

AGRI-FACTS

Practical Information for Alberta's Agriculture Industry

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Anaerobic Digesters

The anaerobic digestion process is gaining attention in the agriculture industry because of its potential for renewable energy production and manure stabilization. These potential benefits are significant against the current backdrop of rising energy costs and growing environmental concerns.

The process has been adopted in various ways in different parts of the world, predominantly in Europe and the United States. Although knowledge of the process is not yet widespread in Alberta, the agriculture industry is keen to see if anaerobic digestion is suited for its operations.

This factsheet covers some of the basics:

- anaerobic digestion process
- operating conditions
- process materials
- key components
- financial benefits
- environmental benefits
- feasibility
- safety aspects
- commercial technology suppliers list

Anaerobic digestion process

Anaerobic digestion is a naturally occurring process through which organic matter such as manure, feed spills, meat processing wastes and crop residues are stabilized by microorganisms strictly in the absence of air.

During this process, some organic compounds are converted to methane (CH_4) and carbon dioxide (CO_2) gases. This mixture of gases is known as biogas. The composition of biogas is 50 to 75 per cent CH_4 and 25 to 45 per cent CO_2 . Like natural gas, biogas can also be used as a fuel in power generators, engines, boilers and burners.

In practice, specially designed and insulated tanks are used to facilitate the anaerobic digestion process under a controlled atmosphere. These tanks are known as anaerobic digesters. The effluent coming out from the digester after the completion of the digestion process is known as digestate. Digestate has nutrient value and can be applied on land like manure. Digestate also has much less odour compared to stored manure.

Operating parameters

Most anaerobic digesters are operated in the temperature range of 15 to 45°C. The pH of the slurry in the digester is maintained between 6.5 and 7.5. The typical retention time of organic matter in the anaerobic digesters varies from 2 days to 60 days, depending on the type of digester and the concentration of organic matters processed.

Covered lagoon, plug flow, completely mixed and attached growth/fixed film are the most common types of digesters used in North America. These digesters can process liquid organic waste with a solids concentration in the range of 0.5 to

12 per cent. The anaerobic digestion process is sensitive to variation. High failure rates have been reported due to inadequate process control.

Digester feedstock material

Manure, feed spills, crop residues, offal and most domestic and industrial organic wastes can be used as feed materials for digesters. However, care must be taken to make sure that pathogens that cause diseases to livestock, such as mad cow disease or avian influenza, are prevented from entering the anaerobic digesters.

Anaerobic digestion has potential for renewable energy production

Gas purification

Biogas from anaerobic digesters has trace gases such as water vapour, hydrogen sulfide (H₂S), nitrogen, hydrogen and oxygen. Among these trace gases, water and H₂S gases require removal (see Figure 1) before biogas is used to produce energy.

The trace of water vapour is removed as condensate when warm biogas cools in a condenser. A gas scrubber is usually used to remove corrosive hydrogen sulfide. The hydrogen sulfide content in biogas should be less than 200 ppm (parts per million) to ensure a long life for the power generators. Should biogas be distributed using pipelines, Canadian oil and gas pipeline standards may be applicable. According to Canadian oil and gas pipeline standards, hydrogen sulfide content shall not exceed 4.6 ppm.

Power generator

Electricity can be produced from biogas using internal combustion engines and power turbines. While producing electricity, heat energy can also be recovered by using a sophisticated generator known as a co-generator (see Figure 1). Co-generators usually contain an internal combustion engine or power turbine and heat exchanger to capture the heat generated while electricity is produced. Thus, co-generators have higher efficiency in energy production when compared to other electricity generators.

Energy use

Electricity produced on a farm can be used to meet the electricity demand of the same farm. The excess electricity may be sold to neighbouring communities or to the electricity supplier using the grid. Information regarding connecting excess electricity back into the grid can be obtained from the energy supplier.

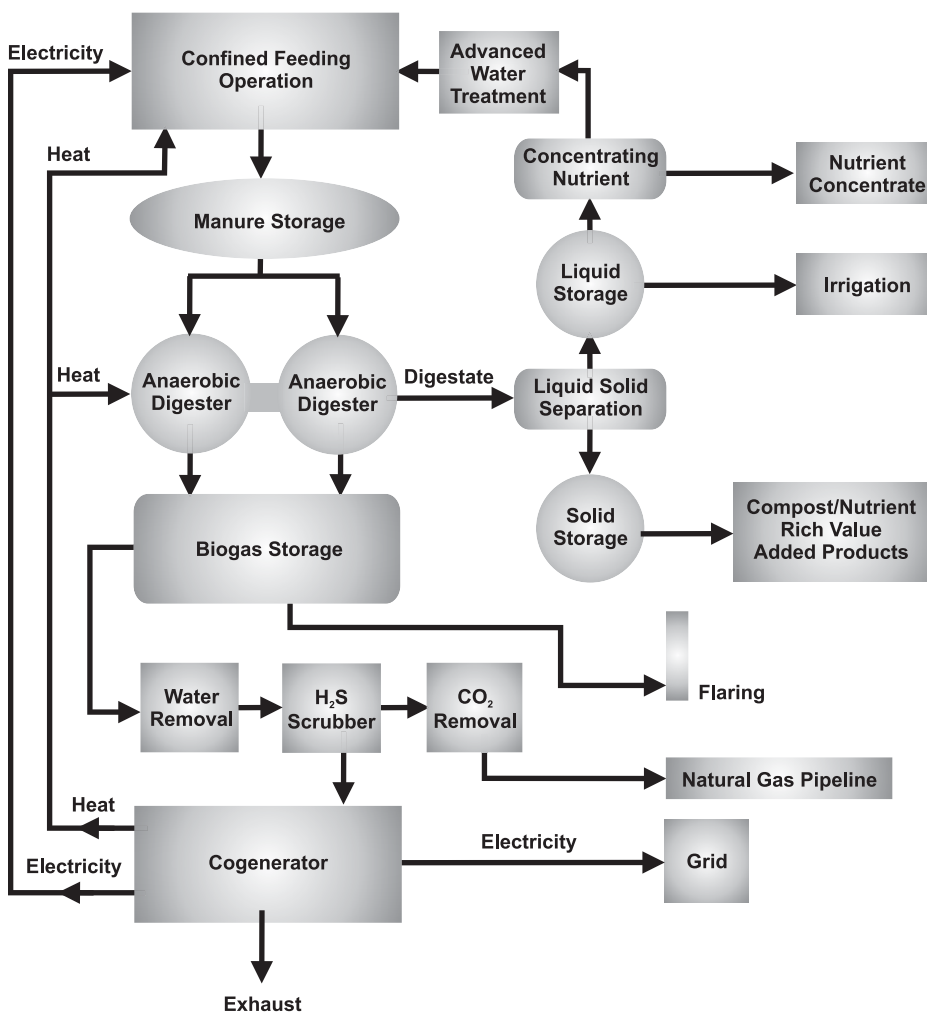


Figure 1. Schematic of an anaerobic digester plant

Part of the heat energy produced during the power generation is often used to heat the anaerobic digester. The rest is used to meet the various heating requirements of the farm. In some cases in Europe, heat energy is also pumped to meet the neighbouring community's heating requirements.

Biogas may also potentially be added to the natural gas lines if carbon dioxide is removed. Figure 1 shows energy utilization.

Environmental benefits

Along with odour, surface water and groundwater contamination are major concerns in expanding the livestock industry. According to most suppliers, anaerobic digesters can reduce odour from livestock facilities by 80 per cent.

Adopting anaerobic digester technology on farms results in better manure management and reduces the risk of ground or surface water contamination due to pathogens and nutrients leaching by run-off. Several studies have claimed that harmful pathogens like *E. coli* bacteria are considerably reduced when this process is used. Apart from this result, energy from biogas is known as renewable energy and reduces greenhouse gas emissions (carbon dioxide (CO₂), methane (CH₄) and nitrous oxide).

Renewable energy sources are those that produce electricity or thermal energy without depleting natural resources. Greenhouse gas emissions are blamed for the accelerated climate change throughout the world. Thus, renewable energy use and greenhouse gas emission reduction are globally recommended.

Feasibility

Anaerobic digesters are installed on individual farms or as centralized digesters. Typically, the capital and running costs of a biogas electricity generating plant are \$3,700 to 7,000/kWh and \$0.02/kWh, respectively. The total capital

costs of anaerobic digester plants are high and may range from a few hundred thousand to a few million dollars. Some of the feasibility studies in North America concluded that the payback period ranges from 5 to 16 years, when operated under optimum and worst conditions, respectively. Government financial incentives for producing green energy can reduce the payback period significantly.

However, most of the other waste processing technologies, which may also require a high capital investment, do not generate revenue like a biogas digester plant does. Multiplying the amount of annual electricity and heat energy potentials in Table 1 by average electricity and heating costs provides the approximate annual energy revenue from processing manure as shown in the example below.

Multiply the corresponding annual electricity and heat energy potentials in the table by the number of animals to find out the total energy that can be produced on a farm when an anaerobic digester is used.

Example

Number of animals	= 100 dairy cows
Average cost of electricity	= \$ 0.06/ kWh
Average cost of heat	= \$ 5.5/GJ
Annual electricity potential	= 1,227 kWh (from the table)
Annual heating potential	= 5.5 GJ (from the table)
Savings from electricity	= 100 x 0.06 x 1,227 = \$ 7,362
Savings from gas	= 100 x 5.5 x 5.5 = \$ 3,025
Total annual savings from energy	= \$ 10,387

Note:

- Alberta Bioenergy Producer Credit Program offers incentives for commercial bioenergy production (<http://www.energy.gov.ab.ca/BioEnergy/bioenergy.asp>).
- Number of cows and the energy costs are assumed in the above example.

Description	Manure quantity as excreted (kg/d)	Biogas production (m ³ /d)	Electricity potential (kW)/year	Energy potential (GJ)/year
Beef	24.0	1.10	663	3.0
Dairies	62.0	2.01	1,227	5.5
Piglet *	3.5	0.16	98	0.4
Poultry (100 – layer)	8.8	0.85	516	2.3

* Multiply the table values for piglet by 12 for every sow in a farrow-to-finish operation.

Land application of digestate on cropland offsets fertilizer costs. Tipping fees for feed materials can also be a part of the revenue stream. Besides these benefits, provincial and federal governments support the adaptation of similar renewable energy production technologies and are likely to come up with incentive programs.

Apart from all these financial benefits, anaerobic digesters have environmental benefits such as reduction in odour, ground/surface water contamination, greenhouse gas emission and pathogens.

Potential by-products

The excess digestate may be processed to produce several value-added products and to reuse water as shown in Figure 1. The first step in processing the digestate is separating the liquid and solid portions.

Both the separated liquid and solid portions have nutrients in them. The nutrients in the liquid portion can be concentrated by removing the water to reduce the handling volume. The solid content in the digestate can be used as bedding material with the appropriate manure management practice or can be further processed.

Both the processed liquid and solid portion can be amended with supplemental nutrients to produce value-added products. The separated water from the liquid portion may be used for irrigation or flushing purposes and purified further using advanced water treatment technologies to meet other water requirements on the farm. However, additional processing always requires additional investment. Figure 1 shows the utilization of value-added products and water reuse after biogas production.

Safety

Biogas is a highly corrosive and flammable gas. The gas storage and utilization system must be constructed in accordance with standard engineering practices for handling a flammable gas to prevent undue safety hazards.

Biogas contains traces of hydrogen sulfide (H_2S). Exposure to high concentrations of H_2S is harmful and may result in human fatality. Therefore, plant operators must be trained to handle H_2S hazards. Canadian oil and gas pipeline standards require that mercaptans be added to domestic natural gas for quick and easy detection of gas leakage during distribution. This procedure is applicable for biogas distribution as well.

Plant operators at the site should follow standard safety procedures such as wearing safety gear, especially for ear protection as co-generators are generally noisy. The plant area should be fenced and have appropriate warning signs like “Danger, H_2S Area,” “Stop” or “High Voltage.”

Suppliers

An up-to-date list of commercial technology suppliers can be found on the Alberta Agriculture and Food website: www.agriculture.alberta.ca

For additional information, check the following web pages:

Anaerobic Digesters: Frequently Asked Questions, Agdex 768-2
[http://www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/agdex11290](http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex11290)

Biogas Energy Potential in Alberta, Agdex 768-3
[http://www1.agric.gov.ab.ca/\\$Department/deptdocs.nsf/all/agdex11397](http://www1.agric.gov.ab.ca/$Department/deptdocs.nsf/all/agdex11397)

Integrating Biogas, Confined Feedlot Operations and Ethanol Production, Agdex768-4
[http://www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/agdex11839](http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex11839)

Biogas Distribution – Rural Utilities Division of Alberta Agriculture and Food
<http://www1.agric.gov.ab.ca/general/progserv.nsf/all/pgmsrv13?opendocument>.

Incentives for biogas production – Alberta Bioenergy Producer Credit Program
<http://www.energy.gov.ab.ca/BioEnergy/bioenergy.asp>

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