New US legislation boosts need for anaerobic digestion biogas facilities

Designing an anaerobic digester

New regulations and legislation, such as the California Low Carbon Fuel Standard and the US Renewable Fuel Standard, are increasing the need for anaerobic digestion biogas facilities in the US.

These sites convert organic waste such as separated food waste, animal manure, agricultural waste and municipal biosolids into clean, green renewable energy and fertiliser products.

Characterising the feedstocks

Many factors need to be considered when designing a digester facility, like knowing the feedstocks the operator wants to process. Identifying quantities is also important to accurately size the system. Knowing how one thing affects another is paramount to your facility design. How organic wastes are hauled and received at the site should inform the staffing needs of the site.

Additionally, the type of feedstock waste material indicates the resulting gas yield. The gas yield potential of a stale loaf of bread, for example, is very different from a gallon of dairy cow manure.

Understanding the types of packages that wastes will come in will determine what kind of pre-processing technology is needed. Systems that deploy a two-stage approach of pre-processing such as a first pass mechanical shredder or bag opener and second stage hammer mill can convert a case of expired yoghurt cups into a clean pile of plastic rejects and clean liquid yoghurt to feed the digester.

Designing the digester

Digesters come in many shapes and styles. The most common is called a 'wet digester.' These units use above ground steel or concrete tanks that are sealed off from ambient air, heated to about 95°F (35°C) and mixed with mechanical agitators. Water may be added to get the incoming feed mixture to the proper consistency of about 10% solids. The typical detention time of three to four weeks allows the anaerobic bacteria to convert long chain carbon molecules into methane-rich biogas.

A 'dry digester' runs in tall cylindrical units or in units that have wastes stacked up inside like large garages. The tall cylindrical units feed liquefied, pulped waste into the top of the 50-foot tall, heated tube and waste flows downward for three to four weeks while it is converted to biogas. In the garage-style units the waste is mixed with yard wastes like leaves and grasses and stacked in piles that fill the 50-100-foot long garage bays. These units are heated, and water is sprinkled on the waste to inoculate the system with bacteria and keep it damp. Waste is kept warm in the garage unit for about a month while it makes clean, green, renewable biogas energy.

Every system has a loading rate that should be closely monitored. In a wet system, for instance, the feed rate is about 2lbs of food waste to feed a gallon of tank capacity every week. Feeding more than that can cause system upsets and loss of gas yield, while feeding much less can make for poorly performing, underfed bacteria and poor project economics.

Digester tank design

Heating

Digesters need to be kept warm for proper bacteriological function. Heating coils can be mounted inside the tank itself or placed within concrete tank walls. External heat exchangers can also be used and can include a plate and frame, spiral or shell-in-tube designs. For systems without combined heat and power units or other sources of heat, a boiler system may be required for ongoing heat. A heat source should be considered for system start-up.

Mixing
Good mixing is important to ensure proper stirring of the tank, suspension of heavier solids and proper contact between the microbes and waste. Mixing time can vary from continuous to periodic to save on power costs. Various configurations of mixers are widely adopted in digester design and should be considered a major point of focus for the system's long-term reliability and mechanical integrity. Some digester projects will incorporate a combination of the following mixing techniques in a given project.

Mechanical mixers
Mechanical agitation can be done in a variety of ways:

- A fixed vertical shaft hanging from the digester roof
- A side-mounted propeller-style mixer penetrating the tank wall
- Submersible mechanical mixers mounted on rails connected to the interior tank wall, powered by a motor or high pressure hydraulics
- A mixer on a short shaft mounted inside the digester basin that spins horizontally with paddles extended from the spinning shaft

Gas mixers
Gas mixers compress digester biogas and reintroduce the gas back into the tank bottom through long, gas lance pipes where large bubbles agitate tank contents on their way back up to the tank surface.

Tanks
Concrete poured in the shape of a cylinder or egg is commonly used for digester tanks. Precast concrete panels that are formed at an off-site factory can also be shipped by truck to the project site where they are tipped up vertically and then tied together with a network of horizontal cable ties.

Steel tanks are also common, built with panels that are either bolted or welded together. If the panels aren't made of stainless steel, they are coated with epoxy paint or a glass-fused-to-steel coating.

Digester tanks are commonly insulated with either spray-on foam or rigid foam that is attached to the exterior tank surface. Subsequent metal cladding, brick veneer, split block or other materials are often attached to the foam's exterior for durability and aesthetics.

Roofs and covers

Fixed and floating
Many municipal digesters have a hard-fastened roof on their digesters with mixers hard mounted on the rooftop. Another common municipal digester roof is a metal structure that floats on the digester contents and rides vertically on steel guide members and roller mechanisms.

Dual membrane
These covers have an outer membrane that spans the tank, is inflated by a blower and provides protection from severe weather and contains odour. There is a separate, inner membrane that moves based on the quantity of biogas stored under the outer cover.

Gas bladder holders
This soft, double membrane, inflatable cover is mounted at grade and holds enough gas volume to buffer swings in demand. The outer membrane is inflated by an air compressor while the inner layer holds the biogas. Inner pressure settings can be adjusted to users' gas pressure requirements.

Digestate management
The resulting liquid from a digester contains dissolved organic matter, fibrous material and nutrients. Digester operations that have ample land nearby can apply this fertiliser seasonally to crop lands that are looking for nutrients. Fertilisers derived from AD systems can provide results that are equal to or better than comparable synthetic fertilisers. The form of nutrients in digestate is readily available. Nitrogen is present as mostly dissolved ammonia, phosphorous as phosphate and potassium in the ionic form. Furthermore, the fertilisers add hums and microbes to the soils improving plant productivity.

Many farm-based digesters have sizable storage volume to hold this nutrient-rich liquid until their crops call for fertiliser. Digestate can be further processed as outlined below, based on particular site needs.

Dewatering
Liquid digestate commonly leaves a digester with roughly 2-10% total solids and thus 90-98% water. Common devices used to squeeze the water out of these solids are screw presses, belt presses and centrifuges.

Screw presses press the solids-laden feed liquid against a firm plate, which squeezes the liquid out from the digestate. Belt presses utilise permeable belts that sandwich the solids between rollers that squeeze the water from the solids. Centrifuges have a spinning bowl at the heart of the process which, through centrifugal action, builds a sludge cake on the inner surface of the bowl as material flows through with relatively clean water emerging at the outlet. These technologies generate a solid digestate material that is about 15-30% solids and 70-85% water. Fibre and cellulose in the incoming feed can help make for a better quality solid digestate product out the back end.

Drying and pelletising
For those applications looking for a very dry, solid product, a thermal drying step can be used. Systems like paddle dryers, direct fired dryers or infrared dryers can generate a solid fertiliser of greater than 95% solid matter. Pelletisers add an additional amount of solid particle recovery control generating a hard, nutrient dense, dry fertiliser. Ideally, there would be enough waste heat at the site to drive the dryers and avoid purchased gas for drying purposes.

Gas safety
Gas safety equipment must allow a digester to vent gas should system pressure elevate. Vented gas should be sent to a flare. Pressure relief valves must be properly designed, insulated and heated to ensure proper year-round operation. Burst discs, foam traps and flame arrestors round out the safety equipment needed. ●

For more information
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