Manure Management Program

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Anaerobic Digestion at Sheland Farms, Inc.: Case Study

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October 2009

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Anaerobic digestion overview

Digester type	Vertical Complete Mixed
Digester designer	Siemens Building Technologies, Inc.
Date commissioned	2007
Influent	60% raw manure blended with 40% pre-digested screw-press solid-liquid separator liquid effluent
Stall bedding material	Separated manure solids treated by a rotary drum composter and little to no green sawdust
Number of cows	650 total cows
Rumensin® usage	Yes
Dimensions (diameter, height)	30’x 35’
Cover material	Hard top
Design temperature	100°F
Estimated total loading rate	14,000 gallons per day
Treatment volume	238,000 gallons
Estimated hydraulic retention time	17 days
Solid-liquid separator	FAN screw-press
Biogas utilization	Caterpillar engine with 125-kW generator
Carbon credits sold/accumulated	No
Monitoring results to date	Yes; see page 6.

Farm overview

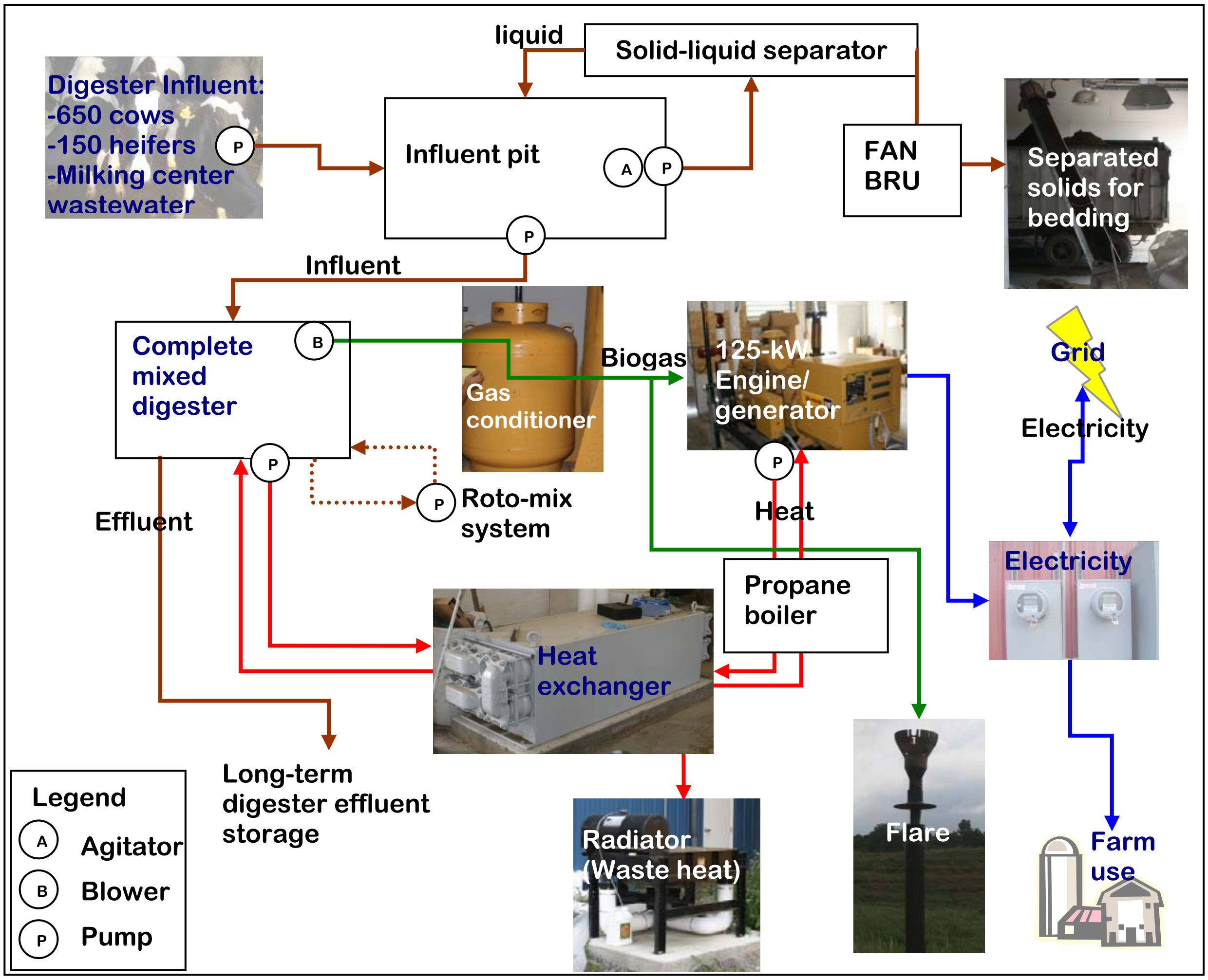
- Sheland Farms is located in the town of Ellisburg in Jefferson County, NY.
- The farm is a fourth generation family farm operated by Donald, Douglas, and Todd Shelmidine.
- The farm property has been in the family for over 100 years, and has grown significantly from 50 milking cows in 1963, to 650 total dairy cows at the present time.
- Cows are housed in one 6-row and one 4-row freestall barn, and are milked three times-a-day.
- Digester effluent is recycled to a land base of 1,100 acres, used to raise forage crops.
- Lactating cows and heifers are fed Rumensin®
- Copper Sulfate is used in two footbaths, one located in the dry cow pen and the other in the springing heifer pen.
- Considerable time was spent identifying, investigating, and responding to multiple financial grant opportunities.
- After receiving grant funds from several sources, digester construction began the fall of 2005 with commissioning in the summer of 2007.
- A flow diagram for the digester is shown on the following page.

Why the digester?

The farm sought a solution to both increasing electrical and purchased bedding costs, and determined anaerobic digestion would help meet these goals. Cow cooling electrical loads along with the electrical demands of cooling milk, are significant and thus the farm desired to reduce their annual power costs. A 125-kW engine-generator set is now used to generate electrical power from biogas produced by the digester. Manure solids to be used for freestall bedding are separated out before digestion by a FAN Separator Bedding Recovery Unit (BRU). The BRU in essence is a rotary drum composting machine.

Additional benefits of the anaerobic digester include: a proactive approach to reductions in farm related odor emissions, as well as the preservation of nutrients in digested manure applied to field crops. The risk of run-off and nutrient leaching are drastically reduced when manure is properly applied to crop land in accordance with the governing Comprehensive Nutrient Management Plan (CNMP).

Digester System



System and process description

A 238,000-gallon completely mixed anaerobic digester with a design hydraulic retention time of approximately 17 days, and a design capacity of manure from 660 dairy animals, was engineered for by Siemens Building Technologies, Inc. An annual maintenance fee is paid to Siemens to keep the engine-generator set running smoothly. Siemens guarantees the farm 16 yards^3/day of usable bedding from the system, and 381,240-kWh of electricity produced annually from the engine-generator set.

Liquids and solids process description

Currently, the digester processes 18,100 gallons per day of barn effluent (composed of manure from 650 cows [lactating and dry] and manure from 150 bred heifers) as well as pre-digested solid-liquid separator (SLS) liquid effluent. The ratio is about 60% barn effluent and 40% SLS liquid effluent. The farm is setup to add milking center wastewater to the AD if it is necessary, but this is not a common addition.

Freestalls consist of mattresses bedded with processed separated manure solids and some sawdust. Manure and soiled bedding are conveyed by alley scrapers to centrally located manure drops in each barn. A pump transfers manure from the barns, to a reception pit where it mixes with liquid off the SLS.

The digester is fed unheated influent every 30 minutes with a 10-Hp Vaughan pump, which runs about 5% of that time period. A Roto-Mix® pump/agitator system is used to mix the digester contents, intended to prevent material from settling in the conical bottom of the digester tank. This system consists of a 30-Hp Vaughan 3-phase electrical pump, located on the exterior of the digester tank. There are also two discharge nozzles located at the bottom of the digester tank and a third located at the top. Operating experience has shown that the Roto-Mix® design works well with this particular system when operated continuously for two hours on a four hour cycle.

Digester effluent is transferred to the farm's 3.5 million-gallon earthen storage by gravity. Stored material (digester effluent + rainwater) is recycled to the farm's cropland following their CNMP using either a drag hose injection system or tankers.

Heat and electricity generation

Biogas pressure inside the digester is currently set at 10" of water column. Biogas flows under this positive pressure to a gas conditioner, where it is cooled and condensed to lower the dew point, removing moisture. An electric blower increases the biogas pressure to meet the engine inlet requirements. Siemens chose to install the biogas conditioner in order to reduce the engine-generator set maintenance costs. Biogas is then sent to the gas utilization room where it is used to fire a 125-kW Caterpillar engine-generator set with a spark ignition system. The engine-generator set uses on average 30 ft^3/minute of biogas to generate 80 to 90-kW of power.

Generated power is used on-farm and excess is sold to Niagara Mohawk grid under the provisions of the New York State Net Metering Law (see Fact Sheet No. NM-1). Any excess biogas is automatically routed to and burned by a flare.

Engine oil changes are performed every 700 hours of operation (about once a month) with Chevron HDAX low ash gas engine oil, SAE 40 to reduce damage to the engine from the corrosive hydrogen sulfide.

A 7.5-Hp Vaughan pump continuously transfers digester contents through an external heat exchanger. Reclaimed heat from combustion of the engine-generator set is used to supply heat to the water-to-manure heat exchanger. The target operating temperature for the digester is 101°F. Excess heat is dispersed to the atmosphere with a heat dump radiator.

Economics

Sheland Farms has a contract with Siemens Building Technologies, Inc. for the entire project from design and engineering to meeting operational performance standards. The cost of the contract was $1,347,891 along with an annual fee of about $24,000 to maintain the engine-generator set, switch gear and provide the performance guarantee. The estimated itemized capital costs for the anaerobic digestion system and equipment are shown in Table 1 below. Miscellaneous cost items include: construction supplies and materials, employee travel, and shipping charges for equipment and materials.

Table 1. Initial Capital Costs for Sheland Farms Anaerobic Digester System

Component	Cost ($)
Digester	
-Site Work	15,000
-Engineering design	200,000
-Digester (Including cover, concrete, and heating pipes)	445,500
-Misc.	100,000
Subtotal	*760,000*
Energy conversion	
-Engine-generator set	146,800
-Electrical wiring and control systems and plumbing	60,000
-Biogas utilization building	232,917
Subtotal	*439,717*
TOTAL	***1,199,717***

The farm received funding from the New York State Energy Research and Development Authority (NYSERDA), the United States Department of Agriculture (USDA) Rural Development program, and New York State Environmental Protection Fund totaling $1,160,000. The farm invested about $450,000 of its own money into the project including the purchase of a Fan Bedding Recovery Unit.

Benefits and Considerations

Benefits

- Odor control
- Potential revenue from:
  1) Value-added products
  2) Reduction of purchased energy
  3) Sale of excess energy
  4) Efficient use of biogas production
  5) Carbon credit sales
- Nutrient conversion, allowing use by plants as a natural fertilizer, if effluent is spread at an appropriate time
- Pathogen reduction

Considerations

- Comparatively high initial capital and/or high operating costs
- Long and tedious contracts with the local utility; may require special equipment for interconnection
- Dedicated management of the digestion system is required
- Careful attention to equipment maintenance and safety issues due to the characteristics of raw biogas

Lessons Learned

The farm reported that the following lessons were learned as a result of constructing and operating their anaerobic digester.

Difficulties were encountered when there was disconnection among the design team at Siemens. Different areas of the company were unaware of aspects of the project out of their scope, and the farm received very different recommendations and opinions from people in the same area of expertise.

Investment was made in various pieces of equipment considered "extra" for the manure handling system (example: biogas conditioner, drag hose, SLS separator) in order to reduce future farm maintenance needs for the system and assist in their overall goal of recycling manure from the barn to the field, with as little effect possible on humans and the environment.

The initial design was to maintain the biogas pressure within the digester at 6" of water column. However, it was found that the flare would not function properly at this pressure, thus, the decision was made to increase the pressure to 10" of water column. Since this change has been made, excess biogas has been successfully flared, and emissions of raw biogas have been eliminated.

Initially, operating the Roto-mix system for 20 minutes of a 30 minute cycle resulted in a build up of two feet of crust on the top layer within the digester. This resulted in a significant reduction of biogas production. The farm operated the Roto-mix system continuously for one week to break down the crust and biogas production successfully returned to previous levels.

Previous testing results

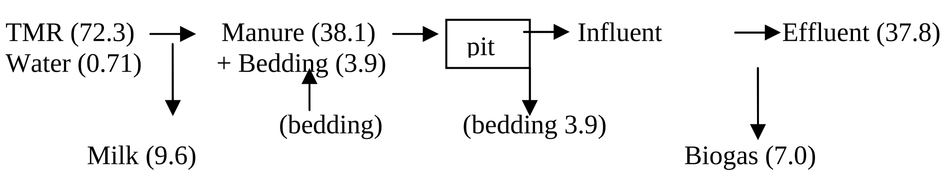
Analysis of manure handling and digester operation is based on data collected during a study of sulfur flow in February 2007. The farm operator recorded the biogas flow, temperature and pressure and analyzed the biogas three times each day for carbon dioxide and hydrogen sulfide.

Dairy Cows: 463 (milking), 93 (dry), 71 (heifers) – 637 total animals
Equivalent milking cows based on total solids entering digester: 553+
Bedding: 3.9 lb/cow-day (separated solids)

Total solids entering digester	9,460 lb/day
Production of biogas (n=30)	39,500 ft^3/day (wet, 60F)
Temperature of biogas (n=90)	72°F
Concentration of CO_2 (n=180)	35.8 % (dry)
Concentration of CH_4	64.0 % (calculated)
Concentration of H_2S (n=180)	2,240 ppm (dry)
Weight of CH_4	1,002 lb/day
Heating value (low)	899,000 Btu/hr
	546 Btu/ft^3 raw biogas

+The ASABE* equations predicted that, based on milk production, the cows would produce 18.7 lbs TS per cow-day. Considering all the total solids entering the digester, the number of "cow equivalents" at Sheland Farms was calculated. The production of biogas was 77.4 ft^3 per cow equivalent-day. The average for the six farms not feeding food waste was 78.8.

Flow of sulfur through system (numbers in brackets are lbs sulfur/day) is shown below.



The sulfur in the drinking water at Sheland Farms had a concentration of 16.0 mg SO_4 / liter and accounted for 0.13 lbs S per 100 milking cows or about 1 % of the total sulfur entering the system.

* ASABE Standard D384-2, 2007

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Acknowledgements

The authors would like to thank the New York State Energy Research and Development Authority (NYSERDA) for funding in support of this work. Any opinions, findings, conclusions or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of NYSERDA or the State of New York, and reflect the best professional judgment of the authors based on information available as of the publication date. Reference to any specific product, service, process, or method does not constitute an implied or expressed recommendation or endorsement of it. Further, Cornell University, NYSERDA and the State of New York make no warranties or representations, expressed or implied, as to the fitness for particular purpose or merchantability of any product, apparatus, or service, or the usefulness, completeness, or accuracy of any processes, methods, or other information contained, described, disclosed, or referred to in this publication. Cornell University, NYSERDA and the State of New York make no representation that the use of any product, apparatus, process, method, or other information will not infringe privately owned rights and will assume no liability for any loss, injury, or damage resulting from, or occurring in connection with, the use of information contained, described, disclosed, or referred to in this publication.