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PRO-DAIRY

Anaerobic Digestion at Ridgeline Dairy Farm: Case Study

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Anaerobic digestion overview

Digester type	Complete Mixed
Digester designer	RCM Digesters, Inc.
Influent	Raw manure & food waste (by-products from processing milk/ice cream, grapes and salad dressing)
Stall bedding material	Sawdust
Number of cows	600 dairy cows
Rumensin® usage	Yes; used on the dry cows only
Dimensions (width, length, height)	68’ x 78’ x 16’
Cover material	Soft top (Hypalon 45)
Design temperature	100°F
Estimated total loading rate	25,000 gallons per day
Treatment volume	634,826 gallons
Estimated hydraulic retention time	20 days
Solid-liquid separator	Not currently in use
Biogas utilization	Biogas boiler, Waukesha engine with 130-kW generator
Carbon credits sold/accumulated	Yes; AgCert™
Monitoring results to date	Yes; see page 5.

Farm overview

- Ridgeline Farm (formerly Matlink Dairy Farm), operated by Carl Neckers (dairy facility) and Vinny Howden (anaerobic digestion facility), is located in the town of Clymer in Chautauqua County, New York
- The farm, with 600 milking cows, employs 16 people, and has a considerable impact on the local economy
- To address a variety of issues, including odor emissions, nutrient planning, and revenue, the farm installed an anaerobic digester with support from New York State Energy Research and Development Authority (NYSERDA) in late December 2001
- Matlink Dairy Farm started the construction of their anaerobic digester system in the summer of 2000; the system was in operation by the end of 2001
- As of 2005, Matlink Dairy changed management and was renamed Ridgeline Farms.

Why the digester?

Known as Matlink Dairy at the time, the farm sought anaerobic digestion as a solution to: odor problems and community dissatisfaction, possible groundwater contamination, and to reduce fuel/electricity costs. Manure generated at Matlink Dairy Farm was stored in a lagoon and spray-irrigated on the ground in March, April and November. The farmstead is located one mile upwind of the Village of Clymer. During periods of spray irrigation, the public school was forced to keep its windows closed and neighboring businesses also received complaints about the odor. The farm knew that anaerobic digestion is an effective technology to reduce odor from animal waste. Thus, to create a better standing in the community, Matlink Dairy Farm initiated construction of an anaerobic digestion facility. Additionally, concern was raised as to the potential of nutrients from land-applied manure leaching to groundwater supplies. This became more of a concern when a test of the Town of Clymer's public water supply exceeded the maximum contaminant level of 10 mg/l for nitrate-nitrogen in 1994. Lastly, the economic benefits of the installation of a methane digester were projected to reduce the farm's electrical and natural gas costs by approximately $41,000 per year, according to the estimate in an EPA AgSTAR program's feasibility study.

Digester System

System and process description

Ridgeline's complete mix anaerobic digester is a rectangular below-grade cast-in-place concrete tank covered by two flexible plastic covers to collect biogas. The digester was built at the middle of a slope, using gravity to transfer manure from the barn collection system to the digester, and from the digester to the long term storage.

Liquids and solids process description

Barn manure is collected by continuously operating alley scrapers to a transversely-oriented drop gutter. Gutter contents flow by gravity to the digester influent pump pit. In addition to manure from some 600 cows, influent to the digester historically included food waste, usually in the form of ice cream waste, salad dressing, fryer grease, and an occasional load of rejected milk. Food waste comes in loads of approximately 5,000 gallons. Two 20-Hp agitators fixed at opposite corners of the digester run two hours per day to blend the digester contents. The design hydraulic retention time (HRT) is about 20 days. The farm is not currently operating their solid-liquid separator, but is planning on purchasing a new unit and incorporating it into the system.

Digester effluent flows to a 4.2 million gallon earthen long-term storage pond. Material from the long-term storage is spread on 1,800 acres of corn and hay cropland.

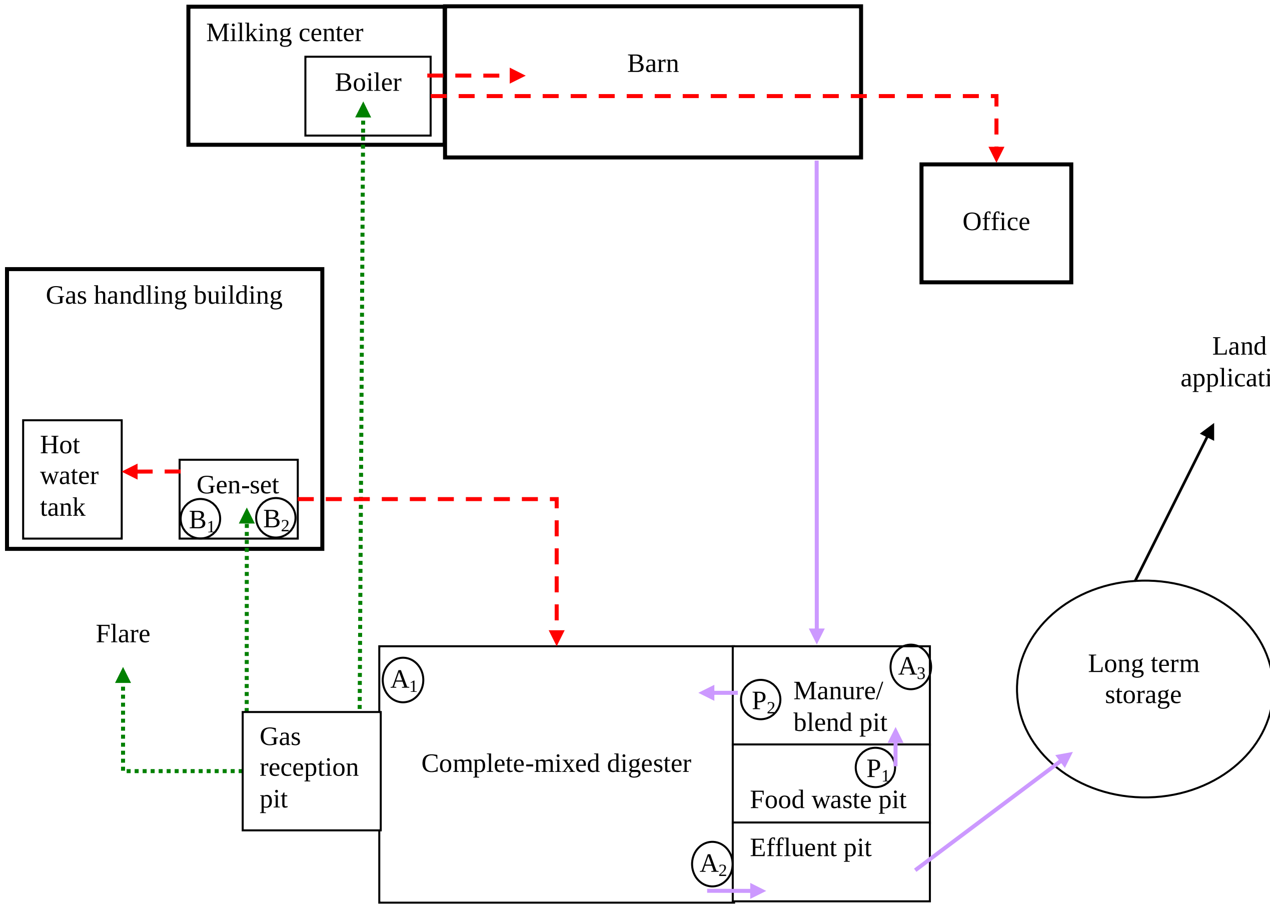

Figure 1. Flow diagram for the manure treatment system at Ridgeline Farms

Heat and electricity generation

Biogas is collected and sent to a Waukesha engine attached to a Marathon generator (130-kW). The engine operates 90-92% of the available hours per year. Due to the corrosive hydrogen sulfide in the biogas, engine oil is changed every 500 hours using about 22 gallons of oil. This engine-generator set produces about 884,000 kWh/year, which meets the electricity needs for the dairy farm and also provides excess electrical power for sale to the local utility (National Grid), as well as to a plastics molding company next to the farm. The farm is currently applying for a grant to cover costs associated with installing an additional engine-generator set with a 225-kW capacity.

Heat is generated using a biogas boiler, which provides hot water to maintain a constant 100°F temperature in the digester; heat is also produced and used to heat the barn floors.

Economic Information

Table 1. Initial capital costs for Ridgeline Farm

Component	Costs/Benefits ($)
Digester	
- Digester Construction and Materials	260,000
- Mix Pumps	77,000
Subtotal	***337,000***
Engine-Generator Set	
- Engine Generator	96,317
- Switching Equipment	10,000
- Engine Building	22,614
Subtotal	***128,931***
Solids and Liquids Separation	
- Separator	46,613
- Separator Building	15,076
Subtotal	***61,689***
Liquid Storage	45,000
Other	56,900
Total Capital Cost	**622,520**
Total Annual Capital Cost	**61,232**

Lessons Learned

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

Accepting food waste is highly profitable – tipping fees make the manure treatment system a profit center for the farm. This is a win-win situation. The food company has an environmentally responsible and relatively less expensive way to export their waste product(s), nutrients from the food waste are recycled back to the land and power is produced from a renewable source.

The food waste is high in energy, having almost three times more gas production per unit of mass than manure, yet the nutrient content is comparable to manure so imported nutrients are manageable. Not all farms can take advantage of this. Only farms that have a land base able to accept extra nutrients should consider this option.

The sizing of the gas handling system needs to account for the additional production of biogas that food waste creates. Pre-planning and analysis of possible food waste sources should be done in order to estimate gas production potential.

The complete mixed digester performs well and offers flexibility to accept various consistencies of manure and food waste.

Shock loading of a digester with high energy food waste will create substantial amounts of foam. Loading the digester incrementally reduces the potential for foam.

The design of the anaerobic digestion system including manure handling, gas collection, gas utilization, and digester heating should be designed as a system. This site experienced a beam failure due to lateral loads that were not anticipated. If the concrete design had been better integrated with the rest of the system, this problem may have been avoided.

Although food waste supplies additional solids to the digestion system, the effluent contains a lower solids content than if manure were digested alone. The farm interprets this to mean the extra energy content of food waste apparently makes it possible for additional solids destruction. Solids are destroyed in the long-term storage as well. The existing manure storage was approximately half full of manure solids when digested effluent was introduced. After two years of operation, the solids in the storage had decreased significantly without excessive agitation.

There is a significant amount of heat recovered from the engine-generator set. The recovered heat is used to warm the digester influent, to maintain the digester operating temperature, and to heat water in the calf barn and milking parlor. Despite the many uses for waste heat, a radiator is still required to dissipate extra heat. The un-insulated gas utilization building is kept very warm, even in the winter months, due to the excess heat produced. This offers a prime opportunity for a shop facility, and should be sized for that function. The farm expresses a need for more heat "storage" or opportunities for use of the excess heat, instead of expelling the heat to the atmosphere.

Previous testing results

Ridgeline Dairy's anaerobic digester system, along with seven others in NY State are in the process of being monitored to determine digestate stabilization, engine-generator set performance, reduction in greenhouse gas emissions, and economic benefit to the farm. Ridgeline and four of the other systems currently being monitored were also monitored in the past. The following data was taken from an interim monitoring report[A] written in 2007. The complete report is available on line at www.manuremanagement.cornell.edu and can also be obtained by contacting the authors of this case study.

<u>Waste stabilization results</u>

Digester influent and effluent samples were collected monthly from 5/2001 to 6/2002 and from 7/2003 to 4/2005 and analyzed by a commercial laboratory. The values in Table 2 are the average (Avg), standard deviation (St. Dev.), 99 percent confidence interval (CI) and the number of samples (n) for the constituents analyzed. A negative value for the percent change in concentration indicates an increase in the constituent concentration as a result of the digestion process, while a positive value represents a constituent concentration reduction.

<u>Solid-liquid separation performance results</u>

Separator influent (digester effluent) and both the solid and liquid effluent flows were sampled monthly and analyzed by a commercial laboratory. The average (Avg), standard deviation (St. Dev.), 99 percent confidence interval (CI), and number of samples (n) for the solid-liquid separator influent stream, liquid effluent stream, and solid effluent stream are shown in Table 2. For Ridgeline farms, the Solid-Liquid separator influent constituent concentrations were equal to the digester effluent constituent concentrations.

<u>Biogas and energy production results</u>

Data on energy production/use was taken between 1/2004 and 5/2005. The total monthly metered biogas data were obtained from the farm log sheets and monthly farm visits. Ridgeline Farm used biogas to fire an engine-generator set, a biogas boiler, occasionally a six million Btu biogas food dryer, and to boil maple sap for syrup production during the spring season; excess biogas was flared. The average daily biogas production used was divided by the average daily weight of VS consumed by the digester to compare the digester's efficiency in production of biogas. The biogas carbon dioxide concentration was measured using a Bacharach, Inc. FYRITE gas analyzer. The analyzer measured the concentration of biogas CO_2 in a range of 0 - 60 percent. The biogas was tested by the farm or the researchers during farm visits, and the average of the recorded values are shown in Table 3. The electrical energy generated, purchased, sold, displaced, and used is also shown in Table 3. Displaced energy was the energy sold subtracted from the energy produced. Farm utilization was calculated by adding the energy displaced and the energy purchased. Energy generated at Ridgeline was obtained every farm visit from the Watt-hour meter included as part of the engine-generator set control panel instrumentation. Energy purchased and sold at Ridgeline was obtained from spreadsheet files containing 15-minute power data developed by Niagara Mohawk and supplied by the farm. A capacity factor that exceeds 90% is desired.

Table 2. Anaerobic Digester and Solid – Liquid Separator Performance at Ridgeline Dairy

		Anaerobic Digester					Solid-Liquid Separator	
Constituent	Statistic	Influent (raw manure) Constituent Concentration	Influent (food waste) Constituent Concentration	Calculated Influent Constituent Concentration	Effluent Constituent Concentration	Change in Concentration	Liquid Effluent constituent Conc.	Solid Effluent Constituent Conc.
pH (Std. units)	Avg.	5.43	3.65	5.36	7.60	--	6.58	6.55
	St. Dev.	0.96	0.77	0.83	0.13		0.63	0.91
	CI	0.37	0.30	0.44	0.05		0.24	0.35
	n	26	25	24	26		26	26
TS (percent)	Avg.	13.06	26.1	15.5	5.60	63.9	5.13	28.1
	St. Dev.	4.16	18.7	8.21	0.74		0.77	5.64
	CI	1.60	7.34	4.31	0.29		0.30	2.17
	n	26	25	24	26		26	26
TVS (percent)	Avg.	11.73	25.21	14.31	4.35	69.6	3.99	25.96
	St. Dev.	4.19	18.8	8.33	0.51		0.75	5.65
	CI	1.61	7.37	4.38	0.20		0.29	2.17
	n	26	25	24	26		26	26
Volatile acid as Acetic acid (mg/kg)	Avg.	3,382	3,654	3,623	469	87.1	--	--
	St. Dev.	1,174	2,035	1,277	273		--	--
	CI	451	798	671	105		--	--
	n	26	25	24	26		--	--
COD (mg/kg)	Avg.	171,761	364,169	200,756	63,070	68.6	82,669	208,397
	St. Dev.	82,745	206,665	103,487	12,516		91,099	77,308
	CI	32,435	82,682	55,583	4,906		35,710	30,304
	n	25	24	23	25		25	25
DCOD (mg/l)	Avg.	38,712	46,335	39,111	13,244	66.1	21,170	17,651
	St. Dev.	11,624	22,330	11,956	7,257		10,118	8,212
	CI	4,650	8,934	6,566	2,903		8,868	7,198
	n	24	24	22	24		5	5
Log_{10}MAP (cfu/gram)	Avg.	3.1	-	3.0	2.0	94.8	1.8	1.4
	St. Dev.	0.8	-	0.8	0.5		0.6	0.3
	CI	0.6	-	0.6	0.4		0.5	0.4
	n	13	-	13	11		10	6
Log_{10}F. Coli. (mpn/gram)	Avg.	5.5	1.0	5.4	3.4	98.4	3.2	3.3
	St. Dev.	0.6	1.1	0.6	0.6		0.6	0.7
	CI	0.3	0.6	0.3	0.3		0.3	0.4
	n	24	23	24	22		23	22

Table continued on next page…

	Anaerobic Digester						Solid-Liquid Separator	
Constituent	**Statistic**	**Influent (raw manure) Constituent Concentration**	**Influent (food waste) Constituent Concentration**	**Calculated Influent Constituent Concentration**	**Effluent Constituent Concentration**	**Change in Concentration**	**Liquid Effluent constituent Conc.**	**Solid Effluent Constituent Conc.**
TKN (mg/kg)	Avg.	3,366	3,086	3,174	3,263	-2.8	3,071	4,877
	St. Dev.	984	1,118	877	513		485	1,499
	CI	386	447	471	201		190	588
	n	25	24	23	25		25	25
NH3-N (mg/kg)	Avg.	1,296	571	1,177	1,326	-12.7	1,256	1,274
	St. Dev.	558	234	438	381		374	498
	CI	214	92	230	146		144	191
	n	26	25	24	26		26	26
ON (mg/kg)	Avg.	2,095	2,392	1,944	1,921	1.2	1,697	3,583
	St. Dev.	643	1,212	698	421		620	1,399
	CI	252	475	367	165		238	548
	n	25	25	24	25		26	25
TP (mg/kg)	Avg.	570	446	534	553	-3.6	523	964
	St. Dev.	189	168	143	122		109	296
	CI	73	66	75	47		42	114
	n	26	25	24	26		26	26
OP (mg/kg)	Avg.	329	198	296	290	2.0	279	514
	St. Dev.	137	119	90	89		101	189
	CI	53	47	47	34		39	73
	n	26	25	24	26		26	26
K (mg/kg)	Avg.	2,756	931	2,742	2,592	5.5	2,472	1,966
	St. Dev.	875	1,165	909	590		573	578
	CI	458	633	649	309		300	303
	n	14	13	13	14		14	14
Cu (mg/kg)	Avg.	12	2.82	7.00	15.4		--	--
	St. Dev.	11	0.73	2.68	3.51		--	--
	CI	10	0.64	3.45	3.07		--	--
	n	5	5	4	5		--	--

Table 3. Electrical energy generated, purchased, sold, displaced and used at Ridgeline Dairy

	Monthly metered biogas (ft^3)	**Average biogas CO_2 content (%) [1]**	**Monthly energy generated, purchased, sold, displaced, utilized (kWh)**	**Capacity factor**	**Energy (Wh) per cubic foot of biogas used**
Average	3,964,428	31.5	Produced: 92,738 Purchased: 6,149 Sold: 33,178 Displaced: 55,573 Farm used: 58,334	0.881	40.2
Range	2,031,481 9,383,185	26 34	Produced: 80,522 to 103,569 Purchased: 819 to 42,038 Sold: 2,162 to 48,364 Displaced: 46,443 to 69,443 Farm used: 47,406 to 75,998	0.960 0.665	30.3 44.4
Number samples	17 months	35	10 months	17 months	17 months

[1] Estimated CH_4 concentration is equal to 100 – [CO_2]

Who to Contact

- Vinny Howden, Ridgeline AD facility operator
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- Curt Gooch, Manure Treatment Specialist, PRO-DAIRY, Cornell Cooperative Extension
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References

[A] "Big-5 Interim Report": See "Biogas Distributed Generation Systems Evaluation And Technology Transfer - Interim Project Report. April, 2007" Project #: 6597. http://www.manuremanagement.cornell.edu/HTMLs/Project_Reports.htm

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