TURNING MANURE INTO GOLD:
CONVERTING AGRICULTURAL WASTE TO ENERGY

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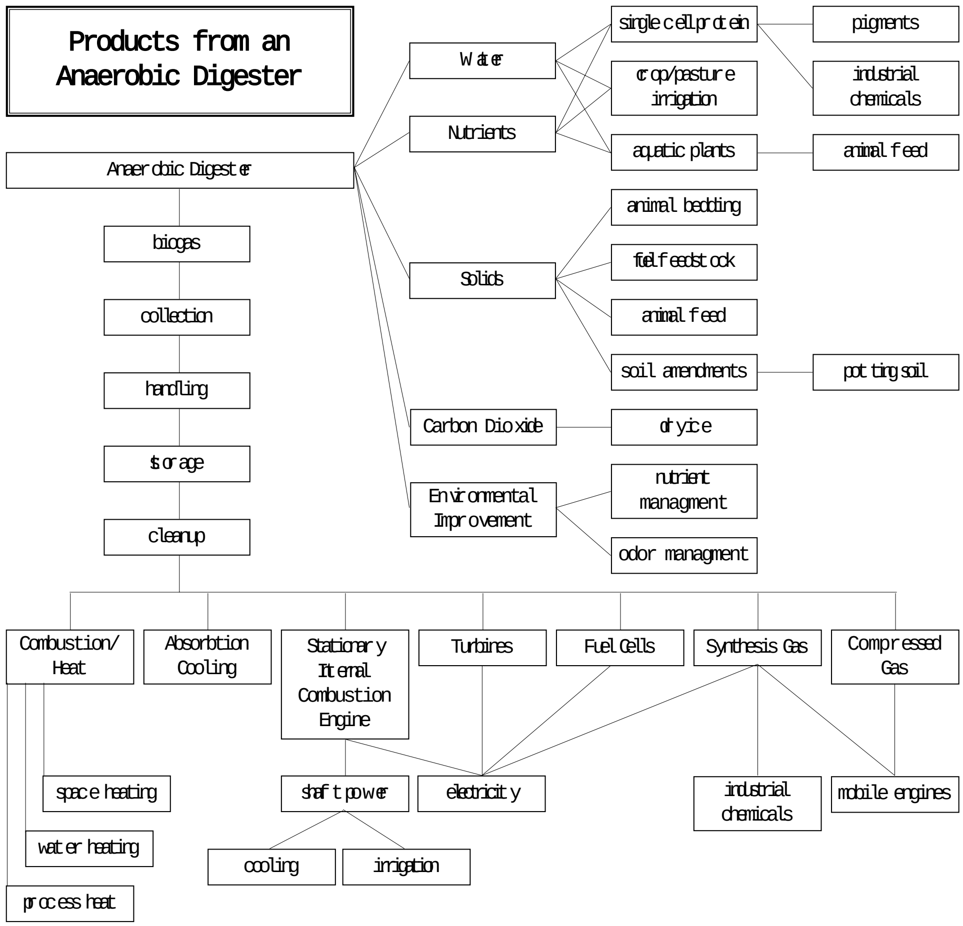
Introduction

Biomass energy is nothing more than energy produced from organic matter — wood, agricultural residues, food wastes — essentially anything that grows! Most folks in the agricultural community are familiar with ethanol, the liquid fuel produced from biomass. However, farmers have a number of other biomass resources available to convert into useable forms of energy. This handbook focuses on the potential for using animal manure to produce energy.

Using animal manure as fuel offers a number of advantages for large livestock and poultry operations. Wastes are either inexpensive or cheaper than propane, electricity and most natural gas. In fact, there are costs associated with disposing of manure which can be minimized through use as a fuel. In addition, using manure as a fuel minimizers odor, run off (non-point source pollution) and other nuisances which may be associated with large livestock and poultry operations. Using animal manure as fuel can improve the financial bottom line of the farm operation.

This handbook is built around a checklist which can help you determine whether using manure to produce energy makes sense for your operation. The handbook describes the various types of manure and the volumes which are necessary to make a project viable. The handbook also looks at various end-use applications for the energy; space heat, steam and electricity separately or in combination are all possibilities. It discusses the conversion options, such as combustion, gasification and anaerobic digestion. Equipment options, permitting requirements and maintenance issues are also included.

Generally, anaerobic digestion is the most flexible biomass conversion option for a farm operation. It produces biogas which has a heating value of approximately 600-800 Btu/cubic foot, 60 to 80% of the energy value of natural gas. The gas can be used to generate electricity, as a boiler or furnace fuel or to run refrigeration equipment.



Other options include gasification, where the manure is cooked to produce a biogas with a heating value of 100-200 Btu/cubic foot, 10 to 20% of the energy value of natural gas. This is also known as producer gas and can be used in any gas-fired appliance.

The final conversion option is direct combustion, where the manure is used directly as fuel. Fresh manure has too high a moisture content to burn and must be dried prior to combustion. Direct combustion systems on the farm will generally produce process or space heat, though large-scale operations could produce electricity if the fuel is burned in a boiler and a steam turbine is used.

We hope this handbook is helpful to large livestock or poultry operations looking for answers regarding the handling and profitable use of animal manure. The biomass energy option isn't for everyone but for many it can help reduce energy costs and the costs associated with manure management.

Biomass Project Checklist

The following checklist is designed to allow the operator of a livestock or poultry operation to determine if a biomass energy project is feasible. Each question refers you to a section of the text which explains how to answer the basic question and produce the information necessary to move on to the next step.

I. Why Should You Consider Converting Animal Manure to Energy?

II. Do You Have Enough Animal Manure to Fuel an Energy Recovery Project?

III. Do You Have a Need for the Energy Which the Project Can Produce?

IV. Do You Have the Basic Skills Needed to Operate an Energy Recovery Project Efficiently?

V. What Type of Conversion Technology is Best Suited to Your Fuel Supply?

VI. What Types of Financing are Available for the Project?

VII. What Types of Permits or Approvals are Required for Your Project?

At the end of the handbook you will find additional materials to consider as a part of the project including a list of consultants, equipment suppliers and vendors, as well as a glossary of terms.

I. Why Should You Consider Converting Animal Manure to Energy?

If you raise cattle, poultry, pigs, horses or run a dairy operation, you have manure. Proper manure disposal is always a concern. Small, integrated farming operations generally use the manures as fertilizers, surface applying the collected manure on crop land. There are limits to how much manure can be spread. Putting too much manure on fields can reduce yields. Additionally, spreading more than the crops can remove will result in groundwater and surface water pollution.

Once a livestock operation gets to the point when land application can no longer use all the manure, the operator needs to look for disposal alternatives, all of which involve spending money.

The most common disposal option is to build storage areas or lagoons to hold the manure and sell it or give it away for use as organic fertilizer. Storage areas or lagoons are not perfect solutions. They can produce odors and attract flies. Both problems can be offensive to those living nearby.

Direct combustion or gasification technologies solve potential odor and disposal problems by burning the manure. Odors are reduced because storage time prior to conversion is minimal. Disposal problems are lessened because the processes reduce the volume of waste by 70% or more. The ash is also free of pathogens, viruses and other disease causing organisms because of the high temperatures in the burner or gasifier. The ash retains much of its fertilizer value and can be land spread.

Anaerobic digestion systems solve the same problems through a different technique. Odors are controlled because the volatile organic acids which produce the odors are broken down or digested by methane producing bacteria. Potential water pollution from the waste is minimized because of the biochemical conversion caused by the bacteria. Destruction of more than 99% of pathogens, viruses and other disease-causing organisms is achieved. Costs for hauling manure to crops is reduced because the reduction in solids content of up to 95% allows the nutrient rich effluent to be spread using pumps and commercial spray irrigation equipment. Finally, 70% of the organic nitrogen in the manure is converted into ammonia, a primary constituent in commercial fertilizers.

It all boils down to two basic questions. Is disposing of manure costing your operation money? Or, is the storage and handling of manure causing a nuisance because of odor or fly problems? If the answer to either question is yes, a biomass energy option may be right for you.

Of course, there is another way to look at the situation. What at first may appear to be a problem, can actually be an opportunity. All large scale livestock operations have need for energy in some form–electricity to run lights, milking machines, fans, or refrigeration. There may also be a need for space heating, hot water or steam. Purchasing the propane, natural gas, diesel fuel or electricity to fulfill these requirements directly affects the financial return from your operation.

Most animal manures can be used as fuel to produce the energy you need. Direct combustion, gasification or anaerobic digestion technologies using manures as a feedstock, a term used to describe raw materials used as fuel, can be used to produce space heat, process heat, steam or hot water, and/or electricity. Your disposal problem can provide a fuel which minimizes your need to buy other types of energy. In addition, new legislation passed in Ohio deregulating the electric utility industry includes a provision which allows individuals and companies which are not utilities to generate electricity for their own use and sell the excess to utilities or energy marketers. And finally, the by-products of energy producing technologies which use manure as fuel — ash from combustion technologies and digested wastes from an anaerobic digester — are value-added products which can be sold as fertilizer.

This brings us back to the potential nuisance problems associated with manure. Using manures as fuel to produce energy can significantly minimize odor and fly problems. Traditional land application techniques usually require storage of wastes, and odor and pest problems result from the storage.

Using animal manures as a fuel for energy production can be a 'win win' situation for an operator. The manures can substitute for electricity, propane or natural gas purchases and can be used to produce energy for sale to other customers. Using the waste for energy production will minimize or may eliminate odor control and storage problems. And, using the manure for energy improves the fertilizer value of the waste, converting it to a more consistent, easier to handle and low-odor soil enhancement which can be used on-site or sold as a value-added product.

II. Do You Have Enough Animal Manure to Fuel an Energy Recovery Project?

Fuel supply is critical for any energy project, and biomass energy projects are no exception. Whether you're using wood wastes, agricultural residues or manures, having an adequate fuel supply is critical for the project. In addition, there are certain economies of scale associated with making an energy project a cost-effective project.

The volume of waste necessary for a successful energy project depend on the type of waste being produced on the farm. Wastes with high moisture content–over 75%, or conversely 25% total solids–are generally processed using anaerobic digestion technologies, while drier wastes can be burned directly or gasified. Manures as excreted are generally too wet to burn, but can be dried as part of the combustion process or can be mixed with bedding materials to produce a lower overall moisture content.

Another consideration is how the animals are housed. For example, in a free-stall dairy where animals remain confined throughout the year, manure can be collected daily or every other day. However, if the animals are pastured in the summer, it means the waste can't be efficiently collected during that period and the energy project can only operate during periods when the animals are confined. Since the project can only operate seasonally, the economics of the project change dramatically.

The general rule of thumb for a biomass energy project requires an operation to have at least 300 head of dairy cows/steers, 2000 swine in confinement, or 50,000 caged layers or broilers where manure is collected regularly. Smaller operations may be able to use biomass energy conversion techniques successfully given certain site-specific considerations such as odor control. Other considerations can affect the use of manure as fuel. If seasonal heating is the end-use, a very small scale system operating on dried manure can be practical. If there are variations in the numbers of livestock on the farm at any given time of more than 20%, the system will have to be sized to deal with the most consistent flow level and will not be able to use all the waste produced during periods when a larger number of livestock are in residence.

Drylot housing or manure packs produce manure with total solids above 25%. This type of manure can only be converted to energy through direct combustion or gasification. This rule of thumb applies to any situation where the waste dries for a week or more.

Poultry wastes, either from fryers, layers or turkeys, can be low in moisture content, particularly if the manure is mixed with bedding. When the manure is collected mixed with bedding or scraped, direct combustion or gasification is the best conversion option. One caution to be observed, however, is that these manures contain high amounts of uric acid which can damage burners or gasifiers, so mixing the waste with other biomass fuel is a necessity.

When manures are collected with total solids contents lower than 25%, anaerobic digestion is the appropriate conversion technique. The manure management practices must be appropriate for a biomass energy project to succeed. The manure needs to be collected as a liquid, slurry or semi-solid at a single point every day or every other day. The manure must be free of large amounts of other material, such as rocks or straw. If the manure is to be processed by anaerobic digestion, then it needs to be free of large amounts of bedding. The anaerobic digestion option can be used with any type of manure; it is the manure management practice that is the key to making the final decision on the appropriate conversion option.

A biomass energy project can be designed to match with current manure management practices, regardless of the approach being used. It may be necessary, however, to alter management practices in order to maximize the availability of manure to improve project economics. If you are looking to increase the number of animals your raise, it may be a good time to alter management practices so a biomass energy project can be integrated into your farm operation.

III. Do You Have a Need for the Energy Which the Project Can Produce?

Farms use electricity, natural gas, propane or fuel oil. Biogas, produced either through anaerobic digestion or gasification can be used to replace purchased energy for electricity, heating or cooling. Almost all equipment currently fueled by natural gas, propane or butane can be adapted to run on biogas by changing the orifice of the burner tip. Direct combustion systems using solid manures can also be engineered to meet these energy needs.

Energy production varies with the quantity of manure available for conversion, the Btu content of the feedstock and the conversion technology. Typical energy production potential for anaerobic digestion systems are listed in the following table. The Btu values of dry manures range from poultry manure at 2,500 Btu/dry lb to dairy cow manure at 3,200 Btu/dry lb.

Animals	Defecated volatile solids lb/day/1000 lb weight	Expected volatile solids destruction percent*	Biogas production cu. ft/day	Biogas Btu/day[1]	Net potential for electrical generation KWH/day[2]	Net potential for providing heat energy Btu/day[3, 4]
Swine, growing–finishing	4.8	50%	29	17,400	.64-.99	7,650-11,830
Beef	5.9	45%	30	18,000	.66-1.02	7,920-12,240
Dairy	8.6	48%	44	26,000	.95-1.47	11,440-17,680
Poultry; Layers	9.4	60%	72	43,000	1.58-2.44	18,920-29,240

* Source: Iowa State University (Methane Generation from Livestock Wastes)

1 Biogas (60% methane); 600 Btu/cu. ft

2 Electricity: 15,000 Btu/KWH generated (22% efficiency)

3 Btu's in biogas, less the amount needed to operate and heat the digester (15% in summer, 45% in winter)

4 Heat Energy: biogas burned at 80% efficiency

The most profitable energy projects generally produce electricity with waste heat recovery, a process known as cogeneration. The electricity is used to minimize the amount of electricity purchased from the local utility. When electricity production exceeds the needs of the operation, the excess can be sold to the utility. The waste heat from the combustion process may also be recovered for other uses.

The most common approach to producing electricity requires converting the manure to biogas through either an anaerobic digester or a gasifier. The biogas is then burned in a conventional spark ignition engine coupled to generator.

Water or another fluid circulates around the engine, capturing the waste heat for other uses.

An emerging technology that accomplishes the same result is the fuel cell. Fuel cells are nothing more than large batteries that run on the hydrogen portion of the methane produced by anaerobic digestion or gasification. Again, water is circulated around the fuel cell, collecting waste heat for other purposes. Fuel cells are expected to be available commercially in the next several years.

In addition to other applications, biomass can be used to produce space heat. Biogas can be burned in a furnace to produce heat or the heat can be recovered with a heat exchanger if the gas is being burned in an engine to produce electricity or mechanical energy. Space heat can also be provided by burning the biomass in a boiler or in a burner with an attached heat exchanger. Space heat applications are seasonal and this will effect the economics of the project if heat is the only use for the energy.

Hot water is used in dairy and egg production operations and can be produced using any type of biomass conversion technology. The need for hot water is usually stable throughout the year, making it an appropriate end-use for the energy produced by a biomass system.

Cooling and refrigeration can also be provided by a biomass system. Biogas can be used with gas-fired chillers, an especially attractive option for dairy operations where 15 to 30% of the electricity load is used to cool milk. Otherwise, the electricity produced by a cogeneration system can be used to operate conventional cooling equipment.

While the discussion to this point has focused on conversion systems designed for individual large livestock operations, several projects in the planning or construction phase around the country are based on a centralized conversion model. This approach can be used when individual farms produce too little manure to justify the investment in a conversion facility. For example, a project is currently being built in Tillamook, Oregon which will use anaerobic digestion to convert the manure from 10,000 cows or about 500 tons of dairy manure and other organic waste per day. The combined capital cost for the facility is estimated to be $12 million. The farmers involved have formed a manure supply cooperative to ensure a consistent supply of manure to the project, coordinating transportation of manure used as feedstock and liquid nutrients produced by the project.

Another project recently announced will collect chicken manure and bedding from the extensive poultry operations on the Eastern Shore of Delaware and Maryland. The feedstock will be burned in a fluidized-bed boiler, producing electricity and steam for industrial processes. In both these examples, farmer become fuel suppliers rather than system operators. The conversion system is owned by a third-party. While putting together these types of projects can be complex, the benefits can ultimately outweigh the risks, particularly since the risks for the farm operator are significantly reduced.

IV. Do You Have the Basic Skills Needed to Operate an Energy Recovery Project Efficiently?

Biomass energy systems require a commitment of time. Conventional energy sources such as electricity, natural gas or propane are delivered in a usable form and very little, if any time is required to manage these sources. A biomass system requires you to work with a raw material and convert it to a useful form of energy . The production process requires attention. Most farmers have the basic mechanical skills to maintain the components of a biomass system. If electricity production is a part of the system, skills in engine repair and maintenance are necessary. Specialized knowledge for the particular type of biomass system used should be obtained from the designer of the system or the manufacturer of specific components. Proper training will help ensure proper maintenance. Make sure your system designer or equipment manufacturer is willing to spend the time it takes to teach you what you need to know.

Direct combustion and gasification systems have regular maintenance requirements. In addition, the fuel feeding systems will also require maintenance and repair from time to time. Well engineered direct combustion systems generally have few problems. Gasifiers tend to require more attention. The most likely part of the system to require repair is the fuel handling system since it generally has the most moving parts.

Anaerobic digestion systems require 15-30 minutes each day for maintenance and monitoring once the digester has achieved sustained production of methane. Additional blocks of time will be required for repairs and preventative maintenance tasks. The digester designer is responsible for teaching the owner the basic skills to operate the system and should be available for consultation in the event of rare or unusual problems.

Designing and installing any biomass system, other than simple space heating systems like a wood stove or furnace, requires specialized assistance from qualified personnel. When shopping for an engineer or system designer, ask for a list of projects they have worked on and contact the owners as you would with any other contractor. If a firm has worked on biomass projects before, make sure the people involved are still part of their team and the projects were similar to yours. There is no substitute for experience when it comes to biomass energy systems. Systems using manure as fuel are even more unique, so do your homework before you sign a contract.

V. What Type of Conversion Technology is Best Suited to Your Fuel Supply?

Moisture content of the fuels and end-use applications of the energy are the factors which determine the most appropriate conversion option. High moisture content fuels can only be burned after drying. End-use requirements which involve space heating, hot water and/or steam production can produce the heat to dry the fuel. If producing electricity and heat is the goal, anaerobic digestion is probably the best option for a farm operation because animal manures generally have a high moisture content. The biogas produced by these systems is a very flexible fuel and can be readily replace energy currently used in the farm operation.

Anaerobic Digestion

Anaerobic digestion is the most common biomass energy conversion option used on large scale livestock operations. A number of digesters have been operating since the early 1980's, spurred by concerns caused by the energy crises during the 1970's. According to one recent survey, 28 digesters are currently operating on working dairy, poultry and swine farms, and another 65-70 digesters are installed on beef farms or at university research centers. The survey also found 17 digesters that were shut down when farms were sold or quit livestock production. Another 35 digester systems have failed and are not operating. The digesters built since 1984 appear to have a much better track record of success, with 11 new systems installed between 1994-1998 and more in the pipeline.

Anaerobic digestion can use any type of fresh manure. Swine farms, dairy operations and caged layer operations are all using anaerobic digestion to control odors, produce value-added products and in most case produce electricity and heat. Other poultry and livestock operations can use the same technology.

A typical anaerobic digestion system includes the following components:

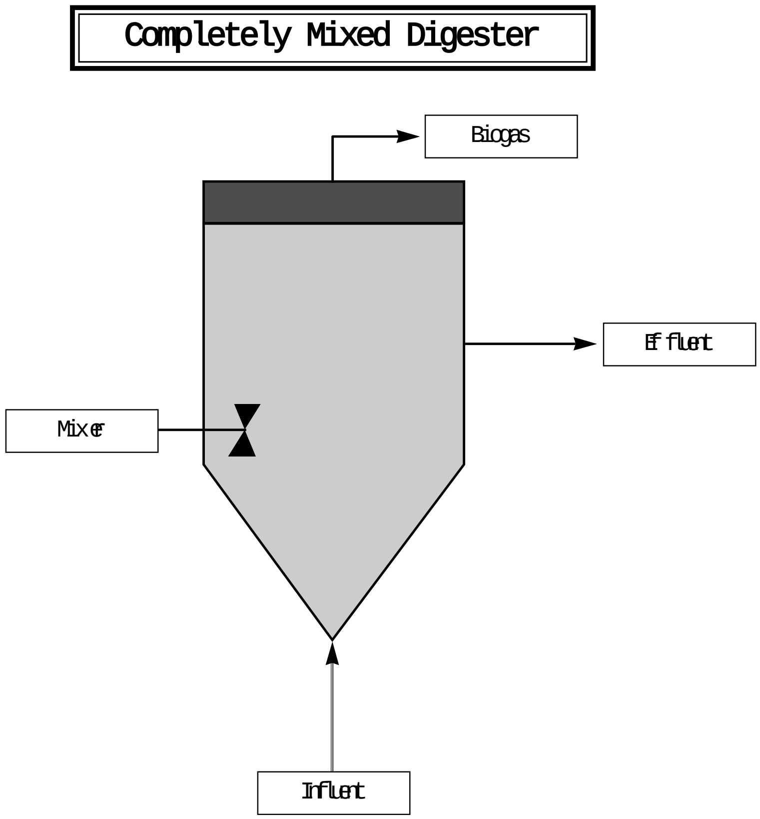
- Manure Collection;
- Anaerobic Digester;
- Effluent Storage;
- Gas Handling; and
- Gas Use.

Manure to be used in an anaerobic digester must be fresh, with a solids content of less than 25%. Manure is collected either through flushing the area where the animals are confined, or scraped. Anaerobic digestion systems are best matched to a manure management system that collects the manure daily or every other day and deposits it to a single storage tank, pond, lagoon or other storage structure where it is held for land application. If your manure management plan does not involve regular collection you will need to alter collection practices. If you pasture livestock seasonally, then the system can only operate when the animals are confined and manure is collected regularly.

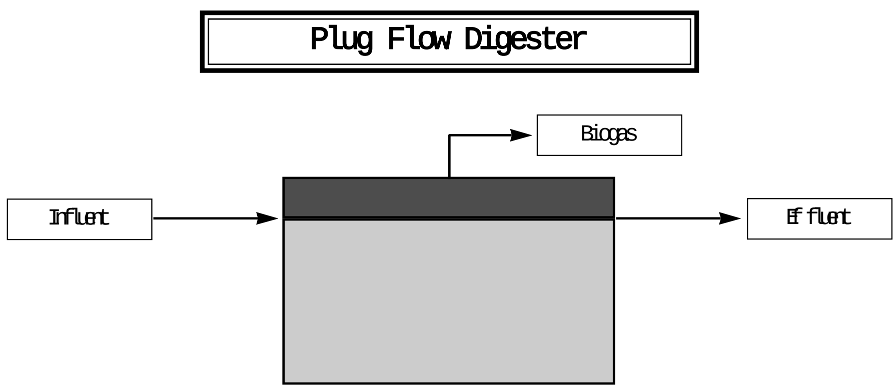
The anaerobic digester is the key component of the system. It is designed to optimize the naturally occurring anaerobic bacteria to decompose and treat the manure, and produce the biogas byproduct. Digesters are tanks covered by an air-tight impermeable cover to trap and collect the biogas for use.

There are three types of digesters. The least expensive option is the covered lagoon. Unfortunately, this type of digester cannot be used for energy production in cold weather states like Ohio because the temperature of the lagoon and the production of methane will vary widely throughout the year. Energy recovery requires equipment sized to a regular gas flow. Lagoon digesters can be covered to collect and flare the gas produced which will significantly reduce the odors associated with manure. However, because the manure is not completely digested, lagoon digesters do not totally eliminate the odor released when the lagoon contents are land spread. The bottom line is that lagoons can be used for odor control in cold weather states, but energy recovery is generally not an economic option.

The second type of digester is the complete mix digester. The unit consists of an engineered tank, either round or square, which is located above or below ground. Burying the tank helps to insulate the system in cold weather states. The complete mix digester can use slurry manures with a solids concentration ranging from 3 to 10%. Appropriate solids content is achieved by adding water. The tanks are heated using waste heat recovered from the burner. This type of digester is compatible with a variety of manures. Mechanical mixers keep the manure in suspension within the tank and prevent the formation of a surface crust. The volume of the tank needs to equal 15 to 20 days worth of manure and waste water production, referred to as the retention time for the system.



The plug flow digester is the third type of digester. These digesters are rectangular, in-ground tanks. The plug flow digester can use manures with a solids content of between 11 and 13%. The tank is heated with recovered waste heat. This type of digester is compatible with dairy scraped manure only. The size of the tank is determined by multiplying the daily plug, or manure input, times the manure retention time of 15 to 20 days. In a plug flow system the manure flows first into a mixing pit, allowing the solids content to be adjusted by adding water. The contents of the mixing pit — the plug — is added to the tank daily, slowing pushing the older manure down the tank.



An new variation on the plug-flow digester is the slurry digester, which uses either a silo shaped reactor or a loop or horseshoe configuration. These digesters can treat a variety of animal manures and can operate at lower solids content levels than conventional plug-flow designs without crusting. Seven digesters using this design are currently operational.

After the waste is processed through a digester, the effluent must be stored until it can be spread in some type of appropriate storage tank or pond. Remaining solids are often separated from the effluent (or processed slurry) and sold separately as soil amendments. The solids can be blended with soil or other additives depending on the final use. The liquid effluent is stored in a pond or tank until it is sprayed on fields, or can in some cases be used as wash down water, starting the process over again.

The gas handling system removes biogas from the digester and transports it to the engine or burner. The biogas produced by the system is trapped under the air-tight cover placed over the tank. The gas is removed by pulling a vacuum on the collection pipe using a pump or blower. A meter to monitor gas flow and a pressure regulator is attached to release excess gas pressure from the cover. Condensate drains are also part of this system to remove any water vapor that may condense as the gas cools during transit through the pipe. The gas is piped directly to the engine or burner. For storage purposes, biogas can be compressed, but this step adds significant complexity and cost to the system.

If anaerobic digestion appears to be the appropriate technology for your operation, more detailed information on digesters and project economics is available from the EPA/USDA AgSTAR Program. The Program has published an excellent handbook and developed a software program which will allow an operator to conduct a technical and financial analysis of the potential project. For more information, call 1-800-95AgSTAR or write: AgSTAR Program, U.S. EPA, 6202-J, 410 M Street, SW, Washington, DC 20460.

The National Resource Conservation Service (NCRS) has developed documents providing guidance to states for the development of standards for the different types of digesters. Contact your local NRCS office for information.

Direct Combustion

Direct combustion of biomass is as old as mankind. Using animal manure as fuel is just about as ancient a practice. Dried cow dung burns well. The same is true for most other manure, if it is dry enough. A recently announced project in the State of Delaware will burn poultry manure and bedding to produce electricity for sale to utility companies.

In a direct combustion system, the biomass material is burned directly, just like coal. Burners are designed for the type of material to be used as fuel. Variables include moisture content or the amount of contaminants or dirt in the fuel. Burners are generally divided into three categories: grate burners, suspension burners and fluidized-bed burners.

Grate burners are the most common type of biomass combustion system. Grate burners can accept fuels with low or high moisture contents. The grate is essentially the floor of the burner. It has holes which allow air to flow at a controlled rate up into the burning fuel. Small systems use fixed grates where ash is removed manually. This requires a periodic shut-down of the system. Larger systems use traveling grates and ash removal systems allowing continuous operation. The burner can be a furnace, which produces hot gas and is usually coupled with a heat exchanger unless the hot gas can be used directly for crop drying, fuel drying or other appropriate applications. Otherwise, the heat exchanger extracts the heat from the flue gas, heating clean air which can be circulated through a structure for space heat or heating a fluid which provides radiant heat. A burner can also be a boiler, where water circulates through the burner and is heated to produce steam; this steam can be used for radiant heat, to run mechanical equipment, or to turn a steam turbine.

Suspension burners are also fairly common. In suspension burners, the fuel is blown in by the air used in the combustion process. Natural gas or propane is used to start the combustion process. Suspension burners can be designed either as boilers or furnaces. These burners require dry fuel, with less than a 10% moisture content. The fuel must also be sized so it is very small because the fuel burns while suspended in the burner. Particles which are too large will not stay suspended long enough for complete combustion.

A third type of burner is the fluidized-bed burner. These burners will accept a wide variety of fuels but are generally too large and expensive for an individual farm operation. They may, however, be practical for a very large operation or a cooperative situation. In a fluidized-bed burner, the bed of the device is made up of fuel and sand. Pressurized air is injected under the bed, causing it to bubble. The sand is heating by the combustion process and heats the fuel to the point where combustion occurs. These devices are almost always designed as boilers.

Gasification

Gasifierscan use most types of relatively dry biomass as fuel. A number of projects using agricultural field and processing wastes as fuel exist and some laboratory testing has been done using animal manures as fuel. However, no operational farm-scale systems have been identified in the United States.

Gasifiers operate by heating biomass in the absence of oxygen. This concept, known as pyrolysis is the same method used to make charcoal. As the fuel is heated, volatile gases are released. The gas has a heating value of between 100 and 200 Btu/cubic foot. These gases are piped from the gasifier and burned separately either in an engine or another burner. There are a variety of types of gasifiers, with the primary difference being how the fuel is loaded into the unit. As with an anaerobic digester, the gas produced is piped to an engine or burner to be converted into heat, steam or electricity.

VI. What Types of Financing are Available for the Project?

Biomass energy systems may be financed like any other piece of equipment used on a farm. This means that debt financing from a bank or agricultural lender is the normal financing approach. Financing a direct combustion system should be fairly straight forward since burner systems are considered to be a conventional technology with no significant risks. Anaerobic digestion systems and gasifiers may be more difficult to finance, since most bankers are unfamiliar with the technologies and may see the investment as risky.

Grants are sometimes available for renewable energy projects or improved manure management systems. Check with the state energy office, the state agriculture department, or the state environmental agency for details. The 1996 Farm Bill also authorized the Environmental Quality Improvement Program (EQIP) which provides funding up to $50,000 in improvements to farm manure management systems. Check with your local or state NRCS office to see if your project qualifies.

Low interest loans are available from government agencies for renewable energy or manure management projects. In Ohio, funds are available from the Air Quality Development Authority for projects which reduce air pollution, though there are some limits. Other funding will soon be available from the Ohio Office of Energy Efficiency from a revolving fund authorized as a part of electric utility deregulation legislation. Loans may also be available from the state agriculture department. The Ohio Biomass Energy Program, operated by the Public Utilities Commission of Ohio, offers periodic funding assistance to support the use of biomass energy resources in Ohio.

Tax credits are sometimes available for renewable energy or manure management projects. A common federal tax credit used in biogas projects is known as the Section 29 credit. Check with your accountant since tax laws change frequently.

VII. What Types of Permits or Approvals are Required for Your Project?

Permits are often required for biomass energy projects, depending on the type of project and the size of the burner. The permits fall into two general categories — air permits and zoning/land use permits. Most farm-scale biomass projects are small enough that air emissions permits are not required. Large-scale systems will have to be permitted but biomass is a relatively clean fuel and conventional air emissions control technologies generally will allow the project to meet all state and federal standards. Check with the Ohio Environmental Protection Agency (OEPA) for details. Zoning issues are uncommon for projects built on existing farm operations.

In Ohio, farms with more than 1,000 animal units and applying manure to the land must file a manure management plan with OEPA. Installation of a biomass conversion system will probably require agency approval to alter manure management procedures. However, because biomass systems reduce the possibility of uncontrolled discharge and reduce the amount of odor and pathogens associated with waste, permit modifications can generally be negotiated. However, make sure to give yourself adequate lead time to ensure permit modifications are made prior to when you plan to have the project online. There is a great likelihood that changes in the regulatory process regarding large scale livestock operations may occur at some point in the future. The project designer should help you secure the necessary permits and modifications.

Case Studies

Valley Pork - Complete Mix Digester for Swine Manure

Valley Pork is located in Seven Valleys, Pennsylvania. The operation is a 1,650 saw farrow-to-finish swine farm. The system operated between 1986 and 1995, shutting down when the farm temporarily went out of the hog business.

Manure flushed from barns is transferred to a complete mix digester with a retention time of 15 to 20 days. Gas output is between 50,000 to 75,000 cubic feet/day with a methane content of 62 to 65%. The biogas is piped to a Model 3306 Caterpillar engine with a 140 kW generator. A second 40 kW engine-generator combination operate during periods of high biogas production.

Estimated electricity purchase offsets and sales provide about $50,000 per year in revenue, based on the production of 775,000 to 850,000 kWh per year. The system also captures waste heat to warm the farrowing rooms and nurseries, as well as to heat the digester, yielding an additional $15,000 in savings. This translates into a system payback of between four and five years. The annual operating cost is around $5,000.

For more information contact Jim Yoder, (717) 229-2988.

Brendle Farms - Slurry-Based Loop Digester for Poultry Waste

Brendle Farms is located in Somerset, Pennsylvania. The farm has 75,000 caged layers. The anaerobic digestion system has operated since 1983.

Manure is flushed from the coops to a 42,000 gallon pre-heating tank at about an 8% total solids content. This tank serves two functions. It allows the waste to be heated to avoid thermal shock to the reactor in the winter and improve gas production. The tank also allows grit and feathers to settle out before the waste enters the digesters. This prevents build up within the digester. Limestone is removed from the pre-heater tank every 6-8 weeks, while the digester has only been cleaned out twice in 16 years.

The slurry then flows into a 145,000 gallon digester which is maintained at 103 degrees F by a heat exchange system which is also used in the pre-heating tank. The digester produces 28,000 cubic feet/day of biogas with a methane content of between 60-65%. The biogas is piped to a Model 3306 Caterpillar engine connected to a 65 kW generator. The system produces about 365,000 kWh per year. The power displaces about $35,000 in purchased energy charges. Waste heat is used to preheat wash water for egg processing and for heating the packing area and office.

Effluent leaving the digester is stored in a lagoon and later sprayed on crop land. The lime removed from the pre-heating tank is also land spread.

For more information contact Mike Brendle, Brendle Farms, 252 School House Road, Somerset, Pennsylvania, 15501, Tel: (814) 443-3141.

Fairgrove Farms, Inc. - Plug Flow Digester for Dairy Manure

Fairgrove Farms, Inc. is located in Sturgis, Michigan. The farm is a moderately large dairy operation with 700+ cows, producing 4,000 gallons of milk per day. The farm installed an anaerobic digestion system in 1981. The system has been operating successfully since then with few modifications.

Manure is pumped from the barns into a 180,000-gallon horizontal tank. The tank is fully insulated with four inches of foam insulation covered by two feet of topsoil. A baffled inspection port allows access to the digester. A heat exchanger using waste heat from the engine is placed near the effluent inlet, maintaining the digester temperature at a steady 95 degrees F.

The digester produces between 50,000 and 57,000 cubic feet/day of biogas with a methane content of 60%. The biogas is piped to a Model 3306 Caterpillar engine connected to an 85 kW generator. The system produces 435,000 to 620,000 kWh per year with an 85% availability factor. The power is sold to the local utility, offsetting $38,500 to $48,000 per year in energy purchases. Payback for the $200,000 system was achieved in about four years.

Effluent leaving the digester is processed by a centrifuge to separate an additional 3% of the original organic solids. The reclaimed solids have the consistency of sawdust and are used as stall bedding for the animals. The remaining liquid effluent flows into a storage lagoon and is ultimately spread on fields semiannually as a fertilizer.

For more information contact David or John Pueschel, Fairgrove Farms, Inc., 6770 Balk Road, Sturgis, Michigan, 49091, Tel: (616)651-6646.

The University of Findlay - South Campus Heating Project

The University of Findlay ‘s Center for Equine and Pre-Veterinary Studies Program is housed in a 73-acre South Campus facility located south of the University. The South Campus houses the Western Equestrian riding program and the Pre-Veterinary Studies program. The present facility features 300 stalls, two indoor arenas measuring 115' x 225' and 90' x 144', all weather turn-out pens, an outdoor sand ring, pharmacy, breeding paddocks, veterinary office, classrooms and related facilities.

During Fall and Spring Semesters, 138 students and 300 horses are on the South Campus. A one-thousand pound horse produces approximately 50 pounds of manure per day or about ten tons per year. In addition, six to ten gallons of urine is produced which when soaked up by bedding can constitute another fifty pounds daily. About 4,800 tons of manure and bedding must be disposed of every year. This is a mountain of manure by anyone’s standards. The University was spending $30-40,000 to have horse manure and bedding hauled away and spread on farm fields.

Ron Gillette, the Business Manager of the program, came up with different option. He saw an opportunity to use the manure as a fuel, eliminating disposal costs and reducing the energy costs associated with operating the South Campus facility.

The University invested $200,000 to install a heating system which operates from October to April, a period of time which matches well with the time the facility is in full use. The project has permits from Ohio EPA.

The system is built around a 5MM BTU/hr solid fuel burner which provides heat for the indoor arenas and also provides the heat energy necessary to dry the horse manure and other stable waste prior to combustion. Waste is collected during the day and moves through a 48" x 144" triple pass rotary drum dryer which has the capacity to dry 28,000 pounds of material per day. The incoming waste, a combination of manure and stall waste, begins the process with a moisture content of approximately 50%. The hot gases from the burner are routed through the dryer, reducing the moisture content to less than 5%.

The drying system produces 14,000 pounds of dry material per day. This material is captured by a medium efficiency cyclone equipped with an airlock as it emerges from the dryer. The material is then transported pneumatically to a storage tank, resulting in a closed loop drying system. The system is equipped with a Flame Eye Safe System which recognizes sparks within the system, and shuts down the fuel processing operation to prevent fires during fuel handling.

The solid fuel burner is a cyclonic combustion system. This means the fuel is blown into the burner, and burned in suspension without a grate. When functioning at peak efficiency, it consumes 300-500 pounds of dry material per hour. The portion of the dry material used as fuel is conveyed from the storage bin into a hammermill to reduce its particle size to the 3/16" required by the burner. The fuel is then pneumatically conveyed into the burner combustion chamber. The fuel auger is controlled by a microprocessor which receives signals from thermocouples placed in the dryer, and automatically make the necessary adjustments to maintain correct burner operating temperatures.

The surplus heat energy available from the combustion process is 2.74 MM BTU/hr and is captured by a heat exchanger with a 75% efficiency rate, leaving a maximum of 2MM Btu/hr of direct heat input to heat the Equestrian Center. Stack gases from the burner enter the heat exchanger at approximately 1500 F-1700 degrees F and travel though its matrix at 4,000 feet per minute, exiting the chamber at 400 degrees F. This rapid transition serves a dual purpose, elevating the exchange air temperature to be delivered inside the building to 85 degrees F and preventing condensation inside the matrix extracting the gases before the temperature lowers to a when condensation could occur. The stack gases are then routed to the triple pass dryer.

Fans convey the hot air to create a pressurized, internal cyclonic current where it enters the building. This current distributes the air throughout the building in a circular motion, pressurizing the entire building and not allowing the cold outside air to penetrate. The air barrier is an efficient approach to raising and maintaining ambient temperature. The airflow of heat is 4500 CFM, resulting in complete air changes within the arena 6-8 time per hour.

The heating system is projected to have a five year payback. The system heats 44,000 square feet and is sized to permit expansion to heat offices and classrooms at a later date.

For more information contact: Ron Gillette, Business Manager, Center for Equine & Pre-Veterinary Studies, University of Findlay, 11613 County Road 40, Findlay, Ohio 45840-3695, Tel: 419-424-0932, FAX: 419-424-4887.

Consultants, Designers, and Equipment Manufacturers

This list includes a sample of the consultants, designers and equipment suppliers which work on biomass energy projects. Other vendors may be able to assist in the development of a biomass energy project.

Anaerobic Systems Designers

Agri-Bio Systems, Inc., P.O. Box 5144, Elgin, IL 60121 (847) 888-7854

AgriWaste Technology, Inc., 700-108 Blue Ridge Road, Raleigh, NC 27606 (919) 829-0014

Agway Farm Research Center, 6978 New York, Route 80, Tully, NY 13159 (315) 683-5700

A.O. Smith Harvestore Products, Inc., 345 Harvestore Drive, DeKalb, IL 60115 (815) 756-1561

BioRecycling Technologies, Inc., 6101 Cherry Avenue, Fontana, CA 92336 (909) 899-2982

Environmental Treatment Systems, Inc., P.O. Box 94005, Atlanta, GA 30377 (770) 384-0602

Environomics, Inc. 36 West 35th Street, Suite 5E, New York, NY 10001 (212) 564-7188

Mason Dixon Farms, Inc., 1800 Mason Dixon Road, Gettysburg, PA 17325 (717) 334-4056

Practically Green Environmental Services, Solar House, Magherafelt, BT45 6HW, Northern Ireland, +44 1648 32615

Resource Conservation Management, Inc., P.O. Box 4715, Berkeley, CA 94704 (510) 658-4466

Sharp Energy, Inc., 20174 Road 140, Tulare, CA 93271 (209)688-2051

Absorption Chillers

American Yazaki Corporation, 13740 Omega Road, Farmers Branch, TX 75244 (214) 385-8725

CECA, Inc. Absorption Technology, 41500 S. 100th East Avenue, Suite 300, Tulsa, OK 74146 (313)737- 4591

Robur Corporation, 2300 Lynch Road, Evansville, IN 47711-2908 (812) 424-1800

Cogeneration

Barnco International, 5410 Kennon Lane, Bossier City, LA 71112 (318) 741-1073

Caterpillar Engine Company, 3701 State Road 26 East, Lafayette, IN 47905 (317) 448-5946

Curtis Engine and Equipment, Inc., 3918 Vero Road, Suite L, Baltimore, MD 21227-1516 (800) 573-9200

Jenbacher Energiesysteme, Ltd., 1502 Providence Highway, Suite 2, Norwood, MA 02062 (617) 255-5886

Kohler Co., Generator Division, 444 Highland Drive, Sheboygan, WI 53044 (800) 544-2444

Martin Machinery Inc., 123 Lakewivew Road, Latham, MO 65050 (816)458-7000

Midwesco Energy Systems, 7720 Lehigh Avenue, Niles, IL 60648 (708) 966-2150

Natural Power, Inc., 3000 Greshams Lake Road, Raleigh, NC 27615 (919) 876-6722

Perennial Energy, Inc., Route 1, Box 645, West Plains, MO 65775 (417) 256-2002

Tecogen, P.O. Box 8995, Waltam, MA 02254-8995 (617) 622-1400

Waukesha Engine Division, 1000 West St. Paul Avenue, Waukesha, WI 53188 (414) 547-3311

Consulting

AgPro, Inc., 32845 South Dryland Road, Molalla, OR 97304)503) 829-4844

Agri-Bio Systems, Inc., P.O. Box 5144, Elgin, IL 60121 (847) 888-7854

AgriWaste Technology, Inc., 700-108 Blue Ridge Road, Raleigh, NC 27606 (919) 829-0014

Agricultural Engineering Associates, 102 E. Second, Uniontown, KS 66779 (316) 756-4845

Brubaker Agronomic Consulting Service, Inc., 4340 Oregon Pike, Ephrata, PA 17522 (717) 859-3276

C & S Engineers, Inc., 1099 Airport Blvd., North Syracuse, NY 13212 (315) 455-2000 ext. 249

Entech Environmental Services, Inc., 180 Hickory Flat Road, Canton, GA 30114 (800) 218-8859

Environmental Treatment Systems, Inc., P.O. Box 94005, Atlanta, GA 30377 (770) 384-0602

Environomics, Inc. 36 West 35th Street, Suite 5E, New York, NY 10001 (212) 564-7188

Perennial Energy, Inc., Route 1, Box 645, West Plains, MO 65775 (417) 256-2002

Resource Conservation Management, Inc., P.O. Box 4715, Berkeley, CA 94704 (510) 658-4466

Boilers and Small to Medium Sized Modular Combustion Systems

Applied Thermal Systems, Inc., P.O. Box 101493 Nashville, TN (615) 366-0221

Bryan Steam Corporation, P.O. Box 27 Peru, IN 46970 (317) 473-6651

Cleaver-Brooks, P.O.Box 421, Milwaukee WI 53201 (800) 535-3275

Coen Company, Inc., 1510 Rollins Road Burlingame, CA 94010. (415) 697-0440.

Cresswood Industrial Furnaces, 4504 Ellwalk Ave. Cortland, IL (815) 758-7171

Decton Iron Works, Inc., 5200 N. 124th St., Milwaukee, WI 53225 (414) 462-5200

EnerCorp, 9369 Olive Blvd., Suite 201, St. Louis, MO 63132 (314) 569-2884

Energy Resource Systems, 424 West County Road D. Roseville, MN 55112 (612) 631-1681

Energy Systems Limited, P.O.Box 1024. Independence, Kansas. 67301 (316) 331-3540

Entech Environmental Services, Inc., 180 Hickory Flat Road, Canton, GA 30114 (800) 218-8859

Eshland Enterprise, Inc., P.O.Box 8A. Greencastle, PA.17225, (717) 597-3196

Fire-View Products, Inc., P.O. Box 370 9003 West Evans. Rogue River, OR 97537. (503) 582-3351

G & S Mill Co., Inc., 75 Otis St. Northborough, MA 01532 (508) 393-9266

Hurst Boiler Co., Inc., P.O.Box Drawer 529. Coolidge, GA 31738 (912) 346-3545

Industrial Boiler Co. Inc., P.O.Box 2258 Thomasville, GA (912) 226-3024

Kewanee Mfg. Co., Inc., 101 Franklin Street, Kewanee, IL 61443 (309)853-3541

Konus Energy Systems, Inc., P.O.Box 1586, Norcross, GA 30093 (404) 368-2744

KW Energy Systems, Routes 5&10. P.O.Box 566 South Deerfield, MA 01373 (413) 665-7081

Messersmith Manufacturing, Inc., Rt.1 Box 45, N13089 Co. Rd 551 Carney, MI 49812 (906) 466-9947

North American Manufacturing Co., 4455 E. 71st Street, Cleveland, OH 44105-5600 (216) 271-6000

Northfab Systems, Inc. P.O.Box 429 Thomasville, NC (919) 889-5599

Precision Temp, 1100 Harrison Avenue, Cincinnati, OH 45214 (513) 651-4446

Ray Burner Company, 1301 San Jose Ave. San Francisco, CA 94112 (415) 335-5800

Saxton Air Systems, Inc., 4651 Smith St. Harrisburg, PA 17109 (717) 545-3784

Will-Burt Company, 169 S. Main St. Orrville, OH (216) 682-7015

Waste Conversion Systems, Inc., 7315 S. Revere Pkwy. Suite 601, Englewood, CO 80112 (303) 790-8300

Yorke-Shipley/Stahl-Farrier, Inc., Box M-34. York, PA 17405. (717) 767-6971

Zurn Industries, Inc. Energy Division, 1422 East Ave. Erie, PA (814) 452-6421

References in Ohio

Ohio Livestock Coalition
Two Nationwide Plaza
P.O. Box 479
614-249-2435
Fax: 614-249-2200
Executive Director: David White

Ohio Biomass Energy Program
Public Utilities Commission of Ohio (PUCO)
180 E. Broad St.
Columbus, OH 43215-3793
614-644-7857
Fax: 614-752-8352
Program Director: Anne Goodge

Office of Energy Efficiency
Ohio Department of Development
77 S. High St.
P.O. Box 1001, 26th floor
Columbus, OH 43216-1001
614-466-6797
1-800-848-1300
Fax: 614-466-1864

Ohio Environmental Protection Agency (Ohio EPA)
1800 WaterMark Drive
Columbus, OH 43215
614-644-3020

Resource Center
1800 WaterMark Dr.
Columbus, OH 43215
614-644-3024
Fax: 614-644-2329

Division of Drinking and Ground Waters
1800 WaterMark Dr.
Columbus, OH 43215
614-644-2752
Fax: 614-644-2909

Office of Pollution Prevention
1800 WaterMark Dr.
Columbus, OH 43215
614-644-3469
Fax: 614-728-1245

Public Interest Center
1800 WaterMark Dr.
Columbus, OH 43215
614-644-2160
Fax: 614-644-2737

Other Ohio EPA Divisions and Programs

Division of Air Pollution Control
614-644-2270

Division of Emergency and Remedial Response
614-644-2924

Division of Environmental & Financial Assistance
614-644-2798

Division of Surface Water
614-644-2856

Ohio EPA District Offices:

Central Division Office
3232 Alum Creek Dr.
Columbus, OH 43207
614-728-3778

Northwest District Office
347 North Dunbridge Rd.
Bowling Green, Oh 43402
419-352-8461

Northeast District Office
2110 East Aurora Road
Twinsburg, OH 44087
330-425-9171

Southeast District Office
2195 Front St.
Logan, OH 43138
614-385-8501

Southwest District Office
401 East Fifth St.
Dayton, OH 45402
513-285-6357

The Ohio Department of Natural Resources
1952 Belcher Dr.
Columbus, OH 43224
614-265-6565
Fax: 614-268-1943

Office of Pollution Prevention
P.O. Box 1049
Columbus, OH 43216-1049
614-644-3469
Fax: 614-728-1245

The Ohio State University Extension
2120 Fyffe Rd. Rm.3
Columbus, OH 43210
614-292-6181
Fax:614-688-3807

Water Pollution Education

ODNR Division of Soil & Water Conservation
1939 Fountain Square Court, E-2
Columbus, OH 43224
614-265-6682
Fax: 614-262-2064

Water Quality Monitoring

ODNR Division of Soil and Water Conservation
1939 Fountain Square Court E-2
Columbus, OH 43224
614-265-6610

U.S. Environmental Protection Agency
77 West Jackson Blvd.
Chicago, IL 60604
312-353-3209
fax :312-353-1155

The Ohio Environmental Council
1207 Grandview Ave. Suite 201
Columbus, OH 43212

614-487-7506
Fax: 614-487-7510

Environmental Education Council of Ohio
P.O.Box 2911
Akron, OH 44309-2911
330-761-0855
Fax: 330-761-0856

References

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-----. AgSTAR Technical Series: Complete Mix Digesters. Washington, D.C.: Author, 1997.

Walsh, James L., Charles C. Ross and Thomas Jefferson Drake. Handbook on Biogas Utilization. Muscle Shoals, Alabama: Tennessee Valley Authority, Southeastern Regional Biomass Program, 1996.

Wimberly, Jim. Anaerobic Digestion and Biogas Recovery & Utilization Workshop. Morrilton, Arkansas: Winrock International Institute for Agricultural Development, 1993.

Glossary

A

Abiotic: Having an absence of life or living organisms.

Aerobic: Life or biological processes that can occur only in the presence of oxygen.

Anaerobic: Life or biological processes that occur in the absence of oxygen.

Anaerobic digestion: A biochemical process by which organic matter is decomposed by bacteria in the absence of oxygen, producing methane and other byproducts.

B

BACT: Best Avalable Control Technology applied to air emissions control equipment. Defined by permitting agency.

Backup rate: A utility charge for providing occasional electricity service to replace on-site generation.

Backup electricity, backup services: Power or services needed occasionally; for example, when on-site generation equipment fails.

Baghouse: A chamber containing fabric filter bags that remove particles from furnace stack exhaust gases. Used to eliminate particles greater than 20 microns in diameter.

Barrel of oil equivalent: A unit of energy equal to the amount of energy contained in a barrel of crude oil. Approximately 5.78 million Btu or 1,700 kWh. A barrel is a liquid measure equal to 42 gallons.

Baseload capacity: The power output that generating equipment can continuously produce.

BDU: *See Bone dry unit*.

Best available control technology: (BACT) That combination of production processes, methods, systems, and techniques that will result in the lowest achievable level of emissions of air pollutants from a given facility. BACT is an emission limitation determined on a case- by-case basis by the permitting authority, taking into account energy, environmental, economic and other costs of control. BACT may include fuel cleaning or treatment, or innovative fuel combustion techniques. Applies in attainment areas.

Best management practices: A practice or combination of practices that is determined by a designated agency to be the most effective, practical means of reducing the amount of pollution generated by nonpoint sources to a level compatible with water quality goals.

Bioaccumulants: Substances in contaminated air, water, or food that increase in concentration in living organisms exposed to them because the substances are very slowly metabolized or excreted.

Biochemical conversion process: The use of living organisms or their products to convert organic material to fuels.

Biochemical oxygen demand (BOD): A standard means of estimating the degree of pollution of water supplies, especially those which receive contamination from sewage and industrial waste. BOD is the amount of oxygen needed by bacteria and other microorganisms to decompose organic matter in water. The greater the BOD, the greater the degree of pollution. Biochemical oxygen demand is a process that occurs over a period of time and is commonly measured for a five-day period, referred to as BOD5.

Biogas: A combustible gas derived from decomposing biological waste. Biogas normally consists of 50 to 60 percent methane.

Biological oxidation: Decomposition of organic materials by microorganisms.

Biomass: Organic matter available on a renewable basis. Biomass includes forest and mill residues, agricultural crops and wastes, wood and wood wastes, animal wastes, livestock operation residues, aquatic plants, fast-growing trees and plants, and municipal and industrial wastes.

Biomass fuel: Liquid, solid, or gaseous fuel produced by conversion of biomass.

Biomass energy: *See Bioenergy*.

Biomass Industrial Process Heat Facility: A facility wich manufactures products, often from biomass resources as the fuel to generate thermal energy for the manufacturing process.

Biotechnology: Technology that use living organisms to produce products such as medicines, to improve plants or animals, or to produce microorganisms for bioremediation.

BOD: *See Biochemical oxygen demand*.

Boiler horsepower: A measure of the maximum rate of heat energy output of a steam generator. One boiler horsepower equals 33,480 Btu/hr output in steam.

Boiler: Any device used to burn biomass fuel to heat water for generating steam.

Bone dry: Having zero percent moisture content. Biomass heated in an oven at a constant temperature of 212 degrees F or above until its weight stabilizes is considered bone dry or oven dry.

Bone dry ton: *See Oven dry ton*.

Bottom ash: Noncombustable ash that is left after solid fuel has been burned.

British thermal unit (Btu): A unit of heat energy equal to the heat needed to raise the temperature of one pound of water from 60 degrees F to 61 degrees F at one atmosphere pressure.

Btu: An abbreviation for British thermal units. The amount of heat that is required to raise one pound of water one degree Fahrenheit.

C

Capacity: The maximum power that a machine or system can produce or carry safely. The maximum instantaneous output of a resource under specified conditions. The capacity of generating equipment is generally expressed in kilowatts or megawatts.

Capacity factor: (1) The ratio of the average load on a generating resource to its capacity rating during a specified period of time. (2) The amount of energy that the system produces at a particular site as a percentage of the total amount that it would produce if it operated at rated capacity during the entire year.

Capital Cost: Cost of construtction of a new plant (including equipment purchase, design, engineering), and expenditures for the purchase of acquistion of new facilities.

Capacity Price: The electricity price based on the cost associated with providing the capability to deliver energy, primarily the capital costas of facilities.

cfm: Cubic feet per minute.

Char: The remains of solid biomass that has been incompletely combusted, such as charcoal if wood is incompletely burned.

Cogeneration: The sequential production of electricity and useful thermal energy from a common fuel source. Reject heat from industrial processes can be used to power an electric generator (bottoming cycle). Conversely, surplus heat from an electric generating plant can be used for industrial processes, or space and water heating purposes (topping cycle).

Coliform bacteria: Bacteria whose presence in waste water is an indicator of pollution and of potentially dangerous contamination.

Combined cycle: Two or more generation processes in series or in parallel, configured to optimize the energy output of the system.

Combined-cycle power plant: The combination of a gas turbine and a steam turbine in an electric generation plant. The waste heat from the gas turbine provides the heat energy for the steam turbine.

Combined heat and power: (CHP) An older term for what is now generally called cogeneration. The term is currently used in Europe and other foreign countries.

Combustion: Burning. The transformation of biomass fuel into heat, chemicals, and gases through chemical combination of hydrogen and carbon in the fuel with oxygen in the air.

Combustion gases: The gases released from a combustion process.

Combustion air: The air fed to a fire to provide oxygen for combustion of fuel. It may be preheated before injection into a furnace.

Condenser: A heat-transfer device that reduces a fluid from a vapor phase to a liquid phase.

Conservation: Efficiency of energy use, production, transmission, or distribution that results in a decrease of energy consumption while providing the same level of service.

Conveyor: A mechanical apparatus for carrying bulk material from place to place; for example, an endless moving belt or a chain of receptacles.

Cost-effective: A term describing a resource that is available within the time it is needed and is able to meet or reduce electrical power demand at an estimated incremental system cost no greater than that of the least-costly, similarly reliable and available alternative.

Cyclone separator: A device used to remove particulate matter suspended in exhaust gases.

D

Digester: An airtight vessel or enclosure in which bacteria decomposes biomass in water to produce biogas.

Discount rate: A rate used to convert future costs or benefits to their present value.

Discounting: A method of converting future dollars into present values, accounting for interest costs or forgone investment income. Used to convert a future payment into a value that is equivalent to a payment now.

Distribution: The transfer of electricity from the transmission network to the consumer.

District heating or cooling: A system that involves the central production of hot water, steam, or chilled water and the distribution of these transfer media to heat or cool buildings.

Downdraft gasifier: A gasifier in which the product gases pass through a combustion zone at the bottom of the gasifier.

Drainage: *See Watershed*.

Dry Ton: 2,000 pounds of material dried to a constant weight.

Dutch oven furnace: One of the earliest types of furnaces, having a large, rectangular box lined with firebrick (refractory) on the sides and top. Commonly used for burning wood. Heat is stored in the refractory and radiated to a conical fuel pile in the center of the furnace.

E

Electrical horsepower*: See Horsepower*.

Emissions: Waste substances released into the air or water.

Energy: The ability to do work.

Energy Price: The electricity price based on the variable costs associated with the production of electric energy (kilowatt-hours).

F

Federal Water Pollution Control Act: A federal regulatory law administered by the states. The act created the National Pollution Discharge Elimination System.

Feedstock: Any material which is converted to another form or product.

Fine: A very small particle of material such as very fine sander dust or very small pieces of bark.

Firm power: (firm energy) Power which is guaranteed by the supplier to be available at all times during a period covered by a commitment. That portion of a customer's energy load for which service is assured by the utility provider.

Flow rate: The amount of water or gas that moves through an area (usually pipe) in a given period of time.

Fluidized-bed boiler: A large, refractory-lined vessel with an air distribution member or plate in the bottom, a hot gas outlet in or near the top, and some provisions for introducing fuel. The fluidized bed is formed by blowing air up through a layer of inert particles (such as sand or limestone) at a rate that causes the particles to go into suspension and continuous motion. The super-hot bed material increased combustion efficiency by its direct dontact with the fuel.

Fly ash: Small ash particles carried in suspension in combustion products.

Fossil fuel: Solid, liquid, or gaseous fuels formed in the ground after millions of years by chemical and physical changes in plant and animal residues under high temperature and pressure. Oil, natural gas, and coal are fossil fuels.

Fuel: Any material that can be converted to energy.

Fuel cell: A device that converts the energy of a fuel directly to electricity and heat, without combustion.

Fuel-cell furnace: A variation of the Dutch oven design, that usually incorporates a primary and secondary combustion chamber (cell). The primary chamber is a vertical refractory-lined cylinder with a grate at the bottom in which combustion is partially completed. Combustion is completed in the secondary chamber.

Fuel handling system: A system for gathering fuel, transporting the fuel to a storage pile or bin, and conveying the fuel from storage to the boiler or other energy conversion equipment.

Furnace: An enclosed chamber or container used to burn biomass in a controlled manner to produce heat for space or process heating.

G

gal/d: Gallons per day.

Gas engine: A piston engine that uses gaseous fuel rather than gasoline. Fuel and air are mixed before they enter cylinders; ignition occurs with a spark.

Gasification: A chemical or heat process to convert a solid fuel to a gaseous form.

Gasifier: A device for converting solid fuel into gaseous fuel. In biomass systems, the process is referred to as pyrolitic distillation. See Pyrolysis.

Generator: A machine used for converting rotating mechanical energy to electrical energy.

Grid: An electric utility's system for distributing power.

Grid connection: Joining a plant that generates electric power to a utility system so that electricity can flow in either direction between the utility system and the plant.

Gross heating value: (GHV) The maximum potential energy in the fuel as received. It reflects the displacement of fiber by water present in the fuel. Expressed as:

GHV = HHV (1 - MC / 100).

H

Hammermill: A device consisting of a rotating head with free-swinging hammers which reduce chips or hogged fuel to a predetermined particle size through a perforated screen.

Heat Rate: The amount of fuel energy required by a power plant to produce one kilowatt-hour of electrical output. A measure of generating station thermal efficiency, generally expressed in Btu per net kWh. It is computed by dividing the total Btu content of fuel burned for electric generation by the resulting net kWh generation.

Heating value: The maximum amount of energy that is available from burning a substance.

HHV: The maximum potential energy in the dry fuel contained in a sample

Higher heating value: (HHV) The maximum potential energy in dry fuel. For wood, the range is 7,600 to 9,600 Btu/lb.

Horsepower: (electrical horsepower; hp) A unit for measuring the rate of mechanical energy output. The term is usually applied to engines or electric motors to describe maximum output. 1 hp = 745.7 Watts = 0.746 kW = 2,545 Btu/hr.

hp: *See Horsepower*.

Hydraulic load: Amount of liquid going into a system.

Hydrocarbon: Any chemical compound containing hydrogen, oxygen, and carbon.

I

Inclined grate: A type of furnace in which fuel enters at the top part of a grate in a continuous ribbon, passes over the upper drying section where moisture is removed, and descends into the lower burning section. Ash is removed at the lower part of the grate.

Induction generator: A variable speed multi-pole electric generator.

Infiltration: Leakage of ground water or surface run-off into a manure collection system.

Influent: Waste water going into the anaerobic digester.

Interconnection: A connection or link between power systems that enables them to draw on one another's reserve in time of need.

Interruptible load: Loads that can be curtailed at the supplier's discretion or in accordance with a contractual agreement.

Investment tax credit: A specified percentage of the dollar amount of certain new investments that a company can deduct as a credit against its income tax bill.

Investor-owned utility: (IOU) A private power company owned by and responsible to its shareholders and regulated by a public service commission.

J/K

Kilowatt: (kW) A measure of electrical power equal to 1,000 Watts. 1 kW = 3,413 Btu/hr = 1.341 horsepower.

Kilowatt hour: (kWh) A measure of energy equivalent to the expenditure of one kilowatt for one hour. For example, 1 kWh will light a 100-watt light bulb for 10 hours. 1 kWh = 3,413 Btu.

kW: *See Kilowatt*.

kWh: *See Kilowatt-hour*.

L

LAER: See Lowest achievable emission rate.

Leachates: Liquids percolated through waste piles. Leachate can include various minerals, organic matter, or other contaminants and can contaminate surface water or ground water.

Levelized life-cycle cost: The present value of the cost of a resource, including capital, financing and operating costs, expressed as a stream of equal annual payments. This stream of payments can be converted to a unit cost of energy by dividing the annual payment amount by the annual kilowatt-hours produced or saved. By levelizing costs, resources with different lifetimes and generating capabilities can be compared.

Life-cycle costing: A method of comparing costs of equipment or buildings based on original costs plus all operating and maintenance costs over the useful life of the equipment. Future costs are discounted.

Load factor: Load factor is the ratio of average demand to maximum demand or to capacity.

Load: (1) The amount of electrical power required at a given point on a system. (2) The average demand on electrical equipment or on an electric system.

Lowest achievable emissions rate: (LAER) Used to describe air emissions control technology. A rate of emissions defined by the permitting agency. LEAR sets emission limits for non-attainment areas.

M

Management plan: A plan guiding overall management of an area administered by a federal or state agency. A management plan usually includes objectives, goals, standards and guidelines, management actions, and monitoring plans.

MC: *See Moisture content.*

MCDB*: See Moisture content, dry basis.*

MCWB*: See Moisture content, wet basis.*

Megawatt: (MW) The electrical unit of power that equals one million Watts (1,000 kW).

Mesophilic: An optimum temperature for bacterial growth in an enclosed digester (25 degrees to 40 degrees C).

Methane: An odorless, colorless, flammable gas with the formula CH4 that is the primary constituent of natural gas.

Methanogen: A methane-producing organism.

Mill/kWh: A common method of pricing electricity. Tenths of a cent per kilowatt hour.

Mill: A tenth of a cent ($0.001).

Mitigation: Steps taken to avoid or minimize negative environmental impacts. Mitigation can include: avoiding the impact by not taking a certain action; minimizing impacts by limiting the degree or magnitude of the action; rectifying the impact by repairing or restoring the affected environment; reducing the impact by protective steps required with the action; and compensating for the impact by replacing or providing substitute resources.

MMBtu: One million British thermal units.

Moisture content, wet basis: Moisture content expressed as a percentage of the weight of biomass as-produced.

weight of wet sample: weight of dry sample

--- x 100

weight of wet sample

Moisture Content: (MC) The weight of the water contained in biomass, usually expressed as a percentage of weight, either oven-dry or as received.

Moisture content, dry basis: Moisture content expressed as a percentage of the weight of oven-dry biomass.

weight of wet sample - weight of dry sample

-- x 100

weight of dry sample

N

Net heating value: (NHV) The potential energy available in the fuel as received, taking into account the energy loss in evaporating and superheating the water in the sample. Expressed as

NVH = (HHV x (1- MC / 100)) - (LH(2)O x MC / 100)

Net present value: The sum of the costs and benefits of a project or activity. Future benefits and costs are discounted to account for interest costs.

Nitrogen fixation: The transformation of atmospheric nitrogen into nitrogen compounds that can be used by growing plants.

Nonutility Generator (NUG) An all encompassing terms for independent power producers.

O

Opacity: The degree to which smoke or particles emitted into the air reduce the transmission of light and obscure the view of an object in the background.

Organic: Derived from living organisms.

Oven dry: *See Bone dry*.

Oven dry ton: (ODT) An amount of biomass that weighs 2,000 pounds at zero percent moisture content.

P

Particulate: A small, discrete mass of solid or liquid matter that remains individually dispersed in gas or liquid emissions. Particulates take the form of aerosol, dust, fume, mist, smoke, or spray. Each of these forms has different properties.

Particulate emissions: Fine liquid or solid particles discharged with exhaust gases. Usually measured as grains per cubic foot or pounds per million Btu input.

pH: A measure of acidity or alkalinity. A pH of 7 represents neutrality. Acid substances have lower pH. Basic substances have higher pH.

Pound: Pound mass (sometimes abbreviated lb(m)). A unit of mass equal to 0.454 kilograms.

Pound of steam: One pound mass of water converted to steam.

Power conversion factors: (Rate of flow of energy) - Watts=3.413 BTU/hr. Kw=1,000 watts=1.341 horsepower=3413 BTU/hr. Horsepower=745.7 watts.

Present value: The worth of future receipts or costs expressed in current value. To obtain present value, an interest rate is used to discount future receipts or costs.

Process heat: Heat used in an industrial process rather than for space heating or other housekeeping purposes.

Producer gas: Fuel gas high in carbon monoxide (CO) and hydrogen (H2), produced by burning a solid fuel with insufficient air or by passing a mixture of air and steam through a burning bed of solid fuel.

Psi: Pounds force of pressure per square inch.

Psig: Pounds force of pressure per square inch gauge (excluding atmospheric pressure).

Public utility commissions: State agencies that regulate investor-owned utilities operating in the state.

Pyrolysis: The thermal decomposition of biomass at high temperatures (greater than 400 degrees F, or 200 degrees C) in the absence of air. The end product of pyrolysis is a mixture of solids (char), liquids (oxygenated oils), and gases (methane, carbon monoxide, and carbon dioxide) with proportions determined by operating temperature, pressure, oxygen content, and other conditions.

Q

Quad: One quadrillion Btu (10^{15} Btu). An energy equivalent to approximately 172 million barrels of oil.

R

Rate schedule: A price list showing how the electric bill of a particular type of customer will be calculated by an electric utility company.

Recirculation: Returning a fraction of the effluent outflow to the inlet to dilute incoming wastewater.

Refractory Lining: A lining, usually of ceramic, capable of resisting and maintaining high temperatures.

Renewable energy resource: An energy resource replenished continuously or that is replaced after use through natural means. Sustainable energy. Renewable energy resources include bioenergy, solar energy, wind energy, geothermal power, and hydropower.

Return on investment: (ROI) The interest rate at which the net present value of a project is zero. Multiple values are possible.

ROI: See Return on investment.

S

Saturated steam: Steam at the temperature that corresponds to its boiling temperature at the same pressure.

SCF: Standard cubic foot.

SCFM: Standard cubic foot per minute.

Shaft horsepower: A measure of the actual mechanical energy per unit time delivered to a turning shaft. 1 shaft horsepower = 1 electric horsepower = 550 ft-lb/second.

Slow pyrolysis: Thermal conversion of biomass to fuel by slow heating to less than 450 degrees C in the absence of oxygen.

Spreader stoker furnace: A furnace in which fuel is automatically or mechanically spread. Part of the fuel is burned in suspension. Large pieces fall on a grate.

SS: *See Suspended solids*.

Steam conversion factors: (approximations)

> 1 pound of steam = 1,000 Btu = .3 kW. 10,000 lbs/hr steam = 300 boiler horsepower.

Steam turbine: A device for converting energy of high-pressure steam (produced in a boiler) into mechanical power which can then be used to generate electricity.

Stoichiometric condition: That condition at which the proportion of the air-to-fuel is such that all combustible products will be completely burned with no oxygen remaining in the combustion air.

Sunk cost: A cost already incurred and therefore not considered in making a current investment decision.

Surplus electricity: Electricity produced by cogeneration equipment in excess of the needs of an associated factory or business.

Suspended solids: Waste particles suspended in water.

T

Therm: A unit of energy equal to 100,000 Btus; used primarily for natural gas.

Thermal resource: A facility that produces electricity by using a heat engine to power an electric generator. The heat may be supplied by the combustion of coal, oil, natural gas, biomass, or other fuels, including nuclear fission, solar, or geothermal resources.

Thermochemical conversion process: Chemical reactions employing heat to produce fuels.

Transmission: The process of long-distance transport of electrical energy, generally accomplished by raising the electric current to high voltages.

Traveling grate: A type of furnace in which assembled links of grates are joined together in a perpetual belt arrangement. Fuel is fed in at one end and ash is discharged at the other.

TSP: *See Total suspended particulates*.

Turbine: A machine for converting the heat energy in steam or high temperature gas into mechanical energy. In a turbine, a high velocity flow of steam or gas passes through successive rows of radial blades fastened to a central shaft.

Turn down ratio: The lowest load at which a boiler will operate efficiently as compared to the boiler's maximum design load.

Turnkey system: A system which is built, engineered, and installed to the point of readiness for operation by the owner.

U

Ultimate analysis: A description of a fuel's elemental composition as a percentage of the dry fuel weight.

V

VOC: *see Volatile organic compounds*.

Volatile organic compounds: (VOC) Emissions of non-methane hydrocarbons, measured by standard methods.

Volatiles: Substances that are readily vaporized.

W

Waste streams: Unused solid or liquid by- products of a process.

Water-cooled vibrating grate: A boiler grate made up of a tuyere grate surface mounted on a grid of water tubes interconnected with the boiler circulation system for positive cooling. The structure is supported by flexing plates allowing the grid and grate to move in a vibrating action. Ashes are automatically discharged.

Watt: The common base unit of power in the metric system. One watt equals one joule per second, or the power developed in a circuit by a current of one ampere flowing through a potential difference of one volt. One Watt = 3.413 Btu/hr.

Wheeling: The process of transferring electrical energy between buyer and seller by way of an intermediate utility or utilities.

X/Y/Z

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