with a student population that can influence a higher organic load to the WWTF. However, with the student population also comes more siloxanes in the biogas; this is due to the increased use of hygiene products, which are a source for siloxanes.

The WWTF then moved forward with the installation and startup of an electric generation system fueled by the biogas produced at the wastewater treatment facility. The biogas production is sufficient to operate a 180 kW electric generation system. This energy is utilized to offset the energy consumed onsite – not just the aeration system, but the entire wastewater treatment facility. The volume of electricity generated will be sufficient to offset more than 50% of the yearly consumption by beneficially utilizing the biogas the WWTF is producing. During a recent weekend, the generation system produced more than 100% of the electric energy utilized onsite. Also, heat captured from the generation system offsets all anaerobic heat demands of the treatment process.

Sheboygan, WI. This community operates a 10 MGD activated sludge regional treatment facility with anaerobic digesters. The WWTF has implemented a variety of energy efficiency projects to minimize its electric consumption while still maintaining its discharge permit quality. It has installed a new technology, energy-efficient aeration blower; variable speed drives on various process pumps; energy consumption monitors on all large motors; and has developed a monitoring system to identify their on-peak demand so they can limit their own on-peak demand value. The WWTF superintendent recognized the WWTF had anaerobic digester capacity to produce a large volume of biogas if they had sufficient feedstock to feed it regularly at design conditions. The superintendent scanned the area within and surrounding the community to identify what industries had high-strength wastes that could be hauled to the WWTF for auxiliary feedstock for the digesters. The community soon was receiving feedstock from a soft drink bottler, a dairy operation, and a cheese operation. The WWTF even had an ethanol processor truck some feedstock to the WWTF. With the auxiliary feedstock, the digestion system began to produce more biogas than they had equipment to beneficially utilize it. Therefore, the superintendent acquired ten 30 kW microturbines, followed by the purchase and installation of two 200 kW microturbines for electric generation.

The auxiliary feedstock has proven to be a definite advantage for the community. Further, the WWTF is just completing a project that includes the installation of new digester mixing equipment, which is enhancing the digestion process to the extent that biogas production continues to increase. Presently, the WWTF is assessing the potential to utilize the remaining heat from the generation systems and combine it with heat generation from the additional biogas generation to fuel a dryer system to dry their biosolids prior to disposal.

Currently, the electric generation systems at the WWTF are producing 85% to 95% of the daily WWTF power consumption. However, the systems have at times produced 110% of their power requirement, pushing the additional power out into the grid. This is a success story about how to achieve or nearly achieve energy neutrality through beneficial utilization of biogas as a renewable energy source through utilizing auxiliary feedstock. It also presents a strong case to push anaerobic digesters to operate at design conditions throughout their design life and not just when the WWTF receives sufficient organic material through their sewer system.

Conclusion

Communities can reduce their dependency on electric grid-provided energy resources through the beneficial utilization of renewable energy sources produced at their wastewater treatment facility. Most communities with anaerobic treatment processes at their wastewater treatment facility have the ability to produce and beneficially utilize biogas as a renewable energy source. As presented, communities with biogas production capability can offset 50% or more of their facility's energy consumption.

Energy neutrality can be achieved at a community's wastewater treatment facility if a strategy is developed and implemented to maximize the utilization of biogas when coordinated with energy-efficient modifications and operation.

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