Our energy working for you.™

Power Generation

Power topic #GLPT-5769-EN | Technical information from Cummins Power

Wastewater Treatment Plant Biogas for Spark-Ignited Engines

White Paper

By Bruna Ferro, Application Engineer

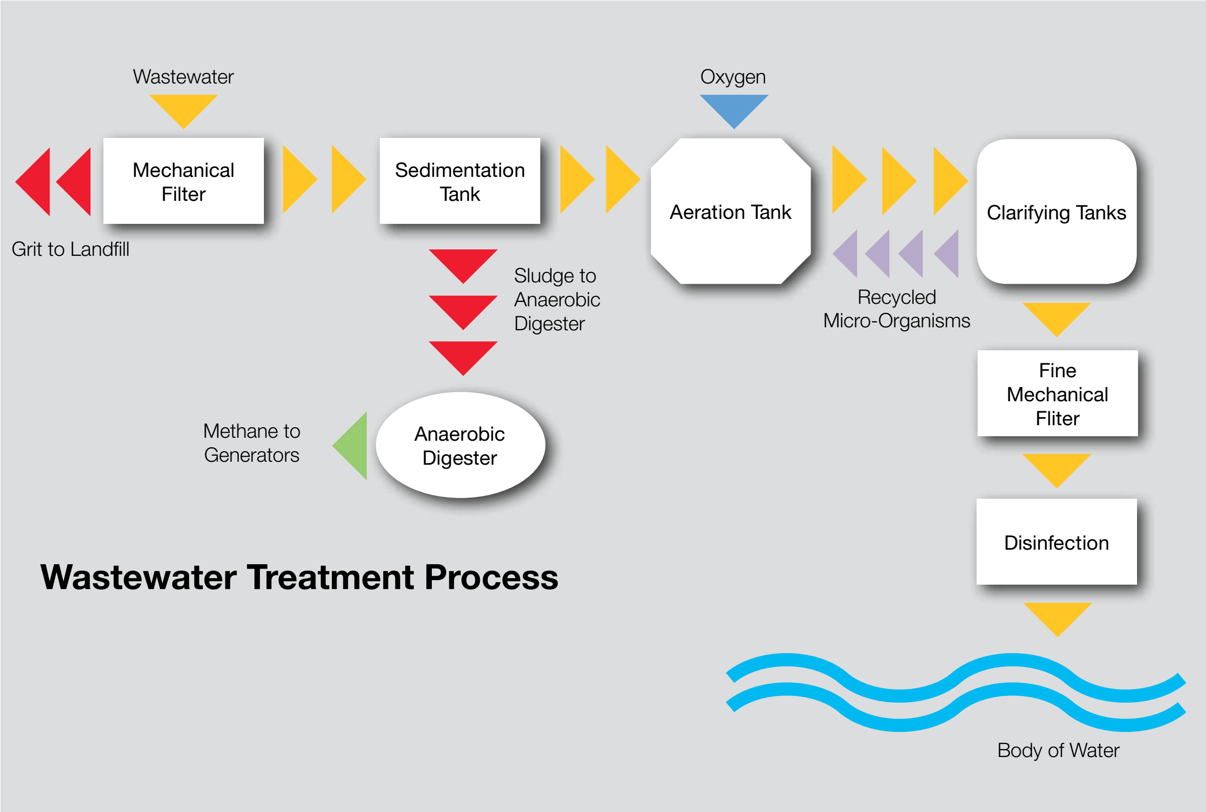
The modern wastewater treatment plant's processes are uniquely well-suited for generation of on-site power, but currently only a minority of eligible plants do so. The processes in a wastewater treatment plant can be viewed simply as cleaning wastewater to be returned safely to the environment. During treatment, waste streams such as biogas are created that can be converted into useful energy again. Biogas fueled spark-ignited engine generators present wastewater treatment plants with an opportunity for operational cost savings as well as environmental solutions to growing energy and carbon concerns.

To understand the power generation opportunities at a wastewater treatment plant, it is important to have a basic understanding of its operations. This paper serves to give an overview of modern wastewater processing and discuss the benefits and opportunities of using a spark-ignited engine generator to produce on-site heat and power.

How Municipal Wastewater Treatment Plants Work

The key design goal of wastewater treatment plants (WWTPs) is to process incoming wastewater streams, comprised of over 99% water, to a quality that can be safely returned to the environment using often complex physical, biological and chemical methods. To analyze a WWTP for power generation potential however, only a basic understanding of the plant's design is necessary.

WWTPs, also commonly abbreviated POTWs (publicly owned treatment works), are typically designed based on the size of the community that it is intended to serve. The standard in the United States is that 10,000 people produce 1 million gallons per day (MGD) of wastewater. Plants can be compared in size by their design flow rate in MGD and are designed to accommodate peak flows that can be 2-4 times larger than average daily flows.



Wastewater exiting a home or commercial property is collected via a network of gravity-flow pipes and delivered to the wastewater treatment plant. Also called the sanitary sewer system, these pipes are kept physically separate from storm water collection and distribution, which is often discharged directly to a body of water without any treatment or processing. Here are the next steps that wastewater might go through in a modern plant:

- The wastewater flows through a screen or **mechanical filter** to remove larger particles and grit. This material gets separated and sent to a landfill for disposal. The water is typically pumped to an elevated level so that it can flow through the rest of the system by gravity.
- The wastewater flows to the primary, or first stage, **sedimentation** tanks. This is where the wastewater sits for sufficient time to allow heavier sediments and particles, or sludge, to settle to the bottom of the tank.
  - The sludge is then pumped to an **anaerobic digester** (AD), which is a closed dome typically made of a plastic membrane that is designed to allow biological processes to occur naturally in the absence of oxygen, or anaerobically.
  - Naturally occurring bacteria in the sludge feed on the thickened waste material and create methane, or CH_4, as a by-product. This **biological breakdown** of the sludge to produce biogas is optimized when the operating temperature in the digester is constant around 98° F or 36.7° C for mesophilic systems. The retention time for this process to occur can range from less than 15 to 60 days, depending on the amount of mixing and heat applied to the sludge.
  - **Methane** levels can be monitored as it is built up in the digester and then can be **collected via a piping system** to be used as a replacement for natural gas.
- After the wastewater has settled, it then flows to **aeration tanks**, which are typically designed in a snake pattern to allow the required residency times. In the aeration tanks, a mixture of oxygen and micro-organism “bugs” referred to as activated sludge is pumped into the slowly flowing wastewater to consume any organic material in the water.

- The process then leads to **clarifying tanks**, which are often circular in shape. The absence of pumped oxygen causes the micro-organisms to stop their digestion process and they settle to the bottom of the tank, where they can be pumped again into the aeration tanks to start the process with the next batch of wastewater.
- There is often a finer **mechanical separation** at this point which can include a sand or other type of filter.
- Finally, the water goes through a **disinfection process** to ensure that pathogens are removed to a level of efficiency dictated by local or federal regulation. Disinfection can be achieved by chlorination (followed by dechlorination) or non-traditional methods such as UV light.

Composition of Methane Gas from Anaerobic Digesters

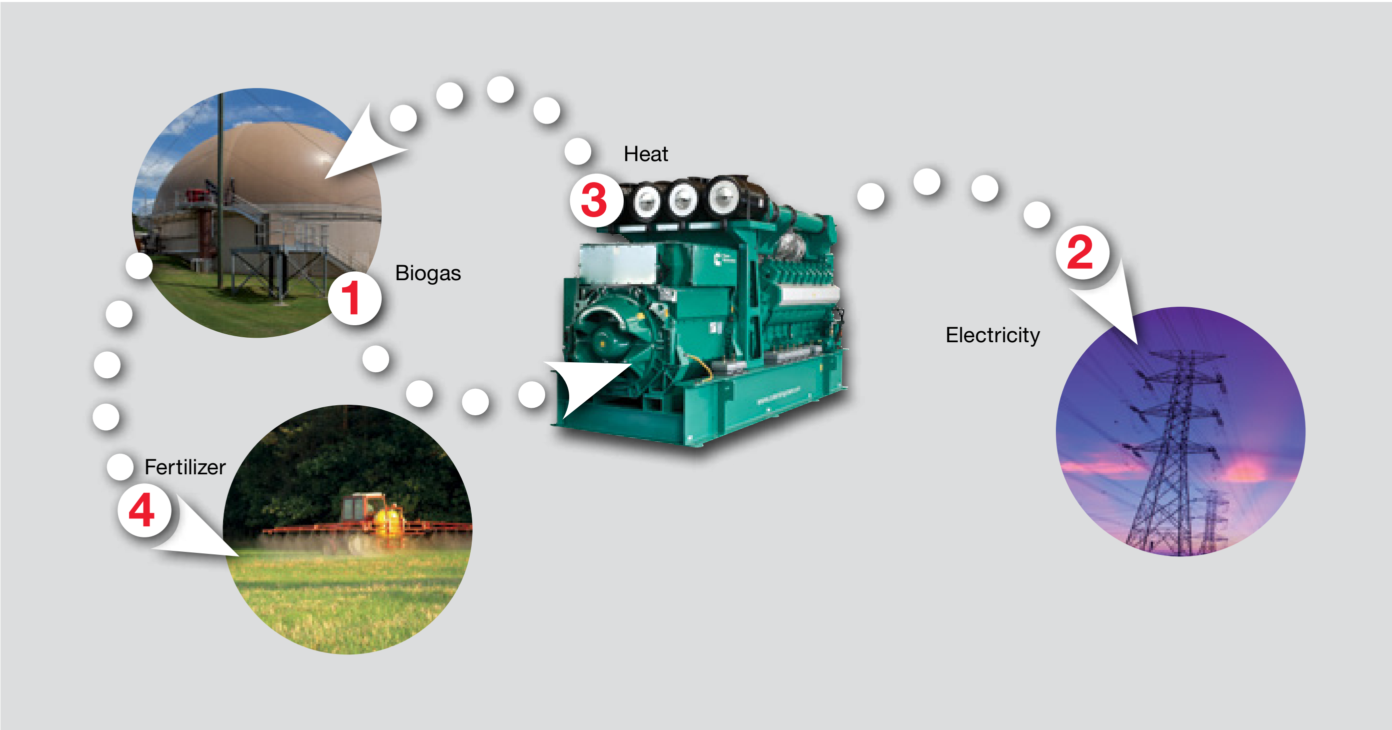
Biogas created during the anaerobic digestion (AD) process is typically composed of about 60% methane by volume. The other main component by volume is carbon dioxide, CO_2, which has no heating value when combusting the biogas to obtain heat. At this composition, a typical digester gas contains 580 BTU/ft^3 or 21.6 MJ/m^3 lower heating value. Pipeline quality natural gas, for comparison, contains between 850 and 1050 BTU/ft^3.

Other contaminants from the wastewater itself or from the digestion process may be problematic if the biogas is to be used as a fuel. Hydrogen sulfide (H_2S), siloxane compounds and ammonia are typical components that can cause damage to any internal combustion engine if not properly treated. Some of today's cost-effective biogas treatment methods are:

- Solid media that adsorb contaminant from the gas stream (such as activated carbon, iron sponge, or silica gel adsorption)
- Liquid media that "scrub" contaminant from the gas stream (such as chemical or water scrubbers)
- Self-regenerating methods (such as deep chilling, pressure swing adsorption, temperature swing adsorption, or dehydration)
- Biological scrubbers that use bacteria to reduce contaminants from the gas stream


Clarifying tank at a municipal wastewater treatment plant


Anaerobic digester producing biogas



Synergies between WWTP and Spark-Ignited Engine Generators

High utilization of the waste streams illustrated above and proper sizing of the power plant can lead to total system efficiencies that exceed 90%.

1. Biogas (a by-product of anaerobic digestion) is delivered to the generator set as fuel.
2. The generator creates electricity for the plant's on-site needs or for export to the local grid.
3. Engine heat can be recovered via the engine's cooling circuit or exhaust gas and converted to hot water or steam for the digester. This heat can keep the digester at its optimal temperature for increased biogas production.
4. Recovered generator heat can also be used to dry the remaining digester solid for plant fertilizer, which can be sold for additional revenue for the WWTP.

Making it Work for You

Sizing Your Plant: Heat or Electricity?

Selecting the right size power plant is key to realizing operating savings. This means a careful yearly analysis of the local heat demand for hot water, digester heating, sludge drying, and space heating purposes. Recognizing that the demand greatly fluctuates seasonally will ensure a proper evaluation.

On-site electricity demand is also important, but typical WWTPs generate far more biogas than is needed to meet the plant's electrical load. In this case the economics become favorable if the WWTP can sell excess or all electricity to the local utility grid (a system called net metering) or if nearby power, heat or cooling consumers can utilize any excess generation.

Costs and Benefits

Heat recovery can increase the total system efficiency from around 40% (from using the generator set only) to above 90% by replacing grid electricity and boiler heat. These efficiency gains translate into direct cost savings for WWTPs. The return on investment for WWTP power generation should take into account:

- New equipment capital expenditures
- Any appropriate stimulus or grant for renewable power generation equipment purchases
- Operations and maintenance costs of the power plant considering low to no-cost biogas as fuel
- Cost savings from displacing purchased electricity and natural gas from the utility with on-site generated power and heat
- Available net metering payments from the electric utility in $/kW-hr

Significant environmental benefits are realized as well. The first is evident: these projects replace the non-renewable fuel source (such as coal and natural gas) with a recognized renewable energy source (AD biogas). Secondly, although on-site generation produces more CO_2 emissions at the WWTP than if purchased from the grid, the distributed generator reduces overall heat and transmission losses that are inherent to centralized power plants. This holistic approach is recognized and incentivized by regulatory bodies as a means to reduce aggregate greenhouse gas emissions.

The Cummins Energy Solutions Business delivers turnkey lean-burn gas generator set projects ranging from 300 kW to 20+ MW. For WWTP, reciprocating engine generator sets provide:

- **Proven technology** for generating reliable power
- **Enhanced technology** to operate at full-rated power with AD biogas
- **Lower installed cost** per kilowatt than combustion turbine technology
- **Higher tolerance** for contaminants than fuel cells, microturbines, or gas turbine technologies
- **Flexible combined heat and power generation** to meet the customer's unique energy needs.

For more information, visit www.cumminspower.com/energysolutions.

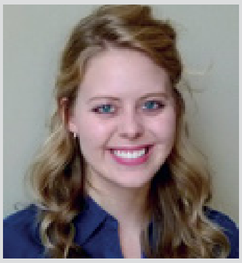
Guidelines:

The following guidelines are based on biogas with 580 BTU/ft^3 LHV and 41% generator electrical efficiency.

> 10,000 people served = 1 MGD wastewater flow
> 1 MGD wastewater flow= 29 kW power from biogas
> A 1 MW biogas CHP system in the U.S. reduces about 3,320 tons CO_2e per year.
> A WWTP serving 345,000 people can generate about 1 MW of renewable power.

Assumptions:

- Generator efficiency: 41%, 1 MW unit C1000N6C Low BTU
- CHP system: operates 8000 hr per year, heating only (hot water), HT and exhaust heat recovery, displaces existing gas boiler (80% efficient), no cooling, displaces average US grid (2009)
- Fuel heating value: 580 BTU/ft^3 LHV, no sulfur, 644 BTU/ft^3 HHV



About the author

Bruna Ferro is an application engineer for Cummins Power Generation, and provides technical support to the North and South America Energy Solutions Business project companies on the design, installation, and operation of gaseous fueled power plants. Her focus is on biogas and alternative fuel integration and treatment for power generation. She holds a Master's degree in Energy Systems Engineering and a Bachelor's degree in Civil and Environmental Engineering from the University of Michigan.

For more information on biogas and alternative fuel, contact your consulting engineering firm, power system manufacturer or email energysolutions@cummins.com

Power Generation

Our energy working for you.™
www.cumminspower.com