

Anaerobic Digesters and Methane Production...

Questions that need to be asked and answered before investing your money



A number of Wisconsin livestock producers are considering the installation of anaerobic digestion systems and the equipment necessary to generate electricity from the methane produced and collected by these systems. There are several reasons these systems are being considered: decreasing on-farm energy costs by using methane to generate electricity; mitigating odor problems on livestock operations; and improving the handling of manure nutrients and control pathogens. In addition, electrical generator companies are mandated in some areas to increase the amount of “green” energy produced, and may pay a premium for it.

However, producing and managing methane requires a substantial commitment of financial and management resources on the part of the operator. Farmers need thorough and accurate information before starting methane production on their farm.

Anaerobic digestion and the production of methane gas are not new concepts. They have been used profitably for many years in the waste management industry (municipal wastewater treatment plants and sometimes landfills). Until recently however, not many farms were generating electricity. Recent changes in the rising cost of energy, improvements in the technology used to convert methane to electricity and the environmental pressures agriculture is facing in terms of livestock production, has increased interest in anaerobic digestion systems.

The purpose of this publication is to provide brief answers to the common questions farmers often ask about anaerobic digestion and methane generation. It is not our goal to provide all the information needed to make a decision on whether or not this technology will work on your operation. The goal of this publication is to provide information on the basic questions producers have. Once you have answered

these questions and you desire additional information, more detailed and specific guidance can be found in the recommended publications, web sites and other materials referenced by this publication.

In general, a well-designed and managed anaerobic digester will have few safety concerns. Still, the gas-handling components of the digester and engine-generator must be designed to ensure safety. Inhalation of biogas can pose health risks, and biogas is flammable and even explosive in confined spaces.

There are only a few examples of methane digesters on which to base construction costs. Numbers vary, but some examples indicate about \$250,000 for a 1,000-cow dairy operation. In many cases, farmers have found low-cost loans or even grants to assist in start-up. This \$250,000 estimate includes design, engineering, construction, generator and engine, and some electrical connections, depending on how sophisticated they need to be.

Anaerobic Digestion Systems

What types of digesters are being used, and what are the advantages and disadvantages of each type?

An anaerobic digester is an enclosed tank that excludes oxygen. A specific population of naturally occurring bacteria break down manure into a variety of gases, including methane and carbon dioxide.

The digestion of manure occurs in four basic stages: hydrolysis, acidogenesis, acetogenesis and methanogenesis. The final stage, methanogenesis, is the step that breaks down the intermediate compounds to produce methane. The gas released during the digestion process is captured and can be burned. This biogas contains 50 to 70 percent methane, 30 to 50 percent carbon dioxide, and trace gases, including hydrogen sulfide. Methane-producing bacteria are most active in two temperature ranges, 95 to 105 degrees F and 130 to 135 degrees F.

As a means to increasing methane production, some digesters contain heating pipes that circulate hot water and heat and maintain the digester in the desired temperature range. A flexible, impermeable cover on the digester traps the biogas, which is then either burnt in an open flame or passed through an electrical generator. There are several types of generators. Most are driven by modified internal combustion engines. The electricity can be used strictly on the farm, or it may enter the electrical grid that feeds the farm.

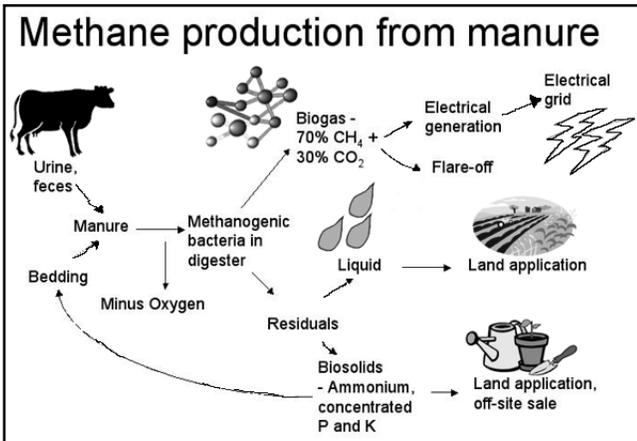




photo courtesy of RCM Digesters

Covered Lagoon Digester, Wisconsin

Types of Digesters

Covered Lagoon Digester: Frequently farmers cover manure lagoons to minimize odor problems. A covered lagoon digester can be used on large-volume, liquid manure lagoons with less than 2 percent solids. The cover is usually an impermeable plastic membrane. The cover traps gas produced during the decomposition of the manure. Collecting methane involves a floating lagoon cover and may require a gas pump to move the gas. This system can be used on both swine and dairy operations and works optimally where the manure is handled as a liquid and the climate is temperate to warm year round. This is the least expensive of the three types of digestion systems, but may not function well in cold climates.

Complete Mix Digester: A complete mix digester is used for manure containing 2 to 10 percent solids, which includes dairy manure or swine manure collected by a flush system. Above- or below-ground tanks are heated in this system. A mechanical or gas-mixing system keeps the solids in suspension, which accelerates the digestion process. These digesters are expensive to construct and cost more than covered lagoon digesters to operate and maintain. One concern of this system is that excessive water addition increases the digester size requirements and the cost of construction and operation, without increasing benefits.

Plug-Flow Digester: Plug-flow digesters are suitable for ruminant animal manure (cows), collected by scraping and containing a solid concentration of 11 to 14 percent. This system is not appropriate for manure with lower solids concentration, such as swine manure or dairy manure

collected through a flush system. In a plug-flow digester, the solids in manure with lower than desirable solids concentrations are poorly digested because they gradually settle to the bottom of the tank. Under optimal conditions, the plug passes completely through the digester in 15 to 20 days. This system has few moving parts and requires minimal maintenance.

Temperature-Phased Anaerobic Digestion (TPAD): The TPAD method, developed at Iowa State University, combines traditional types of digestion technology in a two-stage reactor. The first stage operates at high (thermophilic) temperatures of 55 degrees C/135 degrees F, while the second stage digests at lower (mesophilic) temperatures of 35 degrees C/95 degrees F. The system

is a complete mix, which works best with the more dilute manures coming from dairy farms operating their parlors more or less continuously. A variety of other organic products can be added to increase methane yield during the process. Research data indicates improved odor control, reduced foaming, additional volatile solids destruction, and improved dewatering characteristics compared with conventional plug-flow designs. The high heat process destroys Class A level pathogens, thus producing a higher quality biosolids product. Although the TPAD system holds promise, very little data is available on field-scale systems.

What types of manure management practices – water content, bedding, storage, and treatment – are required for anaerobic digestion?

In general, methane generation systems are most appropriate where most manure is recoverable (e.g., complete confinement), where manure is regularly scraped, and sand bedding is not used.

Water content: Anaerobic digestion systems are available for wet or dry manures. Maintaining constant water content is important for consistent processing. Collecting



photo courtesy of RCM Digesters

Complete Mix Digester, Colorado



photo courtesy of RCM Digesters

need to handle the nutrients in the biosolids, manure storage and treatment systems must be modified appropriately. Heat recovered from the digestion/electricity generation process can be used to dry the solids.

Pre-treatment: Ideally the digester should be set up to accept manure as it is produced. In some cases water may be added if needed. Most operations will have a manure collection pit that can handle manure for a pre-determined amount of time, which feeds fresh manure into the anaerobic digester.

Heated Mixed Covered Lagoon, Illinois

manure through a flush system (using water to flush manure to storage) usually makes the manure too diluted for effective processing.

Bedding: Mixed with feces and urine, bedding becomes another feedstock for the digester. The chemical and physical properties of the bedding must be considered. Research has shown that shredded newspaper is not only easily digested, but it increases the amount of methane produced. Other sources of bedding (straw, corn stalks, etc.) can affect the digestion process. Anaerobic digestion systems are not adaptable for livestock housing systems that use sand as the bedding source because the sand accumulates and clogs the flow of nutrients in any of the digestion systems.

Manure Storage: In most cases the digester serves as the storage system for the fresh manure. After anaerobic digestion, manure can either go to a storage system directly, or go through a separator to separate the solids from the liquids. The biosolids remaining after the digestion process have to be stored but are smaller in volume and usually have much less odor. Depending on how producers want or

Are there any special requirements for handling the biogas?

Biogas is primarily a mixture of methane and carbon dioxide, with some trace gasses; including ammonia, hydrogen sulfide, mercaptans (strong odors) and other noxious gases. Biogas is combustible and must be handled to avoid sparking when mixed with air. When the gas is thoroughly combusted, most of the organic compounds are oxidized to carbon dioxide. Unfortunately, the hydrogen sulfide is converted to sulfuric acid, making it very corrosive. The hydrogen sulfide can either be removed (scrubbed) from the gas before combustion, or combusted in the generator engines. Scrubbers typically decrease maintenance requirements and extend the useful life of generator engines.

Why do digesters fail?

The primary reason for the failure of anaerobic digesters is bad design and/or installation. The second most common reason for digester failure is the selection of poor equipment and materials. The third reason for digester failure,



photo courtesy of RCM Digesters

Plug-Flow Digester, New York

and an important reason, is poor farm management. A digestion system should be engineered specifically for the individual farm operation, and then properly installed. It is critical the farm operator understands that a digestion system is similar to other farm equipment. The system must be operated and maintained by a producer who understands how the system should work and watches it closely just like any other piece of farm equipment (tractor, chopper, etc.).

Another factor in digester failure can be specific compounds in livestock diets passing through the manure, which can cause problems with the anaerobic digestion process. Excessive ammonia concentration, produced from animal urine, can inhibit or kill the methane bacteria. Rumensin or similar products affect the microbes and change the digestion process. An anaerobic digester relies on organisms to digest the manure and produce methane. Care must be taken to insure the desired organisms can survive and thrive in the digester.

Methane Generation and Electricity Production

How many cows or animal units do I need to make methane generation economical?

The Ag STAR Program (a joint program of the Environmental Protection Agency, the U.S. Department of Energy, and the U.S. Department of Agriculture) suggests that a farm should have at least 300 head of cattle. However, there are examples of successful methane digesters on smaller farms. Since initial digester start-up



photo courtesy of RCM Digesters

Methane being safely flared off of a digester.

can be time-consuming and inefficient, the digester needs to be constantly and regularly supplied with fresh manure to maintain the methane-producing bacteria. Therefore, it is important there be a year-round supply of fresh manure. Economies of scale include both the anaerobic digester and the electrical generation system.

In determining whether or not an anaerobic digestion system could be financially successful, one of the most important factors is whether or not your local electric company is willing to buy your biogas and if so, at what price? If your goal or intention is to build a digester on the hopes of selling the biogas, it is important to contact the local electric utility and determine what your options are and their availability for handling green gas.

How much electricity can I produce? What types of generators and electrical connections are used for electrical production from biogas?

As a rule of thumb, if the anaerobic digester is working efficiently, a dairy farm can produce two to three times the electricity it normally uses. For example, a typical dairy milking an average of 500 cows per day can produce 30,000 - 50,000 cubic feet of biogas daily. With this volume of gas, a 70 kW generator can produce 1000 - 1,400 kWh of electricity per day, along with significant heat recovery from the engine. The recovered heat can be used to heat water, to heat the digester or for space heating.

When deciding on the size of generators, each operation should do their own evaluation based on animal numbers, the type of digester and other factors unique to the farm. However, as broad guidelines, a 70 kW generator has been recommended for a 500-cow herd, and one 2,300-cow dairy installed a 750 kW generator.

Modifying engines to burn methane is not difficult. The generator engine, rather than the generator itself, requires the most maintenance. Maintaining the generation equipment usually requires 15 to 30 minutes per day, and entails checking the oil and monitoring gauges. The farm operator can normally do this common routine maintenance. Monthly maintenance includes engine oil change, valve adjustment and spark plug cleaning. Estimated engine maintenance for an on-farm biogas generator engine, including periodic engine overhaul, was \$3,700 per year in one case, for about 1,800 milking cows.

Electrical equipment and connections in areas where flammable or explosive gases may develop require special adaptations to avoid spark ignition.

How much more time will it take to produce methane than my typical manure handling requires?

Moving the manure to the digester, checking gas production, removing solids from the digester are all part of the process. The plug-flow system is the most appropriate system for cow manure collected by scraping. With a herd of 500 cows, this system requires about 45 minutes of routine operation per day. This includes system inspection, mixing and pumping manure into the digester twice a day, and checking and recording gauges to measure biogas and electricity output. On average, routine daily maintenance requires less than one hour, depending on herd size.

What factors determine how much money I can save or make in using methane generation?

The simple answer to this question is that it depends on the amount of methane produced. There are several factors affecting the amount of gas produced, including the feed ration, solids content of the manure, constant temperature, length of time manure is in the digester and bedding materials. High-energy diets can more than double the methane potential of manure compared to manure from animals fed a lower energy diet. The higher the solids content, the greater the biogas production per gallon of manure, because there are more energy-rich organic materials in that gallon.

The frequency and regularity of manure collection is important, because this creates a stable environment for the organisms. Maintaining a constant temperature throughout the digester is very important for microbial activity. The longer the manure remains in the digester, the more methane will be produced. The pH of the manure can also be a factor. The pH should be as close to 7.0 (neutral) as possible. Higher or lower pHs can kill or inhibit the methane-generating bacteria. Addition of readily decomposed organic materials in bedding (like shredded newspaper) can increase biogas production, although they are not required.

What issues relate to connection to the electric grid?

A number of important issues must be addressed if the farm decides to go "on the grid" and sell its power to the utility company. In all cases, the utility company should be consulted very early in the process to get the specific information needed to evaluate this option. Issues include the following: (1) The alternating current cycle (phase) of the farm's generators must always be matched with those of the line coming into the farm. (2) The electrical service line system to the farm must be large enough to handle additional load from the farm when it is selling significant quantities of power. (3) Interruption of current from either side – the farm or the outside line – must be handled by the system in place.

With up-to-the date anaerobic digesters the equipment used to connect the generator to the public electric grid can ensure that the connection is both safe and reliable. Controls are built into the system that balance the output from the digester system with the line current.

Environmental Benefits and the Handling of Biosolids

What are the characteristics of the residual byproducts? What is the market for them?

The biosolids produced from anaerobic digestion can be an excellent soil amendment, either for direct use or when blended with other materials. Anaerobic digestion typically



photo courtesy of RCM Digesters

Maintaining the digester engine is a key to success in this process.

decreases the manure solids volume by 50 - 60 percent, but there is little effect on total volume because the slurry is 90 - 95 percent water. The biosolids contain higher concentrations of N, P, K, and trace elements than manure. They also contain relatively high concentrations of ammonium-N, making the N rapidly available (more like commercial fertilizers) once it is spread on fields. However, to avoid ammonia losses and odor problems the material must be handled appropriately.

Because manure digestion is anaerobic, most weed seeds and pathogens are killed during the process. The numbers of most pathogenic organisms are reduced by more than 90 percent by the digestion process. Fecal coliform bacteria numbers in the biosolids are only about 1 percent of those in fresh and stored manure, lowering the potential for this source of water pollution. Pathogens causing some of the common food production diseases, can be practically eliminated from the manure by anaerobic digestion. Fly eggs are killed during anaerobic digestion, eliminating this important disease vector and general pest.

The liquid portion of the digested manure has a high value as fertilizer. The liquid effluent from the digested manure has been used as a dietary supplement, and reportedly contains 40 to 50 percent crude protein on a dry matter basis.

Some livestock operations have installed digesters and additional equipment to separate suspended solids from the liquid. The separated fibers (solids) contain 20 - 30 percent of the total nutrients compared to the original manure. For example, if a farm with approximately 500 head of cattle installs a digester and a liquid/solid separation system, the nutrients contained in the solids would be worth approximately \$40,000 per year compared with commercial fertilizer prices. Depending on the market and price received for electricity, the value of the nutrients in the solids is very comparable to the value of the electricity produced.

As with fresh manure, the digested solids must be stored and handled appropriately to minimize risk to the environment. Ammonia can be lost to the air through volatilization, and ammonia in the air is a pollutant.

Maintaining a crust on the storage pond or reducing its surface area can reduce nitrogen losses, although this may be more difficult after the materials have been digested than with undigested manure. When applying the digested manure to fields, incorporating the digested manure into the soil rather than leaving it on the soil surface can minimize nitrogen loss.

Air emission from combusting biogas is also a concern even though it is cleaner than burning coal. The combusting gas contains small concentrations of sulfur dioxide and other trace gases. The generation system must be designed to handle the exhaust properly.

How will my odor management be improved by going to methane generation?

Anaerobic microorganisms break down many odor-causing compounds in the manure as it moves through the digester. This basically eliminates odor problems. Research has shown anaerobic digestion reduced odor by 97 percent over fresh manure. In farm expansion projects, odor control can be a primary reason for installing a digester, especially covered lagoon systems. Where the only objective is odor control, the gas produced is simply burned (flared off). However, using the biogas to produce energy offers a significant economic return depending on the farm size.

What are other environmental benefits of methane digestion?

On farms where manure is stored in manure pits or lagoons, methane is generated and released into the atmosphere. Methane is 21 times more potent than carbon dioxide in causing global warming. By capturing and burning the methane produced from animal manure, anaerobic digesters lower the rate of global warming. Where manure management systems result in aerobic decay of manure, such as grazing systems and dry manure packs, significant amounts of methane are not produced.

Where can I go for additional information?

General references covering many aspects of methane generation and use:

- AGSTAR, US-EPA: www.epa.gov/agstar/
- The Minnesota Project: www.mnproject.org
- US Dept of Energy. 1995. Methane Recovery from Animal Manures: A current opportunities casebook. Washington, DC 20505
- Methane generation from Livestock Waste: Purdue University Cooperative Extension Service, AE-105, www.agcom.purdue.edu/AgCom/Pubs
- Commercial infrastructure takes shape for anaerobic digestion, by Jerome Goldstein, Biocycle, Nov. 2001.

Case studies:

- Haubenschild Farm report, from Minnesota: www.epa.gov/agstar/library/haub.html and www.mnproject.org
- Long-term digester operation case study: www.rcmdigesters.com
- Case studies of anaerobic digestion projects: www.biogasworks.com
- Craven Farms, Oregon: www.energy.state.or.us/biomass/digester/craven.htm

Screening tests:

- Agricultural Utilization Research Institute: www.auri.org/Research/digester/

Odor control:

- Case study: www.rcmdigesters.com/publications/index.htm



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