Introduction
Dairy manure is well-suited for anaerobic digestion, having a relatively high dry matter content of about 12%. A dry matter content of 6 to 14% is considered the best range for digestion. Currently there are two AD systems operating on dairy farms in Ontario, one of which is operated by brothers Paul and Fritz Klaesi, located near Cobden, Ontario.

Anaerobic digestion (AD) is used in agricultural, municipal and industrial systems to treat organic materials. The process typically holds the material in an oxygen free environment for a 2 to 20 day period at a temperature of 30 °C to 60 °C. At this temperature and in the absence of oxygen, microorganisms break down the organic materials to produce biogas, consisting primarily of methane and carbon dioxide.

Depending on the system design, the biogas can be combusted to run a generator producing electricity and heat, or it can be burned as a fuel in a boiler or other burner. In addition, the following advantages are usually found with AD systems:
- reduced odour and pathogen levels in the manure
- production of energy usually in the form of heat and electricity
- reduced greenhouse gas production from the farmstead, and
- improved fertilizer value of the manure through homogenization and mineralization.

Several anaerobic digesters were constructed in Ontario in the 1980’s, but were abandoned due to mechanical difficulties and limited payback. Since this time, anaerobic digestion technology and farm needs have changed.
Fepro Farms – Klaesi Brothers, Cobden, Ontario
Paul and his brother Fritz immigrated with their families from Switzerland to Canada in the spring of 1990. In Switzerland they had both farmed together, with Fritz being the farm manager and Paul working at Zurich Hydro as well as helping on the farm. After looking at many farms in Ontario and elsewhere, they chose a dairy farm near Cobden north of Ottawa. It was purchased as a working dairy farm with 68 cows being milked in a tie stall operation and 500 acres of available cropland.

Since then the Klaesis have expanded their dairy herd to 142 cows milking in a tie stall barn. In 1995 they added a 110’ dia x 12’ deep circular concrete manure storage to replace a solid storage and associated manure runoff challenge.

The Klaesi Brothers had always been interested in anaerobic digestion, and were familiar with the technology while in Switzerland. Over the years they had kept in touch with what was going on there. In 2001 they became more serious about the possibility of constructing an anaerobic digester on their farm. They saw an ad for an AD design manual in a Swiss farm newspaper, and purchased a copy.

They decided that it was not possible to build a typical digester design on their farm because they had no room to put it. They came up with the idea of building it inside their manure storage, and after consultation with the Swiss consultant who had written the design manual, became convinced that it could be done.

**Digester Design and Construction**
The Klaesis started construction in the summer of 2002 by forming the walls of the digester inside the manure storage, resulting in a digester that is roughly oval shaped. The wall was formed using an insulated sandwich wall system consisting of a 10” reinforced concrete core with 2 ½” of Styrofoam insulation on either side (Figure 1). The Styrofoam had to be sprayed with a thin layer of polyurethane foam to allow for the application of an acid resistant coating. The digester was designed with a capacity of 18,000 ft³ (500 m³).
A floor of loose fitting wooden boards covered with loose fitting insulation separates the digester portion from the gas storage. The gas storage portion of the digester is covered with an EPDM membrane. EPDM is a synthetic rubber polymer that is often used in pond covers. It is UV resistant, and very elastic. The membrane is sealed to the digester walls by means of a slot formed in the top of the wall, which in turn is sealed with an inflated tube. Two standard electric manure agitators are placed at either end of the digester for mixing (Figure 2).

Most of the work in building the digester was done by the Klaesi brothers, with their families and various sub-contractors. The digester was finished in February of 2003, and received hydro inspection approval in March. Biogas production began in the summer.

**Figure 2**  
Finished digester - expansion of storage dome indicates amount of gas production

**Loading the Digester with Manure**

Manure is transferred from the barn to the digester twice daily. Manure is collected from the 142 cow tie stall barn with a gutter cleaner that drops the manure into a 3’ dia. gravity flow pipe. A slatted floor heifer barn also feeds manure to the system at the top end. Milking centre wash water is pumped to the heifer barn to dilute the heifer manure and also enters the system.

Manure enters the digester through the gravity flow pipe into a 10’ dia x 10’ high insulated cylinder. This allows the manure to warm up before it spills over the top, mixing with the rest of the digester manure. About 500-700 ft³ (15-20 m³) of manure enter the digester per day, resulting in a retention time of about 25 to 35 days. The agitators operate 5x/day for about 10 minutes at a time.
Manure from an open front heifer barn can also be added to the digester through a lid in the digester. The lid has a gas tight seal. The agitator next to the opening can be turned to mix the manure as it is added. Heifer manure is not added to the digester during the winter months when it is cold or frozen.

**Production of Biogas**

Biogas production has been very uniform (Figure 3). The digester holds the manure an average of 30 days at a temperature of 40 °C (104 °F), producing about 15,000 ft³ (425 m³) of biogas per day. Production and pressure are checked twice daily. The expansion of the dome also provides a visual check (Figure 2).

![Electricity and Biogas Production](image)

**Figure 3**

Graph of biogas production and electricity generated

**Flow of Manure from Digester to Storage**

Manure exits the digester through gravity as well. An 18” dia. plastic pipe siphons the manure from about 2 to 3 feet below the top surface to the entrance cylinder into the digester. The exit pipe loops through the entrance cylinder to help warm up the fresh manure before it exits from the digester.

Currently nutrient testing has not been done on the digested manure. Nutrient testing will be done in a future monitoring project. The Klaesis used to take one day to agitate the
manure pit before spreading. Now they don’t agitate at all. The manure “falls apart” as the organic matter has been digested. The Klaesis also note that there is much less odour produced during pumping and spreading.

Collection and Transfer of Biogas from Digester to Engine
Biogas is collected in the gas storage portion of the digester through a 3” dia. PVC pipe. The pipe exits the digester and runs underground with a slope back to a “T” connection in a sump. In the sump any moisture from the gas drains after condensing underground. The pipe then slopes up towards the generator room, so that any additional moisture can condense and then run backwards to the sump as well.

Biogas also has a high concentration of hydrogen sulphide (2000 to 3000 ppm). Sulphur causes corrosion in the combustion chambers of the engine and the level must be reduced to about 200 ppm before the biogas enters the engine. Oxygen is added to the gas and chemically reacts with the sulphur and falkes out as a precipitate. It is important to maintain the correct oxygen to biogas ratio or an explosive mixture could occur. The biogas to oxygen ratio must be maintained at 10%. This biological approach takes approximately 24 hours to initiate. Initial gas flows from a digester should not be burned in the engine or oil changes should be done more frequently at startup to avoid engine damage due to the high initial H₂S levels.

It is also important to ensure that too much pressure does not build up in the gas storage portion of the digester. There are three safeguards to release gas if the pressure becomes too high:
1. A pressure sensitive switch will turn on the generator engine automatically
2. A rope over dome is connected to a release valve. If the dome gets too big, the rope pulls the release valve.
3. There is also a pressure sensitive release valve. If the gas pressure gets too high one inch of liquid is blown out of the valve and gas escapes.

Operation of Engine and Generator
The generator engine is a 100 Hp Perkins diesel engine capable of generating 65 kW of electricity (Figure 4). It is a bi-fuel motor capable of running on either diesel or biogas. It was specifically designed to run on biogas generated from landfill sites. The chamber shape was modified to spray more fuel on the inside of the chamber for a better burn.

The engine is set to turn on by a time clock, so that electricity is generated at the peak need times during chores and milking. It turns on at 5:30 am and again at 5:15 pm as well as for a couple of hours in the afternoon. In total, the generator runs for about 12 hours per day. Once or twice per day the gas storage is completely emptied.

The engine starts and warms up on 100% diesel fuel. During this time the generator is producing 6 kW-hr of electricity and the engine is using 5 litres per hour (1.4 US gph) of diesel fuel. When the generator is synchronized with the electrical power grid an automatic controller connects to the grid. After the generator is connected to the power
grid, the computer controlled gas valve starts to introduce biogas so that the generator is producing 50 kW-hr with 6 kW-hr coming from diesel fuel (5 l/hr), and 44 kW-hr from biogas. After running this way for 5 minutes the mixture is automatically switched to 1.5 to 2 l/hr of diesel fuel with the remainder being biogas. The engine typically runs at 1.7 l/hr of diesel fuel, but the mixture has to change depending on the quality of biogas. The Klaesis can tell how good the quality of biogas is by how the engine sounds.

The engine is maintained much the same as a tractor engine would be. The oil is changed every 600 hours of operation. A second oil filter is changed every 300 hours. The injectors were changed after 1000 hours of operation and still looked fine. The injectors must spray and not drip at all.

Paul Klaesi does a daily operating inspection, where he checks diesel fuel consumption, biogas consumption, electricity output etc. Release valves and the membrane seal is checked, as well as the air pump for hydrogen sulphide removal. The whole process takes about 5 to 10 minutes.

**Generation of Heat**

The generator engine produces about 300,000 BTU/hr (88 kW) of heat. Heat is collected from the generator engine through a heat exchanger that links to three other heat exchangers with one collecting the heat off of the engine, and the two others collecting heat off of the exhaust system.

Heat is transferred to the digester through 1 ½ miles of ½” dia. poly floor heating pipe. Fifty loops of heating tube are fastened to the walls of the digester. If a loop ever develops a leak it can be isolated from the rest.

The operating temperature of the digester is between 35 °C to 42 °C (95 °F to 108 °F). Heat from the generator engine is used to keep the temperature at between 38 and 39 °C (100-102 °F).

The Klaesis are able to reclaim about 48% of the biogas energy in the form of heat, 36% as electricity, while the remainder is lost. In the summertime about 70% of the heat goes
to keep the digester at operating temperature while 30% is exhausted. In the wintertime about 80% of the heat goes to the digester while about 20% is used as heat for the two farmhouses.

Heat is transferred to the farmhouses through an outdoor furnace. The generator engine provides enough heat until the outside temperature falls below –4 to –5 °C (23 to 25°F). Below this temperature wood has to be added to the outdoor furnace to heat the houses.

The Klaesi have recently built a 2480 ft³ (70 m³) insulated hot water tank that they can divert heat to when heat is not needed for heating the houses.

Heat from the generator room is blown to an adjacent workshop through an underground 12" dia. pipe using a furnace blower. Excess heat from the generator building is removed by means of a fan and shutter system.

**Generation of Electricity**

The Klaesi anaerobic digester has generated an average of 450 kW-hr of electricity per day (Figure 3). As mentioned before the generator is designed to run during peak usage at the farm. In the summer the Klaesi use about 550 kW-hr/day and in the winter they use about 480 kW-hr/day.

The Klaesi have a “net metering” agreement with Hydro One, Ontario's major generating company. Under the net metering agreement the Klaesi are limited to producing 50 kW of power. Net metering measures the energy used against the energy generated, resulting in a "net" energy total from which their bill is calculated. Under net metering agreements, excess generation cannot be carried forward beyond the meter reading and billing period. Hydro One will not pay for excess generation. The Klaesi purchased a special hydro meter which shows what is produced on the farm compared to what is used. Net metering is suitable for customers wishing to reduce their energy costs by producing their own electricity and, in effect, selling it back to Hydro One.

**Costs / Benefits**

The Klaesi anaerobic digester cost approximately $180,000 (Cad) plus labour inputs from the Klaesi. The power and control system was purchased from Switzerland for approximately $110,000. With the digester generating 450-550 kWh per day and a replacement electricity rate of 12 cent per kWh the digester produces $20000 of electricity per year, resulting in a 10 year payback on electricity savings.

The Klaesi produce about 60% of the hot water and about 70% of the heat for the two houses. They also hope to see some cost reduction in herbicide costs as the digestion process kills weed seeds. Manure odours and pathogens are also reduced, but at this time it is difficult to estimate the value of these reductions and the improved fertilizer value of manure.
Research and Monitoring
Currently there is a research project beginning to monitor the manure input and digester output to measure nutrient contents before and after digestion, as well as pathogen contents before and after digestion.

Another phase of the research project will be to investigate what materials are available locally that could be added to the digester to increase biogas production. This phase will investigate what legal hurdles there may be to accepting off-farm wastes at the farm, as well as what facilities and equipment are necessary to store the wastes at the farm and introduce them into the digester.

If it is decided that suitable materials are available, the next phase will be to begin construction on a system to accept materials at the farm, and introduce them into the digester.

At present there is no incentive to produce more power because of the net metering agreement with Hydro One. It is hoped that in the future there will be an opportunity to sell power to Hydro One at a rate that will be worthwhile for the producer.

Summary
A simple low-cost anaerobic digester is operating at the farm of Paul and Fritz Klaesi, near Cobden, Ontario. The digester has a capacity of 18,000 ft³ (500 m³), and is producing about 15,000 ft³ (425 m³) of biogas per day. The biogas is used to generate heat and electricity that is used on the Klaesi farm. Approximately 450 kW-hr of electrical energy is produced per day.

A future research and monitoring project will monitor nutrient content and pathogen reduction of the manure flowing through the digester. The project will also investigate the feasibility of adding off-farm wastes to the digester to increase biogas production.

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