Small Digester Case Study – Joneslan Farm, Hyde Park, Vermont

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Farm overview

Joneslan Farm is owned and operated by Brian and Steve Jones. It is a fifth generation family farm near Hyde Park, VT. The farm grows grass hay and corn over 400 acres. There are 300 head of milk cows, about 45-50 dry cows, and 50 calves under 3 months old. In 2007, the farm was recognized as a Vermont Dairy of Distinction. This award recognizes farms that maintain a well-kept farmstead.

Anaerobic digestion system overview

The digester is a complete mix digester installed underground. It was designed and built by UEM Inc. (1818 S. Australian Avenue, Suite 110, West Palm Beach, FL 33409). UEM supplies turnkey digester plants, which includes design and engineering, all the equipment and controls (including the Combined Heat and Power (CHP) system), and utility interconnection. UEM has been developing standardized designs that make it possible for smaller farms to afford their own digester. These designs are ready to be installed, easier to install, and less customized.

For this project UEM hired a local excavation company, a local concrete contractor, and a local electrical contractor to build the digester as per UEM's design and specifications. Joneslan Farm owns and operates the digester. UEM provides technical assistance as needed.

The digester measures 16 feet by 72 feet in diameter at the top and holds 240,000 gallons of feedstock. The 72-foot diameter cover is a single prefabricated insulated sheet. The digester is sized for 230 cows; however, the herd has increased in size to 350 head (as of August 2013). Rumensin® is used but only minimally in one group. The designed loading rate is 6,000 gallons/day with a retention time of 40 days. The digester operates at 100˚F.

The milking herd was bedded with sawdust before the digester was built but now the milking herd is bedded exclusively with digester fiber. Using organic bedding has not increased somatic cell counts or incidence of environmental mastitis.

The digester does not receive any feedstocks other than manure from the farm.

Power officially went on the grid August 14, 2012. Getting consistent monitoring data has been difficult due to genset down time.

Why the digester?

The reasons for installing the digester were to reduce the farm's electricity bill, reduce bedding costs, control odors, and gain the benefit of hot water for use in the milk house. Water heated by the genset reaches a temperature of 160˚F. Eventually the hot water will be used to heat a nearby home.

Anaerobic Digestion System

The actual volatile solids destruction rate has not been measured yet, but it is expected to be between 50 and 60 percent. UEM designed the digester to have a high hydraulic retention time in order to achieve a high volatile solids destruction rate.

Following is a description and diagram (Figures 1 and 4) of the system from inflow of feedstocks to outflow of digestate.

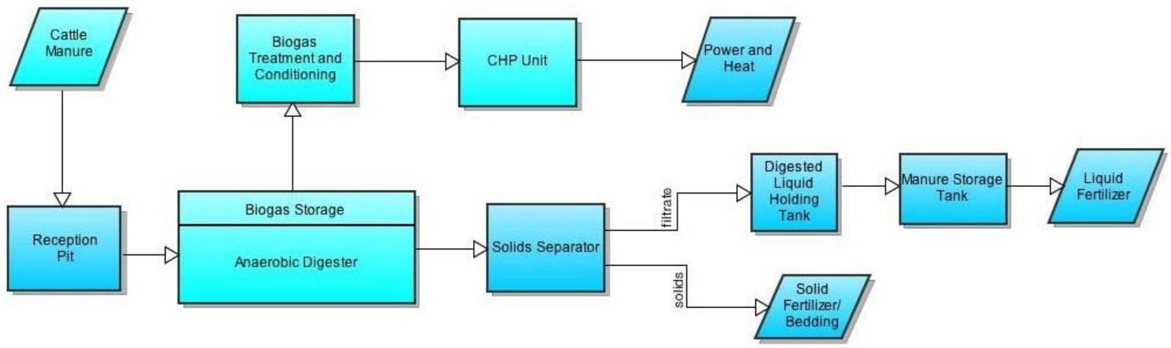

Figure 1. Components of the Joneslan Farm digester. (Used with permission from UEM, Inc.)

- **Manure collection and preheating:** Manure is scraped from the barn into a reception pit where it is agitated into a homogenous mix and pumped 360 feet through an eight inch pipe to the digester. The reception pit is a 15 feet by 30 feet by 14 inches thick egg-shaped structure. Manure in the reception pit will be preheated to approximately 100˚F starting in winter 2013. Manure is not macerated in the reception pit.
- **Digester vessel:** The digester is an insulated geomembrane tank in a truncated cone shape that measures 16 feet deep in the middle by 72 feet in diameter at the top. An earthen pit was dug with a 1:1 slope that tapered down to a flat bottom. A 32 foot in diameter concrete pad was poured at the bottom of the pit. The pit was lined with a heavy geotextile fabric and then overlaid with a 60 mil plastic material with insulation welded to it. Four inches of insulation, starting at the lip of the hole, covers the first 8-foot depth and 2 inches of insulation covers the remaining 8 feet. Once both liners were installed correctly they were hitched together and all pipe holes sealed. A 12 foot by 12 foot precast concrete pad was set at the bottom of the pit on top of the liner as a base for the heat exchanger and agitator units to sit on. Pouches were welded onto the digester cover and filled with four inches of insulation. All liner materials were designed by UEM and either fabricated in a workshop or on site. The liners and the cover were bolted together in a stainless steel ring around the perimeter of the digester to create an airtight seal. Everything in the digester is stainless steel.

- **Mixing and heating:** The heat exchanger and agitator units are housed together in one nine foot stainless steel unit designed by UEM. Water is heated by the genset and pumped through stainless steel pipes to the heat exchanger. The current heat exchanger is undersized and struggled to get the temperature in the digester high enough to produce biogas during the winter months. The average operating temperature during that time was around 80˚F. In early December 2012 the system was only generating about 25 kW. The heat exchanger will be replaced with a larger unit sometime before the winter 2013. A biogas-based mixing system is used to agitate the digester contents. Biogas is collected in the gas storage space directly above the liquid in the digester. This gas is compressed using a biogas blower, and discharged back into the digester through gas piping with a confined tube. As the gas bubbles rise they create a mixing action, which keeps the digester contents mixed and prevents the formation of a scum layer.

Figure 2. Storage container with solids separation equipment (foreground) and fiber storage shed (right). Photo courtesy of Nora Goldstein.

- **Digestate solids separation:** Solids separation equipment is housed in a storage container (Figure 2). Solids separation is a two-step process. Digestate is pumped from the digester to a PT&M vibrating screen first and then to a PT&M Model E-10 screw press. On average, the vibrating screen and screw press run concurrently 5 to 6 hours per day. The vibrating screen produces a fiber product with 20% solids. The screw press removes additional water resulting in fiber of 35% dry matter. The fiber and filtrate are managed separately. The vibrator screen and screw press generate about 5,300 gallons of filtrate and 3.5 cubic yards of fiber per day. The fiber is conveyed to the fiber shed for storage. An analysis of the fiber dated May 2012 indicated there were 5.6 lbs/ton of nitrogen, 3.8 lbs/ton P_2O_5 and 2.6 lbs/ton K_20 at 68% moisture. The end use of the fiber is livestock bedding. Any excess fiber is sold. Filtrate flows into a 2,000 gallon underground holding tank and then is pumped into a 2 million gallon manure storage tank. An analysis of the filtrate was not available. The contents of the manure storage tank are land applied on growing crops.
- **Biogas collection:** Biogas is collected and stored under the digester cover (Figure 3). Weighted PVC pipes lay on top of the cover to keep biogas pressurized. There is no separate biogas storage.
- **Biogas treatment:** Hydrogen sulfide is removed with an iron sponge. Biogas going into the genset was analyzed in July 2013 and came back with a hydrogen

Figure 3. Biogas cover over digester vessel. Photo courtesy of UEM, Inc.

sulfide content of 600 ppm. Biogas with a hydrogen sulfide content of 600 ppm is considered a high quality biogas. Untreated biogas can have a hydrogen sulfide content of around 4,000 ppm. Moisture is removed from the biogas. There is no additional biogas treatment.

- **Biogas use:** The primary use for the biogas is electricity production. Excess biogas is flared off. An I-Power 65 kW biogas genset (an 8.1 L GM engine and a WEG generator) produces both heat and power. Depending on the flow rate and solids content of the manure (assuming a flow rate between 5,500 and 6,000 gal/day at between 6 and 8 percent solids content), UEM predicts a continuous power output of between 35 and 50 kW. Total efficiency of the genset is 87% - electrical efficiency is 28% and the balance is thermal. Electricity produced is net metered to the grid. Power can be sold to the grid or directed back as needed depending on the electricity demand of the farm. The genset went online August 2012 and as of August 2013 only ran an estimated 4,900 hours. The poor performance was due to an engine that was not properly designed for biogas combustion. A new engine will be installed before winter 2013. The WEG generator performed as it was designed to perform. Engine oil is changed every 500 hours.

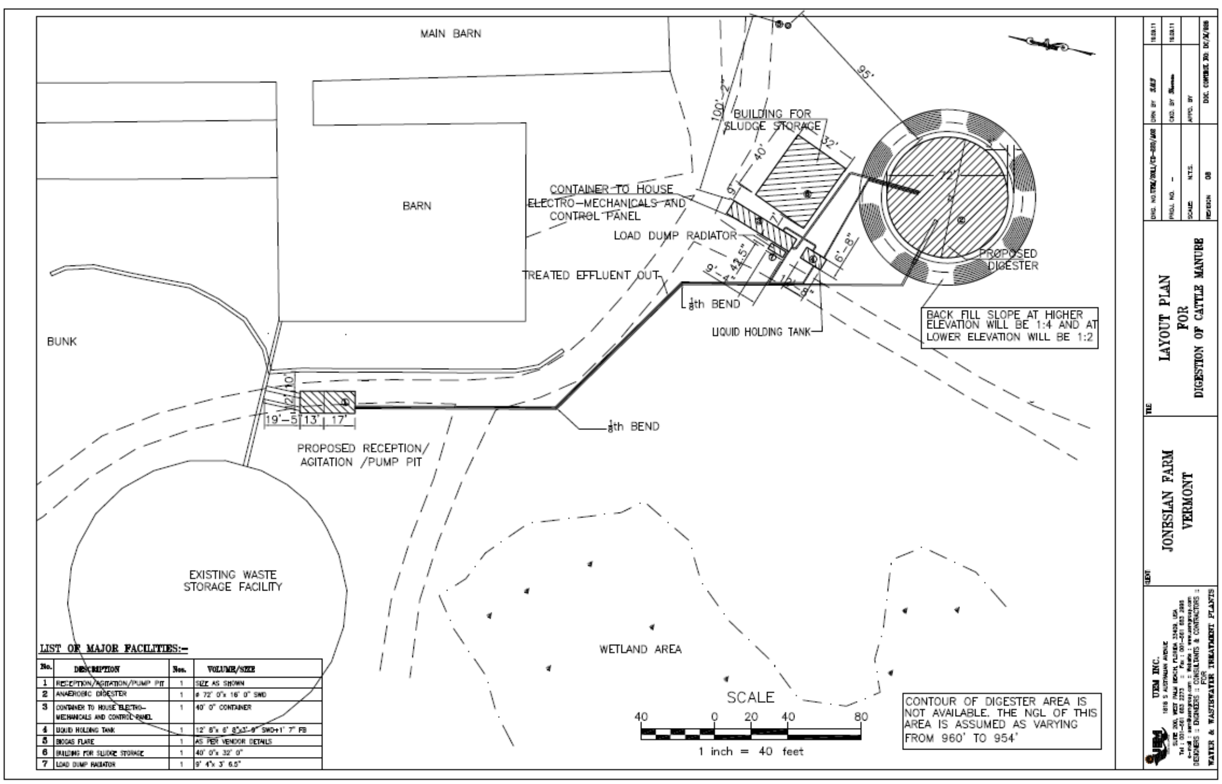

Figure 4. Layout plan for the Joneslan Farm digester. (Used with permission from UEM, Inc.)

Economics

Natural Resources Conservation Service Environmental Quality Incentives Program (NRCS EQIP) funds paid for the blasting and excavation of the pit, the manure pumps and piping, and the solids separator and storage container where the separator is housed. A Section 1603 grant covered 10 percent of the capital costs. A Clean Energy Development grant paid for other capital expenses. Joneslan Farm contributed $64,000. The total capital costs were around $823,000. Grant dollars for the project totaled $759,000, covering 92% of the capital costs. However, UEM notes that actual facility costs are closer to $1 million due to retrofits that have been needed. UEM has paid for the retrofits. An estimated breakdown of capital costs by percent for a typical $1 million (USD) UEM digester project is presented in Table 1. Table 2 lists the source of grants for the project and the amount awarded by each funding source.

Table 1. Estimated breakdown of facility and systems capital costs for a typical $1M (USD) UEM digester project.

Digester system component	Cost (%)
Interconnection and switchgear	2
Site work	10
Mechanical systems (includes motor controls)	23
Heat exchange and pasteurization	4
Digester vessel	23
Biomass and gas storage	N/A
Hydrogen sulfide scrubber	5
CHP unit	25
Engineering installation	8

Source: UEM, Inc.

Table 2. The source of grants for the project and amount awarded from each funding source.

Source of Grant	Amount awarded ($)
NRCS EQIP	426,000
Section 1603	83,000
Clean Energy Development Grant	250,000
Total grant dollars	**759,000**

At a minimum, the value of the electricity produced is equal to the Joneslan Farm's yearly electric bill, which is approximately $50,000. Anything above that is income coming into the farm. No carbon credits are accumulated or sold. Other potential sources of revenue include sales of solids, displacement of sawdust bedding, reduced fuel oil consumption, and reduced synthetic fertilizer consumption.

Joneslan Farm has an excellent working relationship with their utility company, Vermont Electric Cooperative (VEC). VEC is very receptive to renewable energy projects. The farm is on a single phase line and almost at the end of the line. VEC would not let the farm put more than 72 kW on the line unless the farm agreed to replace the line with three phase power. The nearest three phase power line was five miles from the farm and at a cost of $100,000 a mile, it wasn't practical to run a line to the farm.

Testing

The key process parameters that are measured at the digester include power production (continuously), temperature (daily), pH (daily, sensor in manure line), and hydrogen sulfide (as needed). No parameters are currently measured off site, but a check of the engine oil to determine the ideal oil change interval and testing for volatile solids destruction are two parameters that may be measured in the future.

Operational Requirements

It is estimated that the required time commitment by farm staff to operate the digester over the past year is 2 to 3 hours per day. This also includes time allotted for routine system maintenance and repairs. Farm staff does not do any process monitoring. It should be noted that because of extensive downtime with the power generator it is hard to determine an accurate estimate of time devoted to each activity. The genset has never run steady for more than two months. The farm has spent a great deal of time trying to keep the genset running. Of the activities listed previously, repairs to the digester system (in particular the genset) cause the most disruption to the normal activities on the farm.

In terms of annual operating expenses, if the generator engine was functioning correctly the annual operating expenses would be very close to what was projected when the project was put together. If everything was running correctly, the annual operating expenses would be approximately 5% more than what was predicted.

Financial

The projected estimated percent of revenue from sources listed below are as follows:

a. Total revenue from tipping fees (0%)
b. Total revenue from electrical generation (61.9%)
c. Total revenue from "avoided cost" of purchasing fossil fuels for heating (4.6%)
d. Total revenue from "Other" sources:
    - Fiber sales (11%)
    - Avoided cost – On-farm bedding use (22.5%)

The interconnection charges to the utility grid were a lot less than planned. Joneslan Farm spent $5,000 for engineering expenses and UEM had some expense for the switchgear. UEM notes this expense is project specific, and in the case of this project, can be estimated as 2 percent of the $1 million project cost.

VEC credits the farm for power sent to the grid (net metering) at 15.6 cents per kW.

Reported problems/Failures in specific areas

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

1) Site planning and design

- There is not enough room in the cargo container to work on the vibrating screen, the screw press, and the generator. Joneslan Farm knocked out a wall and built a "lean-to" off one side of the cargo container to create more space to work on the generator. UEM is changing the design of future digester systems to allow for more space to work on generator and solids separation equipment.
- The digester was being built as it was being designed by UEM. Joneslan Farm and UEM could have saved both time and money if the design work had been completed beforehand and the farmers consulted about the placement and design of the digester system. One example of this relates to the location of the cargo container in relation to the digester. Had Joneslan Farm known where the pipes were coming into the cargo container from the digester, the cargo container would have been set closer to the digester to prevent so many elbows in the piping.
- A floor drain to remove spilled manure in the solids separation area of the cargo container was included in the original plan at the insistence of the farm.

2) Engineering

- The cost to build the reception pit was twice what it should have been due to requirements mandated by a Vermont State engineer. The reception pit is 15 feet by 30 feet by 14 inches thick egg-shaped structure. It was poured in four pours. The total cost for the structure was $30,000. UEM had to have a state engineer sign off on the reception pit design before it could be built.

3) Construction and equipment

- The GM engine that powered the generator failed. UEM was sold an engine by I-Power that was not properly prepared to run on biogas. Yellow metals within the engine deteriorated from hydrogen sulfide exposure. I-Power used milled steel instead of stainless steel in the exhaust system. Hydrogen sulfide from the engine exhaust also deteriorated the yellow metals in a nearby battery charger.
- The air doors that control the billows in the PT&M screw press have not worked consistently since it was installed. It appears to be an issue with the control panel. It is being resolved by UEM and PT&M.
- The heat exchanger was not big enough to heat the digester slurry to 100˚F during the winter. It worked great in the summer, but not during the winter. A larger unit will be installed before winter 2013.
- UEM engineers failed to understand that manure does not pump and flow the same as other organic materials they have worked with. Improperly sized pumps were employed to move manure. After the first couple of pumps failed, UEM engineers replaced failed pumps with properly sized pumps.

- Shipping the cargo container and its contents from Florida to Vermont was expensive.

4) Biogas utilization and systems

- I-Power specification sheet indicated that their gensets could run on biogas with 100% humidity. Consequently, no moisture removal equipment was installed. Water now condenses in the line between the blower and the flare. The line has to be emptied of water before the blower is turned on otherwise the blower seizes up due to the weight of the water on it. UEM is designing a biogas moisture removal system.
- The I-Power genset runs on biogas at 2.5 psi of pressure. The original pump that was installed provided varying pressure of up to 5 psi. For optimal generator performance the pressure needed to be held constant. A new pump was installed that allowed the volume of biogas to be regulated at a steady pressure of 2.5 psi.

5) System control and operation monitoring and control

- The electronic controls were more complicated than they needed to be. UEM will simplify them in the next digester system design.
- The control panels were assembled in Florida and shipped to the farm. The intent was to control everything from one spot instead of having a control panel for each component. Connecting the control panels to the electrical components of the digester system became a wiring nightmare and was more complicated and expensive than it needed to be. In future digester systems, UEM won't use this type of configuration.

Lessons learned

Joneslan Farm

- It is best to have a turnkey contract with performance guarantees. UEM has stood by their work, made changes as necessary, and honored all their performance guarantees.
- Choose a digester vendor with capital and experience behind them. UEM had $120 million in sales in 2012 and has extensive experience in building all sizes of digesters throughout the world. UEM is not new at building digesters, just farm digesters.
- Install the separator on a mezzanine in the fiber shed and eliminate the conveyer belt. Just let the fiber drop off the end of the separator into a pile. This eliminates another piece of equipment.
- Hiring local skilled labor and making digester components locally reduced onsite costs, which kept the overall cost of the project down.
- Digester vendors should include farmers in the design of the digesters as farmers may have suggestions that can save a project time and money.
- Digester vendors should talk among themselves and share information to avoid the same costly mistakes that seem to be repeated when on-farm digesters are built.

UEM

- Reduce concrete and site works even further.

- Use an above ground digester tank.
- Continue to provide prefabricated components, such as equipment room, control room, CHP system, digester tank, cover, and insulation.
- Simplify the electrical controls and components.

References

- Personal interview by author with Brian and Steve Jones, Joneslan Farm.
- Email communication by author with Nina Kshetry, UEM, Inc.
- PowerPoint presentation by Nina Kshetry entitled *Lessons Learned for Anaerobic Digestion on Small Dairy Farms* given at the 7th AgSTAR National Conference.

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