Small Digester Case Study – Bakerview EcoDairy, Abbotsford, BC

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Farm overview

Bakerview EcoDairy (Bakerview), located on the edge of an urban area near Abbotsford, British Columbia, is owned and operated by Bill Vanderkooi. The farm is both a fully functioning dairy operation and a demonstration farm which showcases the latest advancements in dairy industry technology. Visitors who tour the operation can learn about the history of dairy farming and the farm's efforts to be sustainable and eco-responsible. Examples include a robotic milker, a free stall barn, a green roof with rain water collection, naturally ventilated buildings, induction lighting, and of course the anaerobic digester. Currently, the dairy herd consists of 44 milk cows plus some young stock.

Anaerobic digestion system overview

The digester (model AnD 1B22) is a mixed plug flow anaerobic digester designed and installed by Avatar Energy LLC. According to their website, "AVATAR Energy is a renewable energy company dedicated to increasing profitability and sustainability of agriculture, capturing renewable energy, and protecting the environment. Founded in 2005, the company has developed the world's first scalable anaerobic digester to employ a tubular, modular design platform, geared particularly to small and mid-sized farms of 100 to 1000 cows."

Construction on the Bakerview system began in November of 2010 and was completed in January of 2011. Biogas production was first documented in April/May of 2011. The digester was assembled in an existing calf barn that was retrofitted to house the new system. For this project Avatar provided the system design, major components and oversaw assembly of the system. Bakerview was responsible for securing construction equipment and site modifications. Avatar has provided ongoing support with the system.

Avatar installed a single barrel digester at Bakerview, measuring 8' in diameter and 80' in length, with an operational volume of 22,500 gallons. Based on a 21 day hydraulic retention time, the average daily loading is 1,050 gallons. The hull of the barrel is constructed of fiberglass covered in insulation. System sizing was based on 50 cows; however the farm is currently at 44 milk cows. Only manure from the milk cows is introduced into the digester. A co-feedstock, whey permeate, is fed to the digester at a loading rate of 5 to 20% by mass. The range of co-feedstock addition is largely due to daily fluctuations in permeate production/availability. Normal operating temperature is in the mesophilic range of 95 to 105^{o}F, with the manure feedstock preheated to the operating temperature before entering the system.

Sawdust is the current bedding used at the dairy, though they did experiment with separated manure solids bedding.

Why the digester?

This digester was installed as a demonstration unit for small dairies. In addition, it was anticipated that the digester would also generate excess power for sale or use on the dairy, reduce odors and generate manure solids for bedding. To improve manure management, the farm was also interested in separating nutrients in the digestate, creating high nutrient concentration solids/sludge and low nutrient effluent.

Anaerobic digestion system

Following is a description of the system from inflow of feedstocks to outflow of digestate:

- **Manure collection and preheating:** Manure is automatically scraped from the freestall barn into a reception pit where it is agitated into a homogenous mix. A piston pump in the reception tank is used transfer manure into the preheat tank. The reception tank is a rectangular shaped, below ground concrete vessel. In the preheat tank, manure is heated to between 95 and 105^{o}F using hot water from the combined heat and power (CHP) unit. Manure is not macerated in the reception pit.
- **Digester vessel:** The digester is an insulated, ½" thick fiberglass tank that measures 8 feet in diameter and 80 feet in length. The tank is covered in 3 to 4" of spray on foam insulation to aid in maintaining temperature. Manure is pumped into the "feed" end of the digester using a positive displacement plunger system which feeds the system on the down stroke and refills the feed chamber with preheated feedstock on the up stroke.
- **Mixing and heating:** Feedstock is preheated in a 350 gallon preheat batch chamber. Hot water from the CHP unit and a natural gas boiler is used to supply the heat. Feedstock is preheated to a range of 95 to 105^{o}F before being fed into the digester. A water filled heating loop between the hull of the digester and the insulation provides supplemental heat. Mixing in the digester is achieved using biogas recirculation.
- **Biogas collection:** Biogas is collected and stored in the headspace at the top of the hull. Given the lack of flexible storage, biogas is consumed by the CHP or flare as it is produced.
- **Biogas treatment:** The system is equipped with a hydrogen sulfide removal system, which consist of iron fillings in a sealed canister between the digester and the CHP.
- **Biogas production:** Biogas volume and pressure is monitored by a Sage flow meter and logged daily as a key metric in gas production and the 'health' of the digester. The design biogas flow rate was 8 standard cubic feet per minute (SCFM). Typically, the system produces on average 3.5 SCFM of biogas.
- **Solids separation:** Solids separation equipment is housed adjacent to the digester. A PT&M screw press removes coarse solids from the digestate. Originally, a vibratory screen separator provided by PT&M was used to remove finer solids before the digestate entered a trickling filter for nitrogen removal. In recent months, both the vibratory screen and trickling filter have been taken off line. Fiber separated by the screw press was used as bedding for a period; however the farm has since resumed using wood sawdust shavings as bedding. High somatic cell count was the primary reason

for abandoning the fiber bedding. Currently, filtrate is stored onsite in a long-term manure storage until it is land applied. Separated solids are land applied or sold.

- **Biogas use:** The primary use for the biogas is electricity production. Excess biogas is flared off. An I-Power 20 kW genset, CHP, produces both heat and power. Generally, the system produces about 12 kW per hour based on a 14 hour per day runtime (60%). Due to a lack of monitoring equipment, the quantity of heat recovered was not recorded.

Economics

The total cost of the project was estimated to be $600,000. However, because improvements are still ongoing, an accurate total system cost is difficult to determine at this time. The farm owner contributed approximately $200,000 toward the project. Additional funding support was provided by the Canadian Ministry of Agriculture through the Environmental Farm Plan, BC Biogas Network, ArdCorp, and BC Hydro. It was not clear what dollar amount each partner contributed to the project. Table 1 presents a construction cost summary as of February, 2012.

Table 1: Bakerview EcoDairy Anaerobic Digester Construction Cost (as of February, 2012)

Description	Contractor	Project Budget	Actual Cost
Separator installation	Pacific Dairy	$40,725	$40,725
Facility improvement	Curtis & Co.	$35,000	$36,904
Reception pit	Curtis & Co.	$15,000	$15,000
Pump & mixer (Houle)	Pacific Dairy	$31,767	$31,767
Excavation	Marpaul/Stromeir	$30,000	$30,000
Electrical	Dopenberg Electric	$10,000	$10,000
Anaerobic digester	Avatar Energy	$369,700	$369,700
Contingency		$10,000	$10,000
Totals		**$542,192**	**$544,096**

Testing

The key process parameters that are measured at the digester include biogas production, temperature, total and volatile solids, and pH. On a regular basis, the system operator will collect samples for analysis. The sampling schedule is co-developed with input from the operator and Avatar. Samples are occasionally sent off-site for additional testing including nutrient composition.

A Bacharach Fyrite Gas Analyser was used to measure the ratio of carbon dioxide to methane to assess biogas quality. The target quality for the gas is between 60 to 65% methane. Biogas analysis is not part of the regular operating protocol.

Operational requirements

The required time commitment by farm staff for specific activities is as follows:

- Daily operation: 15 minutes per day when the system is working properly
- Process monitoring - 0 hours/day
- Routine system maintenance - included in daily operation

- Repairs to the digester system - hours to days depending on the severity of the repair and availability of parts

Avatar has continued to support the project and is responsible for all operation decisions. Ongoing operational challenges had made it difficult to assess long-term operational requirements, as the system has yet to operate as a stable system for any length of time (>6 months). Key operation challenges have been related to the interconnection (harmonizing power), combined heat and power unit, digester mixing and solid liquid separator.

Financial

The following summarizes key financial indicators of the project:

Revenue:

a. Annual revenue from electrical generation - $4,680 based on $0.12 per kWh and assuming the system produces 39,000 kWh per year (only measured for 138 days in 2012)
b. Annual revenue from "avoided cost" of purchasing fossil fuels for heating – $0 (no fossil fuel avoided)
c. Annual revenue from "Other" sources
    - Avoided cost of bedding - $4,800. However, the fiber is no longer being used as bedding, so the avoided cost is no longer applicable as the farm is again buying sawdust.
    - Avoided cost of fertilizer– $0. The fertilizer value of the digestate is more or less the same as raw manure, so the farm has not experienced any fertilizer savings. The co-feedstock may add some value, but as of this time that value has not been quantified.

Expenses:

a. Co-feedstocks – Bakerview pays $40 for 1,000 L of whey permeate, or about $1,500 per year when used at 10% by mass
b. Operation & maintenance – $4,500 (budgeted, real cost still to be determined)

Net annual cash flow: $3,480**,** based on the period of June 1, 2011 to December 1, 2012 when electrical production was metered and fiber was used as bedding.

Reported problems/Failures in specific areas

Below are problems or failures experienced by the farm in five specific categories:

1) Site planning and design

    - **Gas Production issues:** The system was designed with the expectation that it would produce biogas continuously at a rate of 4.5 standard cubic feet per minute (SCFM) based on loading manure from 50 dairy cows. Given the that farm is actually maintaining a herd of only 44 cows, the owner still anticipates that a biogas flow rate of 4 SCFM should be achieved based on guarantees made by the technology provider. Actual system performance is averaging below 3 SCFM. It is believed that the low biogas production is mainly attributed to mechanical issues.

Power generation was most stable for a period of 138 days in 2012. During that period, the generator produced 14,754 kilowatts after the parasitic load was deducted. During the period, the system generated approximately 107 kWh per day, equivalent to 39,023 kWh per year.

Design plans indicated that the CHP required a continuous flow of 8 SCFM of biogas to run the CHP 24 hours a day at 20kW. This assumed the methane concentration of the biogas was in the range of 60-65%. The CHP was expected to run 85% of the time, but based on the period of June 1, 2011 to December 1, 2012, the system ran only 42% of the time. During this period, the system produced an average of 13.2 kWh. At times during this period the CHP was run on natural gas to provide heat for the digester. Electrical production data produced during this 6 month period was based on a temporary meter installed by BC Hydro to monitor energy production. The meter was only in place during this period.

2) Engineering

- **Digester mixing issues:** The original mixing system did not provide sufficient mixing and significant solids accumulated in the system. In December of 2011, Avatar drained the system and installed a new more efficient mixing system which operates automatically instead of manually and externally. The digester was back online in mid-January of 2012. The new automatic mixing system takes biogas from the gas bubble, pressurizes it through a gas blower, and injects it into the bottom of the digester through 400 injectors. The system has been operating well since the installation.
- **Effluent separation system issues:** The solid liquid and nitrogen removal system installed to treat the digestate was "experimental" and never performed consistently. Originally, the separation system produced two solid products, bedding from the screw press and a semi-solid from the vibratory screen. Producing two solids products was cumbersome, in addition the overall process and fluid flow was too complicated for the size of the dairy. Plumbing, piping and float controls were modified in 2012. At the same time the vibratory screen was bypassed. Since the modifications were completed the screw press separator has performed well.
- **Bedding changes:** The farm has elected to resume the use of sawdust shavings bedding. Since the farm has shifted back to shavings, the diaphragm pump feeding the separator has experienced regular clogging issues. The farm is planning to switch to a finer wood shavings bedding to alleviate clogging issues. Since the process was changed in late 2012, the system has been working well since the retrofit, removing all of the solids from the manure.

3) Construction and equipment

- **Construction delays:** The start of construction began 6 months late, due to delays with the digester hull construction and shipping. Once onsite, construction was delayed approximately

3 more months due to delays with the shipment of separator and CHP components as well as the fabrication of stands and supports for the digester tail and tanks.

- **Miscellaneous equipment issues:** Due to the limited experience of the digester company, some of the equipment selected for the project was not properly suited for the high solids content of manure or the environment. Equipment challenges experienced during the first two years of operation include:
  - Heat tank overflow line installation
  - Heat tank fill sensor replacements (the original sensors would clog with fibrous manure)
  - Hot water pump replacements
  - Surge protector installation
  - Frost protection for exterior manure handling equipment
  - Generator engine starter replacement
  - Generator engine sparkplug, spark wires, rotor and distributor cap replacement
  - Generator engine muffler replacement (rusted out)
  - Minor spill cleanups (tank overflows, hose failures, sensor failures, etc.)
  - Screw press rebuilt several times because of faulty calibration

4) Biogas utilization and systems

- **Combined heat and power automatic shutdown:** The combined heat and power unit supplied by I-Power was not properly configured to interconnect with the local utility. A number of things were done to address the problem. Avatar recommended installing surge filters to address line surges or stray voltage that may have caused the CHP to shut down. BC Hydro conducted a study to assess power quality and determined that the CHP unit was within the acceptable range of 600 volts +/-10%. Finally, a consultant was brought in to further investigation the issue. In the spring of 2013, the consultant determined that the internal amperage controller on the CHP had never worked. Replacement of the amperage control resolved the CHP issues.
- **High hydrogen sulfide level in biogas:** Due to the high hydrogen sulfide levels in the biogas, the CHP unit experience premature deterioration. Most notably was the exhaust muffler which rusted out in less than 2 years (1 year of full time operation).

5) System control and operation monitoring and control

- **Co-feedstock issue:** Originally, the farm was using milk fat solids as a co-feedstock/off farm substrate. However, while the milk fat was being used, gas production was erratic, did not consistently produce expected biogas increases and on a couple occasions resulted in complete loss of biogas production. While it is unproven, it is believed that sanitation water from the processing plant may have been mixed with the solids, creating a toxic feedstock. Since the farm has switched to the whey permeate, biogas production has been stable and responds normally to permeate feeding events.

Lessons learned

- Keep the system as simple as possible. Minimize moving parts and combine processes as much as possible (eliminate preheat tank). Ideally this will result in a system with lower capital and operational costs.
- Hire companies based on their expertise. Roles and responsibilities of the project should be divided up based on the technology providers experience area. One company may not be available/or responsible for providing a complete turnkey system.
- Be careful with assumptions. Often times assumptions are made, however they should be based on sound scientific principals and operational experience from similar systems. Failure to make accurate assumptions can result in poor performance, extended system down time or catastrophic failures which will negatively impact overall project success.

Sources

- Personal interview by author with Peter Torenvliet, Bakerview EcoDairy.
- Vanderkooi, B. 2013. Project report: Bakerview EcoDairy On-farm Anaerobic Digestion; CHP (load displacement) project.

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