

Is methane production on your homestead practical?

By Jim Tracy

Homesteaders searching for a source of energy independent of power grids and pipelines may have to look no farther than the manure in the barn. This "waste" is teeming with bacteria that produce energy through a process that is almost as old as life itself.

In the absence of oxygen, certain types of bacteria break down organic material and give off methane gas, the chief constituent in the natural gas utilities sell. The major difference between natural gas supplied by a utility and biogas is their methane concentrations. Natural gas is approximately 95 percent methane (or 95 percent combustible gas), while unrefined biogas is only 60 percent to 70 percent methane. So natural gas contains more energy than biogas.

Methane, or swamp gas, is highly combustible when exposed to air at certain volumes and sometimes produces flashes of light visible at night over marshy ground. These strange "will-o'-the-wisps" were once believed to be goblins and fairies. The Middle Ages gave them another name, *ignis fatuus*, or "foolish fire," which later came to signify any delusive goal.

A brief history of biogas

Scientists have only recently begun to fully understand how bacteria convert organic matter into methane even though this curiosity of nature has been a laboratory sideshow for centuries.

Louis Pasteur, the French chemist who disproved the notion of spontaneous generation, discussed the possibility of methane production from manure in 1600. Robert Boyle, the Anglo-Irish physicist and chemist who gave the world the first precise definition of a chemical element, noticed in the 1600s that gas was produced from rotting animal and vegetable wastes.

The Italian physicist Alessandro Volta, inventor of the electric battery, identified methane as the specific gas in 1776. Sir Humphry Davy, the English chemist who discovered chlorine and showed that diamonds are a form of carbon, produced methane from manure in the laboratory in 1806.

Scientists call the process anaerobic digestion, or the controlled decay of biomass without oxygen. Anaerobic digestion was first applied as a technology to treat sewage. As early as 1850, nine years before the world's first oil well was drilled in Titusville in western Pennsylvania, anaerobic tanks were being used to treat settled waste-water sludge in the United States. In 1857, a full-scale anaerobic digester for treating sewage was operating in Bombay, India. And in 1895, Donald Camerson, built the first septic tank in England and used the methane it produced to light street lamps.

Biogas production on the farm is no recent technology either. In 1918, Lord Iveagh built a digester on his estate in Surrey, England, and produced methane with straw and farm yard manure.

Faced with fuel shortages during World War II, farmers in Europe turned to anaerobic digestion to make biogas to power tractors. A few small-scale plants are still in operation in France, Germany, Holland, Denmark, Sweden, England and Wales.

Small scale digesters

Many of the advances in biogas production on a small scale have come from India, where people in the poorest parts of the country depend on firewood, crop residues, and dried cattle dung (a source of disease-carrying bacteria) for their cooking and lighting needs.

Seeking a more healthful use for dung, India's Khadi & Village Industries Commission has promoted construction of small anaerobic digesters. More than 200,000 simple digesters

are in operation scattered across India today. Indians use the residual slurry, which is rich in nitrogen and humus, for fertilizer.

Simple, inexpensive anaerobic digesters, including covered lagoons, are even more common in China. Some Chinese use human waste (or "night soil") as a feedstock. According to statistics compiled by the Guanzhou Institute of Energy Conversion, more than seven million digesters have been built in the country since the late 1950s and nearly 30 million Chinese peasants use biogas for household purposes and to run farm equipment.

Successful small-scale digesters have also been built in Korea, Taiwan, Vietnam, Nepal, Pakistan, Iran, New Guinea, the Philippines, Indonesia, Guyana, and Uganda.

Manure to methane

Most of these digesters are brick, clay, concrete or metal vessels filled with manure about once a month. A lid is placed on the vessel and a pipe is attached to recover the gas. These so-called "batch" plants produce about 100 cubic feet of gas per day, or about 50,000 Btus per day. The heating value of that much biogas is less than a halfgallon of gasoline.

Biogas production even on so small a scale pays in undeveloped countries where other sources of energy either are not available or are exorbitantly expensive.

In the United States where energy is cheap and plentiful, small biogas plants seem less attractive.

On a larger scale, biogas production is a proven, money-saving technology in landfill dumps, wastewater treatment plants, food-processing facilities and slaughterhouses.

It has also been tried successfully on American farms. Estimates of the minimum size farm needed for economic methane production range from

six to 200 cows. Researchers at Cornell University, however, estimate that it takes herds of 50 cows or more to produce biogas economically.

It's a biochemical process

So how does anaerobic digestion work?

The most important thing to remember is that it is a biochemical process.

In the digestive system of a cow, for example, bacteria break down the nutrients in food. Many of these bacteria survive in the animal's manure. If the manure is placed in a tank without oxygen, the bacteria continue to break down the fats, carbohydrates and proteins that were not digested by the animal. This secondary digestion produces biogas—a combination of combustible methane (CH₄), noncombustible carbon dioxide (CO₂), and trace gases, such as oxygen, carbon monoxide, and hydrogen sulfide, a highly corrosive compound that gives the gas a distinct odor, somewhat like rotten eggs.

When thoroughly digested, the remaining waste, which is rich in soil nutrients, can be recycled as fertilizer. It is free of weed seeds and harmful organisms like salmonella bacteria, tapeworm cysts, amoebae and nematodes. It doesn't attract rodents and flies. And it is virtually non-polluting.

Methane has many uses

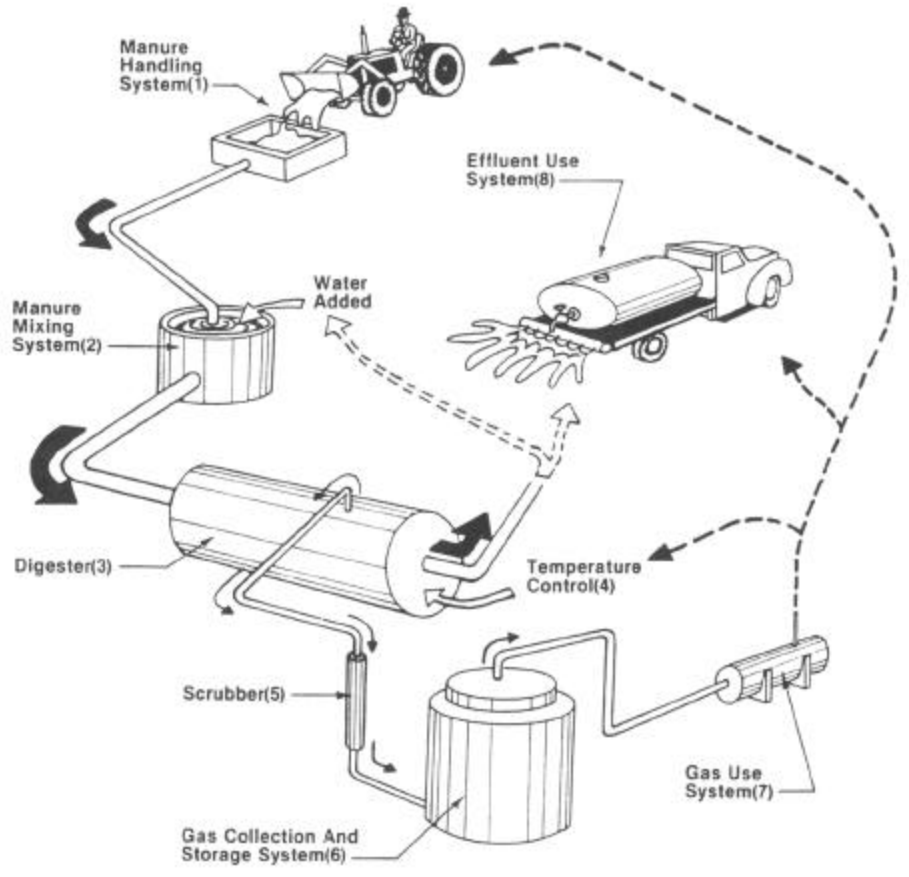
Pure methane, which burns with a violet flame without smoke, has a heat content of about 1,000 Btus per cubic foot. One Btu is the amount of heat needed to raise one pound of water (one pint) one degree Fahrenheit, roughly the amount of heat in a kitchen match. Five cubic feet, or 5,000 Btus of gas, is enough to bring a half gallon of water to a boil and keep it boiling for 20 minutes. Methane produced in a digester would have a heating value of about 600 to 700 Btu per cubic foot, although some researchers have estimated the net heat content of biogas as low as 538 Btu/ft³.

Like natural gas, biogas can be burned to fuel boilers, water heaters, cook stoves, furnaces and engines that

have been properly adapted. Because it has a high octane rating (100 to 110), it burns efficiently in high-compression engines. It can also be used in refrigeration using an absorption cooler and in producing electricity using a generator, although these applications require added equipment and considerably more technical knowledge.

The bigger the digester, the better the economics

Anyone considering biogas production on a homestead scale should first determine the kind of digester to be built, the size of the digester and the end use for the gas and sludge. Generally, the bigger the digester, the better the economics. Economies of scale dictate that larger digesters can



While manure holds the potential to produce energy through anaerobic digestion, many farmers consider it a necessary evil. Agricultural runoff also contributes to pollution of rivers and lakes.

When properly built and maintained, anaerobic digesters can turn this waste into useful byproducts and reduce pollution at the same time.

be built for less on a cost-per-animal basis than smaller digesters.

The basic components

All biogas systems have seven basic components: a waste handling system; a system for preparing the waste for digestion; one or more digester vessels; a system for controlling the temperature of the digester; scrubbers for removing carbon dioxide and hydrogen sulfide from the gas; a biogas collection

system and storage tank; and a system for using the sludge, or effluent.

Collecting manure

The type of collection system depends on whether animals are confined or allowed to forage in the field. Naturally, confined animals provide a more readily available source of manure.

Pig slurry, normally collected in channels under slats, flows slowly. It can be spread on land or transported to a digester by tanker.

Poultry droppings, usually soaked with urine, are handled as solid manure. Several methods have been devised for collecting it.

Digesters using poultry and swine manure have shown limited success, mostly because of the high nitrogen, or ammonia, content in the urine. Too much nitrogen can inhibit, or even halt, the growth of bacteria that produce biogas. These bacteria reproduce best when the ratio of carbon (carbohydrates) and nitrogen (proteins) is between 20 and 30 to 1, such as in dairy cattle manure.

Cattle manure can be collected under slats in a barn or scraped from a solid floor and flushed into a holding tank.

Most farm manures contain 72 percent to 82 percent volatile solids - the organic solids that burn off when dry material is heated to 1,000 degrees Fahrenheit. Volatile solids are the material that can be converted by anaerobic digestion. The remaining fixed solids are biologically inert.

Researchers at Cornell University estimate that every 100 pounds of raw manure from a dairy cow contains 87 pounds of water and 13 pounds of total solids. Of the total solids, 11 pounds are volatile solids available for biogas production. Most digesters can convert only 4 pounds of the volatile solids to biogas. So, 96 pounds out of every 100 pounds of feedstock leave the digester as effluent.

Once manure is collected, it often must be mixed with water either in a holding tank or in the digester to form a slurry. Manure from a dairy cow is 85 percent water and usually does not require water to reach the proper con-

sistency. Swine manure must be mixed with water to dilute the ammonia in it. Poultry droppings, also high in ammonia content, can require as much as two-and-one-half times as much water as manure to reach the proper dilution.

Digesters are of two basic types: batch and continuous.

Batch digester

Batch digesters, usually single upright tanks, are filled with a full charge of slurry and sealed. During an initial aerobic period, oxygen-loving bacteria consume the remaining oxygen, making way for the anaerobic bacteria to begin producing gas. After the feedstock is digested, the slurry is removed and replaced with a new batch of feedstock and the process begins again.

Batch digesters work best on small farms without a regular supply of feedstock. They are less expensive and require little daily attention, but they also produce gas unevenly.

Continuous digester

In a continuous digester, slurry is fed periodically into the system in small amounts, usually only once a day.

There are three major types of continuous digesters: mixed, plug-flow, and two-stage.

Mixed digesters use an upright vessel, often a squat silo, that is loaded and unloaded at frequent intervals. When new feedstock is added, an equivalent amount of processed manure is removed. The new feedstock is mixed with the remaining substrate with mechanical agitators or by pumping in biogas to homogenize the mixture.

One disadvantage of these systems is that the effluent contains a mixture of manure in various stages of digestion, creating the possibility that undigested manure may leave the tank too soon and digested manure may stay too long. Another disadvantage is the added complexity of mechanical mixers or pumps.

A plug-flow digester is a long narrow tank, sometimes placed in the ground. New feedstock is fed into one end, displacing digested manure that overflows at the other end. The length of the tank allows material to remain long enough for adequate digestion.

Continuous digesters produce both gas and sludge at a uniform rate, making them particularly well-suited for systems with a regular supply of feedstock.

Two-stage digesters break down the feedstock in phases. In the first phase, or liquefaction, acid-forming bacteria convert fats, proteins and carbohydrates to simple organic fatty acids. In the second phase, or gasification, methane-forming bacteria convert the organic, or volatile acids, to methane and carbon dioxide.

The acid-forming bacteria are not as sensitive as the methane-forming bacteria to temperature, acid concentration, feedstock loading rates and retention times.

Two-stage digesters create the optimal environment for each type of bacteria to thrive. These systems can be either two separate digesters connected by a pipe or a single chamber divided into two sections with a flow passage through the dividing wall.

Optimal temperature vital

Maintaining the optimal temperature is the single most important factor in successfully operating a digester.

Anaerobic digestion occurs at temperatures ranging from 32 to 140 degrees F (0 to 60 C), although the methane formers are severely inhibited below 68 degrees F (20 C) and above 131 degrees F (55 C). One kind of bacteria thrives in the so-called mesophilic range, 85 to 105 degrees F. Some researchers suggest that optimal biogas production for these bacteria occurs at 95 degrees F.

Thermophilic, or heat-loving bacteria, produce biogas at an optimum rate in temperatures ranging from 120 to 140 degrees F (49 to 60 C).

Most feedstock digests as well in the lower range, which requires less heat to maintain and minimizes heat loss

through the roof, walls and floor of the system.

Researchers at Cornell have found that optimum biogas production from dairy manure occurs at 100 degrees F.

Controlling the digester temperature can be a challenge in northern climates, especially during the winter. There are several ways to counter heat loss. The simplest way is to insulate all the parts of the digester, even if the tank is partly underground. Another way is to dilute the manure with heated water before it is loaded into the digester. The water can be heated by a biogas-powered water heater, a solar water heater, or by a system that captures exhaust heat from a stationary combustion engine that uses biogas for fuel.

Gas scrubbers help biogas burn more efficiently

Biogas burns readily as it leaves the digester, but it burns more efficiently if the water vapor, carbon dioxide and hydrogen sulfide are removed first.

Water vapor can condense and foul the burners and control devices in a furnace or water heater. It can be removed either by cooling the gas and capturing the moisture in condensate traps and allowing it to drain out of the system or by passing it through a medium such as calcium chloride or an organic absorbent.

Carbon dioxide can be removed by passing the gas through a lime-water solution, although this is not necessary if the gas is to be used for fueling an engine or boiler.

Hydrogen sulfide can be "scrubbed out" by passing the gas through iron filings, steel wool or an iron sponge filter consisting of wood shavings coated with iron oxide.

Biogas most efficient as a fuel replacement

Biogas is most efficient when used as a replacement for heating fuels.

Since it has a lower energy density than other common fuels, keeping significant quantities in storage requires large tanks, adding to the cost of the system. Researchers in Wisconsin have found it is least expensive to

store no more than one day's biogas production.

In compressed form, it can fuel tractors and automobiles fitted with large fuel tanks.

Storage tanks

No matter how efficient the digester, a system for storing and handling sludge is required similar to systems used to manage raw manure.

In a batch system, biogas can be collected and stored in the digester. Some batch digesters are fitted with flexible covers that inflate as gas is produced and deflate as it is siphoned off. Gas may also be stored in a flexible bag or rigid tank. It can also be compressed into rigid tanks, such as propane tanks. Perhaps the least expensive option is to provide no storage at all, using only as much gas as the digester produces and allowing the excess gas to escape or burn off.

Biogas production poses several safety concerns. Methane is flammable and highly explosive when mixed with air within the range of 5 percent to 15 percent by volume. Explosions are most likely to occur in confined spaces such as in a recently emptied digester. Hydrogen sulfide can also pose a threat. The Occupational Safety and Health Administration has established a maximum limit of 20 ppm for hydrogen sulfide in a working environment.

Digester sludge as fertilizer

Digester sludge is comparable to unprocessed manure in fertilizer value. But because part of the organic nitrogen has been converted to ammonia, it is more readily available to plants. Digested manure is also easier to spread on gardens and fields.

A word about cost

There's a huge difference between knowing how digesters work and actually building one. Anyone considering biogas production should carefully examine the advantages and disadvantages. Although it can help control pollution and create usable byproducts, it does have liabilities.

Biogas production requires equipment that can cost thousands of dollars and may require the help of a consultant to set it up, adding to the cost. Special storage is needed for the biogas produced. Temperature and acid concentrations must be strictly controlled. Energy is needed to start it. And it requires continuous maintenance.

Biogas production isn't for everyone. But it can be a good investment for some small farms and homesteads. For a free U.S. Department of Energy publication titled *Introduction to Biogas Production on the Farm* write to NATAS, P.O.Box 2525, Butte, MT 59702; or call toll-free (800) 428-2525, or in Montana (800) 428-1718.

Sources

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Ignorance never settles a question.

Benjamin Disraeli,
Earl of Beaconsfield
1804-1881