ALTERNATIVE ENERGY SOURCES – BIOGAS PRODUCTION

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INTRODUCTION

Rising energy prices and concerns about long term sustainability have once again brought renewable energy sources to the forefront

On Monday August 21st a group organized by the Ontario Large Herd Operators left from Toronto Airport bound for Amsterdam. The next seven days were spent travelling by bus through the Netherlands, Germany, and Denmark to study anaerobic digestion technology. The tour objective was to visit anaerobic digestion systems that demonstrated the following characteristics:

- The production of biogas at a variety of agricultural locations, with an emphasis on dairy farms
- Different inputs: manure, corn silage and other energy crops, food processing by-products, and household organic waste
- On-farm and community digesters: ownership, partnerships, manure transport
- Standardized design and companies with proven track-records
- Maintenance experience and down time
- The use or sharing of excess heat, including partnerships with greenhouses

The 32 participants were quite a diverse group, made up of dairy, beef, swine, vegetable and cash crop producers, research and extension people, waste haulers, industry people, plus a financial advisor, and a representative from Hydro One, and the Ontario Power Authority (Figure 1). Although a diverse group, they all had a common goal of seeing and learning as much as they could in seven short days. Or perhaps the group would say seven long days, as the tour started early every morning, and ended late every night.

Many hours where spent riding the bus, but each stop managed to give the group something new to talk about between Amsterdam in the Netherlands to Ribe, Denmark in the North and then back again. In all, the group visited 16 anaerobic digester installations, or biogas plants as they are more commonly referred to in Europe. Each stop was unique in some way either by the technology installed at the facility, or because of the goals that the owners were trying to achieve.

Figure 1. European biogas study group.

BASICS OF BIOGAS PRODUCTION

Biogas is a mixture of mainly methane gas (CH_4) and carbon dioxide gas (CO_2). Natural gas is about 90-95% methane, but biogas is about 50-65% methane. So biogas is basically low grade natural gas.

Biogas is produced when bacteria convert organic matter to methane gas. This process is similar to what takes place in the rumen of a cow, so we often hear biogas plants referred to as anaerobic digesters, or anaerobic fermenters.

Four ingredients are needed for biogas production:

1. Organic Matter
2. Bacteria
3. Anaerobic Conditions
4. Heat

Organic matter is the food source for methane producing bacteria. The primary organic matter source for farm-based biogas production is manure. Biogas can be produced using manure as the only organic source, but the gas production can be greatly increased by adding certain types of food wastes with the manure. Energy crops such as corn silage can also be added to increase gas production. The OMAFRA InfoSheet "Calculations and Information for Sizing Anaerobic Digestion Systems" contains a table with typical biogas outputs from various organic sources.

The second ingredient that is necessary for biogas production is bacteria. Bacteria are necessary to convert the fats, carbohydrates and proteins in the organic matter to simple acids such as acetic and propionic acid. Then, a second type of bacteria transform the acids to methane and carbon dioxide. This process takes place simultaneously. The bacteria are commonly present in manure, and under the right conditions they thrive and multiply.

Two conditions that are necessary for the bacteria are an anaerobic atmosphere (no oxygen) and the right temperature. Most digesters operate in the mesophylic range of 35-40^{o}C, but others are designed to operate in the thermophylic range of 50-60^{o}C, and a few are designed to operate at 15-25^{o}C or the psychrophylic range.

Biogas contains moisture and hydrogen sulphide, so before it is used in an engine the moisture must be condensed out, and the hydrogen sulphide removed to reduce maintenance problems. Biogas can be used directly to produce thermal energy, or it can be used to power a gas or diesel engine to run a generator to produce electrical energy.

POSITIVE REASONS FOR PRODUCING BIOGAS

Not only is biogas a fuel for producing green energy, but it has many other advantages both for the producer, and for society as a whole. Biogas production offers an alternate use for food by-products. Instead of food by-products taking up costly space at land fill sites, they can be used to further boost the biogas production from manure.

The fermentation of manure in biogas production greatly reduces the pathogen content of the manure. It also greatly reduces the odour of the manure, as in the end, all the volatile gases have been removed. The process also serves in homogenizing the manure, so that it is easier to agitate, pump, and spread.

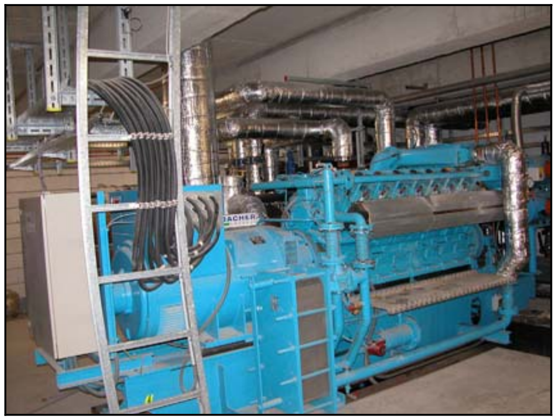
The other major spin-off advantage is rural economic development. The expansion of biogas production in Europe has resulted in expansion in all the related industries leading to the increase in jobs, and millions being poured into the rural economy.

THE EISSEN DAIRY

The first biogas plant visited in the Netherlands was the Eissen Dairy. It served as a good model of how a typical biogas plant operated. Manure from the dairy was pumped into an insulated above ground concrete manure tank. Hot water heating tubes wrapped around the tank kept the contents at about 40^{o}C. At this temperature anaerobic bacteria in the manure are quite active converting the organic matter in the manure into methane gas (CH_4), more commonly referred to as biogas. The biogas was collected off the top of the digester and used to fuel 2- Jenbacher diesel engines running a pair of 625 kW electrical generators. Heat from the engines was collected and used to heat the hot water to keep the digester warm (Figure 2).

Before the biogas could be used in the engines, the hydrogen sulphide and moisture were removed. A small amount of oxygen was added in the head space of the digester to combine with the hydrogen sulphide to produce a precipitate thus removing most of the hydrogen sulphide from the biogas. The biogas was then transferred to the engines underground, so most of the moisture would condense out of the gas.

Figure 2. Heat recovery from Genset.



The majority of biogas was removed directly in the anaerobic digester, but biogas continues to be produced even after the effluent was transferred to the long term storage, and started to cool. Therefore, this tank was also covered so the biogas could be collected and pumped to the engine.

The effluent in the long term storage was eventually applied on adjacent fields. Anaerobic digestion preserves the nutrient content of the manure, so that it can continue to be land applied as a fertilizer. Anaerobic digestion also greatly reduces the pathogen content of the manure, and greatly reduces the odour. This was most evident when the group visited the Futterkamp Research Station. While the group stood and viewed the digester, 50 ft away, the long term storage tank was being agitated and manure was being hauled to the fields. There was no smell, other than what was coming from the cows in the barn!

The group quickly learned that a variety of other ingredients were added to the digesters to increase the output of biogas. The most notable ingredient was corn silage (Figure 3). Many digesters used a modified TMR mixer to meter corn silage into the mix to increase the gas production. At one stop, a German engineer remarked that you had to "Love her like a cow", when referring to the digester. This helped the group to understand that you have to "feed" the digester very similar to how you would feed a cow. You need to concentrate on providing lots of energy feedstocks, and to make changes gradually when you introduce new feeds. The group also saw installations that were further processing the energy crops added to the digester to make the energy more available to the bacteria, in order to increase gas production. One company also added grain to the long term storage to try to keep the digestion process going after the effluent had left the main digester.

The biogas digesters which the group saw were basically of two types. The most common was the vertical totally mixed digester (Figure 4), while the group also saw several horizontal digesters (Figure 5). The horizontal digesters were usually used for feedstocks with higher dry matter content, like poultry litter. There did not seem to be a clear right or wrong, in terms of digester designs. The biogas companies would design the digester to meet the individual needs of the producer. The design would be based on feedstocks available, intended use for the biogas, alternate uses for heat, etc.

Figure 3. Feeding corn silage to the digester.

Figure 4. Vertical anaerobic digester.

Figure 5. Horizontal digester.

Table 1. Farm based biogas plants.

Biogas Plant	Company	Feedstock	Digester	BG Production m^3/day	Methane Content %	Genset kW	Energy Production kWh/day
Eissen Dairy	PlanET	50% hog manure 50% dairy manure corn silage	vertical		54%	2 X 625	20,000
Beeston	Lipp	75% hog manure 25% beef cattle ground corn	vertical	1680	52%	190 250	10,000
Spargelhof Querdl	Bio Energy	turkey manure corn silage	horizontal		52%	120 190	
Bioenergie Ahden	Biogas Nord	30% hog manure 70% food waste	vertical		65-70%	750	
Hohne	Archea	corn silage wheat in secondary	horizontal			500	
RWG Jameln	Biogas Nord	manure corn silage	vertical	7000	53%	250 300	
Agrarenergie Kaarben	BioConstruct	dairy manure corn silage	vertical	28800	51-52%	2 X 1416	
Hegndal	Skaaning	hog manure fish waste	vertical	3600		300	11500
Skovbaekgaard Diary	SKaard	dairy manure vegetable fats glycerine	vertical			625	8000
SNO	PlanET	dairy manure hog manure vegetables	vertical	1600		200	

Table 2. Community and co-operative biogas plants.

Biogas Plant	Company	Feedstock	Digester	BG Production m^3/day	Methane Content %	Genset kW	Energy Production kWh/day
Bio Energie Haestal	Schmack	manure corn silage	horizontal & vertical	10000	52-55%	10 X 80	19200
Wertle	Krieg & Fischer	60% manure 40% food waste	vertical	25000	60-65%	2 X 1250	10,000
Ribe	Kruger	manure food waste	vertical	13150		2 X 1000	
Juhnde Village	Haas Anlagenbau	dairy manure corn silage ground corn	vertical	7800	50-52%	700	

Table 3. Other biogas plants.

Biogas Plant	Company	Feedstock	Digester	BG Production m^3/day	Methane Content %	Genset kW	Energy Production kWh/day
Futterkamp Research Station	Envitec	dairy manure corn silage	vertical			330	
Nij Bosma Zathe	Krieg & Fischer	dairy manure silage crops food wastes	plug flow		up to 75%	37	

CATEGORIES OF BIOGAS PLANTS

The biogas plants studied were in one of two categories. The first was farm based plants (Table 1), and the other was community based, or co-operative plants (Table 2). The farm based plants were located on farm, but some were solely operated by the farm owner, while others involved partnerships between two or three farm owners. Others were located at the farm site, but were owned and operated by companies separate from the farm. The community and co-operative sites were large commercial sites collecting manure from as many as 200 farms, digesting it, and then returning it to the farms to be land applied. Two research station plants were also visited (Table 3).

INNOVATIVE USES FOR HEAT AND ELECTRICITY

The group saw several creative uses for the additional heat captured from the engine-generator sets or gensets. Most biogas plants were using excess heat to heat hot water for the barn or house, but three of the biogas plants were actually selling the heat for use by others. One plant in particular was using the excess heat to provide hot water heating to a nearby airport, and two others were supplying a portion of home heating requirements in adjacent villages, such as Jühnde.

Jühnde is a small German village where all the energy to the village is supplied by the adjacent biogas plant. The plant supplies the electricity from the diesel engines operating on biogas running generators, and then excess heat from the engines is used to heat hot water which is supplied to the villagers for water and heating needs. In the winter when excess heat from the gensets is not enough to provide the homes with heat, extra boilers are fired with wood chips. Plans are currently under way to dry the wood chips with extra heat that is available in the warm summer months.

Another unique stop was to a "gas" station that offered its customers the option of filling up with biogas (Figure 6). The biogas supplied to the gas station was produced at a nearby plant similar to the others, but it had an extensive refining process to concentrate the gas to a level that could be used in natural gas powered vehicles.

Most of the biogas plants visited with the tour had multiple partners. Having multiple partners allowed different feedstocks to be brought together for processing. For instance the group saw several plants where the manure from cattle and hogs was mixed into the same digester. As well different food by-products were also added at several sites. Co-operatives ranged in size from two to three farmers up to one large plant that managed the manure from 300 farms in a 50 km radius from the plant. 20 tanker trucks were used to pick up the manure at the farms and transport it for processing at the centralized biogas plant. After processing the treated manure would be stored in tanks in the area for land application, or spread directly onto fields depending on availability. Not all biogas plants are large scale. If the group could have travelled south to Switzerland, Austria, and southern Germany, biogas plants that were individually owned and operated would have been more evident.

Figure 6. Biogas station.

WHY DOES IT WORK IN EUROPE?

The group also had several opportunities to visit with technology suppliers, and leaders in the biogas industry. One leader from the German Biogas Association noted that, in Germany, direct benefits from the biogas sector included:

1. 650 MW of installed electrical capacity
2. A reduction of 4 million tonnes/yr of CO_2 emissions
3. $960 million spent in construction in 2005
4. Revenues of $500 million to farmers from electricity sales each year

He also noted that the anaerobic digestion/biogas sector in NW Europe is a mature industrial sector with over 200 businesses (8000 employees) offering services to farm-based, cooperative, and industrial biogas facilities. The vast majority of biogas facilities are farm-based systems.

WILL IT WORK HERE?

The European farms visited were similar in many ways to what the producers had at home. So why don't we have a proliferation of biogas plants here in Ontario? There are two main factors that have made biogas generation in Europe wide-spread:

1. European governments have made a commitment to have electricity prices that reflect the cost of producing renewable power. (Table 4)
2. Guaranteed access to the electricity grid with few restrictions or fees.

European governments have made a commitment to have electricity prices that reflect the cost of producing renewable power from different technology systems (biogas, wind, etc), and specifically for biogas systems using different inputs (manure, energy crops, food-based inputs), and with different scales (higher prices for smaller systems). A bonus is also given for making use of the extra heat generated.

Table 4. European energy pricing.

Average Power	Guaranteed Feed-in Tariff CAD¢ / kWh			
	Base Price (2006)	Bonus for Using Ag Inputs	Bonus for Heat Usage	Total Price (2006)
0 – 150 kW	17	+ 9.1	+ 3	29.1
150 - 500 kW	14.6	+ 9.1	+ 3	26.7
500 – 5,000 kW	13.1	+ 9.1	+ 3	25.2
> 5.000	12.5	+ 9.1	+ 3	24.6

At present electrical prices in Ontario offered to farmers producing electricity from biogas are not sufficient in most cases to make biogas production economically feasible. The Standard Offer Contract (SOC) program announced last March is one step in the right direction to having a biogas industry in Ontario. Hopefully this can be improved in the future to provide incentives to increase production of biogas by using energy crops in the mix, and to use excess heat recovered from the generator engines. Let us not forget that anaerobic digestion also greatly reduces the pathogen content of the manure, and greatly reduces the odour for the benefit of society. Anaerobic digestion also gives an opportunity to use food by-products that are presently going to landfill sites.

The technology used by the biogas plants that the group visited in Europe, would apply in Ontario as well. Many companies there are looking to partner with companies here, so if the electricity price paid for biogas improves, the technology is ready to go.

Biogas production in the future could provide farmers with an additional source of income, while providing society with an alternative use for food by-products, and reduced pathogens, and odours from manure, not to mention the tremendous potential for rural economic development. The potential exists for a "win-win" situation.

INFORMATION SOURCES

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