

Great Lakes Fruit, Vegetable & Farm Market EXPO

December 4-6, 2007

DeVo Place Convention Center, Grand Rapids, MI



Alternative Energy

Tuesday afternoon 2:00 pm

Where: Grand Gallery (lower level) Room E-F

Summary: This session will look at a number of alternative energy sources for the farm that are being used or investigated. Presenters will discuss the use of farm by-products as well as wind-powered generators, corn and pellet burners.

CCA Credits: CM(2.0)

Moderator: Tom Kalchik, MSU Product Center

2:00 p.m. Regional Digesters Offer Seasonal Solutions

- Norma McDonald, Operating Manager, Phase 3 Developments and Investments
- Charles Gould, Agriculture & Natural Resources Educator, MSU Extension

2:40 p.m. The Latest on Corn and Pellet Burners

- Christopher Schilling, Mechanical Engineering Dept., SVSU
- Mark Seamon, MSU Product Center Innovation Counselor, MSU Extension

3:20 p.m. The Facts About Energy Markets and Wind Energy

- Stephen Harsh, Agricultural Economics Dept., MSU

Regional Digesters Offer Seasonal Solutions

Norma McDonald, Phase 3 Renewables, LLC, Cincinnati, OH
Charles Gould, Michigan State University Extension, Grand Haven, MI

Regional Digester Concept

Michigan has an abundance of animal and plant agriculture. Both industries rely on high soil, water and air quality, as well as seasonal demands for energy and labor. With the agriculture comes an abundance of organic residuals – animal manures, crop residuals, food processing wastes, yard waste – which can be a liability if accumulated in excess, especially during limited seasons. The Regional Digester Concept would welcome residuals as feedstocks into a common processing center, where seasonal availability fluctuations can be accommodated, and seasonal demands for outputs can be put to the best possible use. The Regional Digester Concept can become a cooperative bridging the gaps between increasingly separated agricultural segments. Forging the right partnerships will produce the strongest economics.

The Anaerobic Digestion Process

What is anaerobic digestion? Simply put, it is a biological process that breaks down organic materials (called feedstocks) in the absence of oxygen (anaerobic conditions) into methane (CH₄) and carbon dioxide (CO₂). Methane and carbon dioxide are the primary gaseous components of biogas. Manure, fruit processing waste, grease and fats, corn silage are examples of feedstocks that can be used in a digester to produce biogas.

Anaerobic processes occur naturally. A helpful way to think of anaerobic digestion is to think of it in terms of your own stomach. Your stomach is a fermentation vat *par excellence*, providing an anaerobic environment, constant temperature and pH, and good mixing. Feeding a human being is very similar to “feeding” a digester. Both must have a balanced diet, be fed at regular intervals, and feeding too much new food without allowing time for digestion creates digestive problems.

Feedstocks

are used by fermenting bacteria to produce organic acids and hydrogen – compounds that are “food” for methanogens to produce methane. A list of organic acids is found in Table 1. Volatile acids shown in bold are produced in greatest quantity by fermenting bacteria during the digestion process.

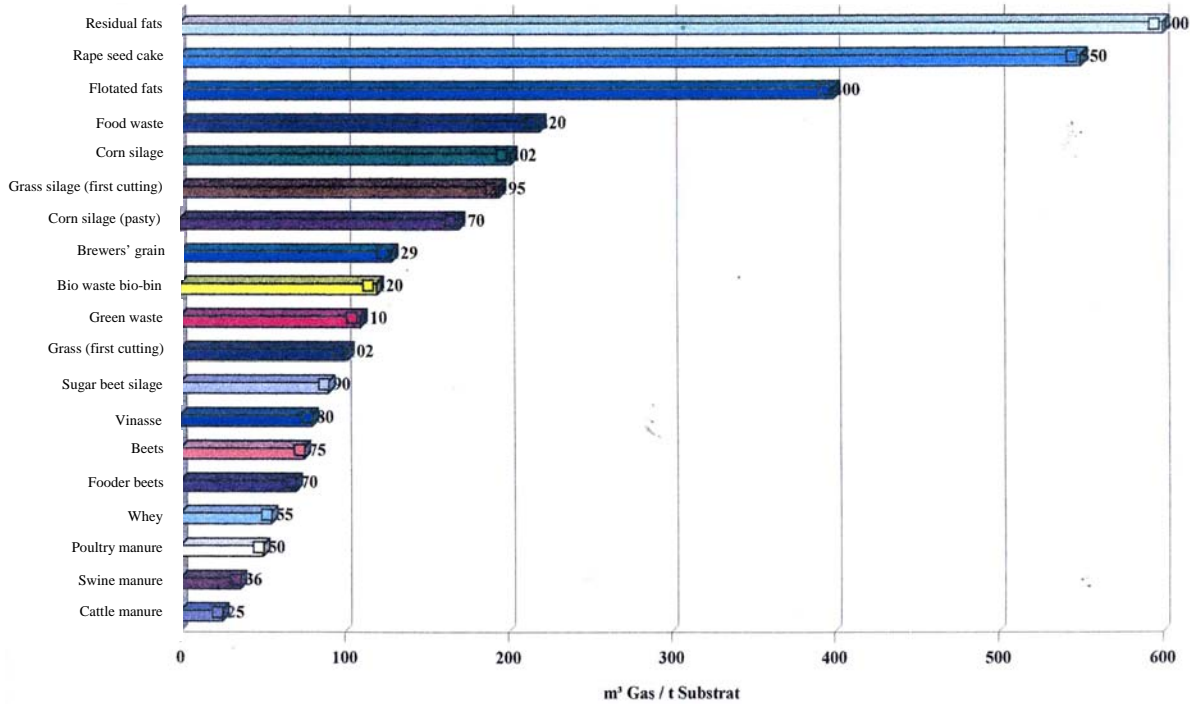
Volatile solids

Table 1. Organic Acids of Significance

Volatile Acids		Non-Volatile Acids
Formic acid	n-Valeric acid	Lactic acid
Acetic acid	Isovaleric acid	Pyruvic acid
Propionic acid	Caproic acid	Succinic acid
n-Butyric acid	Heptanoic acid	
Isobutyric acid	Octanoic acid	

It therefore stands to reason that digesters should receive feedstocks high in volatile solids for maximum biogas production. Figure 1 points out that feedstocks vary in their potential to produce biogas. Fats, which are high in volatile solids, generate the greatest biogas while manures, by comparison, generate the lowest.

Table 1. Biogas Yield of Different Feedstocks



Anaerobic Digestion Process Flow Diagram

The process of anaerobic digestion imitates the human digestive system. Feedstocks are introduced to the digester, acted upon by microorganisms to produce biogas and stabilize the digested feedstocks, and removed when the feedstocks are spent (having yielded its biogas potential). The diagram shown in Figure 1 illustrates the pathway from a raw feedstock to biogas and spent feedstock (this is typically referred to as digestate). There are many options available for biogas and digestate use. The biogas can be used to generate electricity and the digestate can be separated and used as a fertilizer, cattle bedding, or compost. New uses are being developed for the solid digestate including fuel pellets, medium density fiberboard and decking.

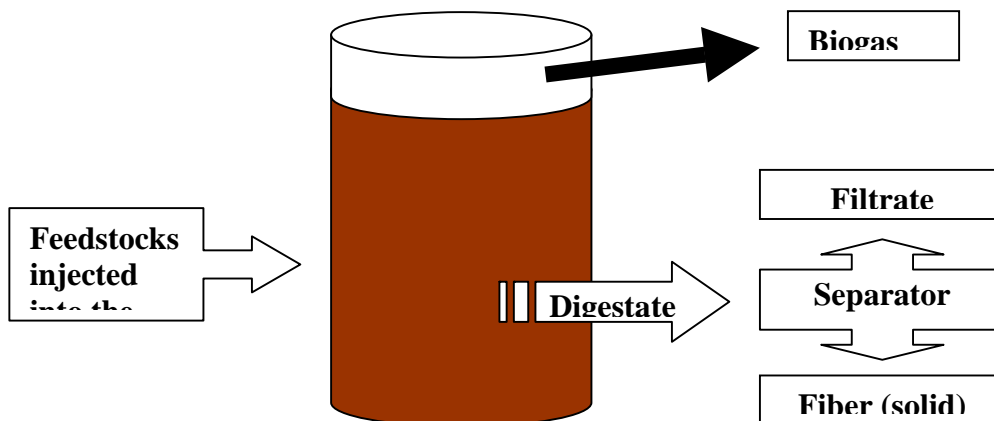


Figure 1. Simple process flow diagram through a digester.

The Biological Process of Producing Biogas

Another way to think of anaerobic digestion is the biological process of converting *volatile solids* into methane (CH₄) and carbon dioxide (CO₂), or biogas, by microorganisms that thrive in the absence of oxygen (anaerobic conditions). This biological process can be considered a four-stage process and is diagrammed in Figure 2.

- **Stage One – Hydrolysis**

The first stage is the liquefaction of complex organic compounds to simpler forms by *hydrolytic bacteria*. Principle end products include soluble sugars, amino acids, peptides, and long-chain fatty acids.

- **Stage Two – Acidogenesis**

The second stage is the metabolization of the products of hydrolysis by *acidogenic bacteria*. Principal end products include short-chain volatile organic acids (propionic, butyric, acetic, and formic acids), CO₂ and hydrogen (H₂).

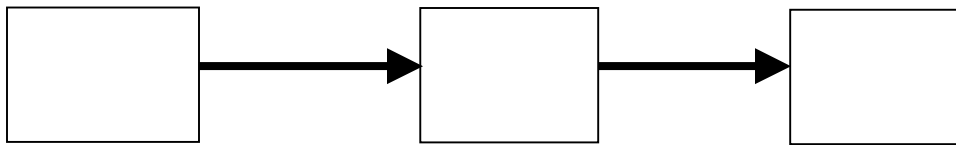
- **Step Three – Acetogenesis**

In this stage, the reduction of CO₂ and catabolization (the metabolic breakdown of complex molecules into simpler ones, often resulting in a release of energy) of short-chain fatty acids produced during Acidogenesis is carried out by *syntrophic acetogenic* and *homoacetogenic bacteria*. Principal end products include acetate, CO₂ and H₂.

- **Step Four – Methanogenesis**

The final stage is the conversion of hydrogen and acetate to methane by *methanogens*. Methanogens belong to a group of microorganisms called Archaea. Archaea are not bacteria but have similar functions as bacteria, and they must work closely together, as in an assembly line, in order to bring about the destruction of organic matter. Archaea and bacteria are generally found together and bring about the destruction or mineralization of complex organic materials. Bacteria ferment and convert complex organic materials into acetate and hydrogen, and methanogens convert organic acids, acetate and hydrogen into methane gas. This process is illustrated in a very simplified way in Figure 2.

Figure 2. Conversion Process from Complex Organic Matter to Methane



The microorganisms involved in the first step grow relatively rapidly, because the fermentation reactions give a greater energy yield than do the reactions that lead to methane formation. In other words, methanogens grow more slowly compared to bacteria since they get very little energy from their food. This means that methanogens are very sensitive to slight changes in loading, pH and temperature. Since methanogens are strictly anaerobic bacteria, they are also extremely sensitive to oxygen.

If methanogens are not happy for some reason (low pH, toxicity, etc.) and are not able to convert H₂ and CO₂ into methane, then H₂ will accumulate. This is a huge problem. A situation where methanogens are unhappy and working slower than their normal rate creates a cascade of events that leads to digester failure. This condition is referred to as “sour digester” or “stuck digester”.

The Products of Anaerobic Digestion

The substrates fed to the digester, and the conditions of digestion, determine the quantity and composition of biogas and digestate. AD processes solids and liquids and converts them to solids, liquids and gases, resulting in a slight reduction in gallons/tons after processing. AD removes the most offensive and cumbersome attributes – high odor, slime, insect larvae, pathogens and weed seeds – while leaving the most valuable – humate, water, macro- and micro-nutrients.

Nutrient Content of Digestate

During the digestion process nutrients are mineralized. This allows these nutrients to be immediately available for uptake by plants. With a better nutrient balance and more plant available nutrients, the requirements for commercial fertilizer may be lessened, which would be a cost-savings for farmers.

Filtrate and Fiber

The solid fraction can be used as a cattle bedding or blended with other materials to make compost, fertilizer pellets, fuel pellets, medium density fiberboard, fiber/plastic composite materials (decking), and other value-added products.

The solid fraction will resemble compost made from manure and other materials in many ways, but production via AD has greater homogeneity and supply availability while requiring significantly less space, energy and labor to achieve the final product. Additional processing options can sequester phosphorus with the solids, or produce vivianite, a helpful compound for the prevention of iron chlorosis.

After the fiber is removed, the remaining liquid organic substance is called filtrate. Some of the organic-N in manure is converted to ammonium-N during anaerobic digestion (de-amination), making it more readily available to plants compared to raw manure. The partitioning of nutrients between the particulate matter (fiber) and liquid (filtrate) can be accentuated using chemical or mechanical treatments. It is possible and often cost-effective to reduce BOD/COD in the final liquid to <5% of the original values, or even to reach discharge quality. It is also possible to remove phosphorus from the liquid, retaining a plant-available nitrogen liquid.

Biogas and its Uses

Biogas formed during digestion is removed continuously. The anaerobic digestion process produces 7 to 12 cubic feet of biogas for every pound of volatile matter destroyed, depending upon the characteristics of the feedstock. The biogas produced from a properly functioning digester is typically composed of 55 to 70 percent methane and 25 to 40 percent carbon dioxide, with the remaining fraction composed primarily of nitrogen, hydrogen and hydrogen sulfide.

The most valuable use for biogas is replacement of purchased energy – vehicle fuel, propane, fuel oil, electricity and natural gas. The chart below summarizes the relative value as a replacement for purchased energy, equipment and operating costs to enable use of biogas as a replacement for each fuel, and the ease with which converted biogas could be transported for use off-site. Replacing Vehicle Fuel, for instance, would save the most money for each BTU of energy purchased and compressed or liquefied biomethane is highly transportable. But the capital investment for the equipment is also the highest per MCF of biogas processed, including costs to retrofit vehicle engines.

The Regional Digester Concept proposes to look at the mix of on-site and local energy demands to tailor the biogas treatment and use processes for the highest benefit, including the flexibility to switch between uses on a seasonal basis.

MARKET COST/MM BTU (Highest to Lowest)	EQUIPMENT/OPERATING COST TO CONVERT BIOGAS (Lowest to Highest)	TRANSPORTABILITY FOR SUBSTITUTION (Most to Least)
Vehicle Fuel	Fuel/heating oil*	Vehicle Fuel
Propane	Natural Gas*	Propane
Fuel/heating oil	Electricity	Fuel/heating oil
Electricity	Propane*	Natural Gas
Natural Gas	Vehicle Fuel	Electricity

In addition, the waste products of energy production can be of value to greenhouse growers. Waste heat and CO2 can be used to expand plant species under cultivation and increase productivity.

Research and Development

As the Regional Digester Concept grows across the State, there are numerous opportunities for collaborative research and development or test-marketing of pilot plants. We will be pairing problems with possibilities to identify the most profitable processes. We will work with universities, farmers and marketers to overcome obstacles in the value chain and identify value added opportunities.

Economic Development

By reducing costs of current operations, Michigan's animal and plant agriculture segments can become more profitable and better compete in a global marketplace. By locating new or expanded facilities alongside or near Regional Digesters, closed loop, full cycle bio-economy sites can be created that enhance the environment and create jobs.

The Latest on Corn and Pellet Burners

Mark Seamon
Michigan State University Extension
MSU Product Center Innovation Counselor

Record high energy prices have placed a financial burden on the cost of heating for Michigan citizens and businesses. One of the responses to these prices has been the adoption of solid fueled heating systems (primarily biomass pellets and corn grain). Recent analysis of the cost comparison of fuels and the research of challenges in operating corn fueled heating systems will help home owners and business owners evaluate the best fit for their situation. Corn continues to be a viable option for those contemplating a change in heating systems.