Anaerobic Digestion at New Hope View Farm: Case Study

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Anaerobic digestion overview

Digester type	Plug-Flow
Digester designer	RCM Digesters, Inc.
Date Commissioned	2001
Influent	Raw manure
Stall bedding material	Sawdust
Number of cows	850 dairy cows
Rumensin® usage	No
Dimensions (width, length, height)	30’x118’x19’
Cover material	Soft top (Hypalon 45)
Design temperature	100°F
Estimated total loading rate	25,000 gallons per day
Treatment volume	503,000 gallons
Estimated hydraulic retention time	20 days
Solid-liquid separator	FAN screw-press; Not currently in use
Biogas utilization	Biogas boiler, microturbine (70-kW)
Carbon Credits sold/accumulated	No
Monitoring results to date	Yes; see page 7.

Farm overview

- New Hope View Farm is an 850-cow dairy operation located in the town of Homer, Cortland County, New York
- The farm changed hands in February of 2007; it was formerly owned by DeLaval and known as Dairy Development International (DDI)
- The construction of DDI broke ground on December 4, 2000 and the first cow was milked on August 7, 2001
- Farmstead odor reduction, due to community concern, was the primary reason the farm incorporated an anaerobic digester into the original design plans
- Biogas cleanup consists of an iron media scrubber to remove hydrogen sulfide (H_2S)
- Biogas is used to fire a 70-kW Ingersoll-Rand microturbine and to fuel a boiler
- The biogas boiler maintains the temperature of the digester and warms the barn floors
- Excess biogas is flared using a power flare
- Digested effluent is directly pumped into an above-ground slurry tank
- A screw-press separator and housing are located next to the digester, should the decision be made in the future to separate effluent solids and liquids. Markets for separated solids are currently being sought, as the demand for compost rises.
- The stored digested effluent is recycled to the land base of 2,000 acres of owned and rented cropland

Why the digester?

Odor reduction is paramount; the farm is sited beside a major interstate and residential areas are located close by. Due to initial local opposition, DDI management was always concerned with choosing the best manure management strategies to reduce odor, and this goal continues with the new owners, the Head family. Authorization of a building permit by the Town of Homer required that the farm follow the proven technology already in use at AA Dairy in the town of Candor in Tioga County (*see "Anaerobic Digester at AA Dairy: Case Study" for more details).*

Digester System

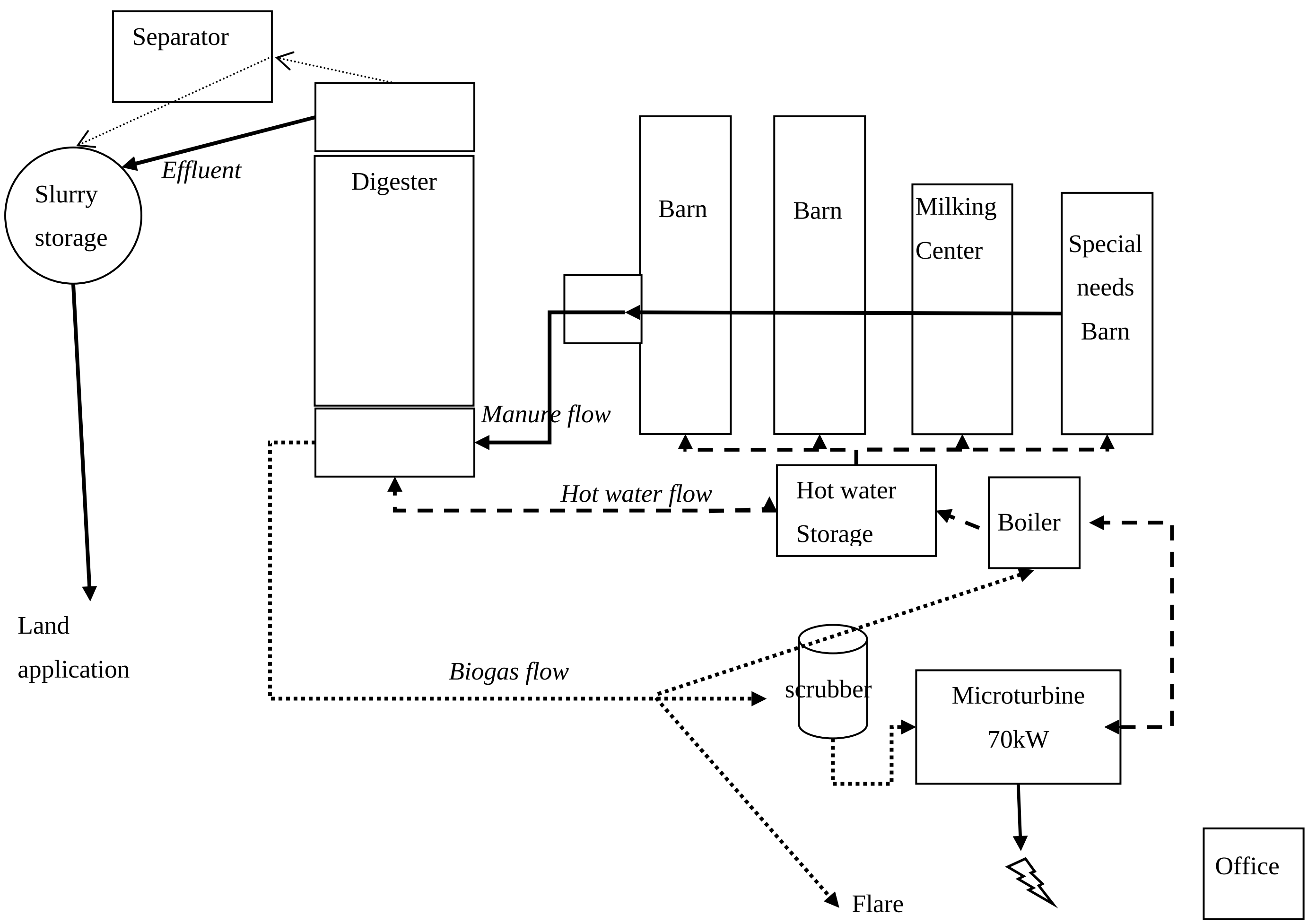
System and process description

A plug-flow digester designed by RCM Digesters, Inc. was constructed at DDI (now New Hope View Farm). The containment vessel is a below-grade cast-in-place concrete vessel with a design hydraulic retention time of 20 days. The digester is equipped with a gas tight flexible membrane cover to collect biogas. Manure is initially heated and maintained at approximately 100°F in the digester. A 7.5-Hp influent pump transfers barn effluent (raw manure and soiled bedding) and milking center wastewater to the digester. Approximately 20,000 gallons of influent are fed into the digester each day. Digester effluent is normally pumped directly to an above-ground storage tank, but can be pumped to a solid-liquid separator if desired.

Liquids and solids process description

Manure is scrapped to the center of each barn using mechanical alley scrapers, it then drops through a slot to the flow gutter. In the first barn (i.e., special needs barn), the elevation of the floor of the flow gutter is 1157 feet. In the second barn, the elevation is 1156 ft., and 1155 ft. in the third barn. Using a series of one-foot step-dams, the manure flows to the final collection pit, which is a 30,000-gallon below-grade cast-in-place concrete storage pit (digester influent pit). An impeller agitator is used to homogenize influent (manure + bedding + milking center wastewater) as needed before being pumped to the digester. Milking center wastewater is collected in a 21,000 gallon holding tank and used to flush the holding pen.

The farm site has a high water table, and so digester effluent is stored in a 2.9 million gallon above-grade steel slurry tank, to prevent groundwater contamination. The effluent from the digester is pumped directly to the tank and hauled off-site in tanker trucks for land application. The effluent can be sent through a screw-press separator to remove the solids in which case, only the separated liquid would go to the slurry storage. If the effluent were to be separated, the solids that were removed could be collected and sold commercially as compost.



Heat and electricity generation

Biogas is transported in underground pipe about 500 ft. and combusted in three different ways: a microturbine, a boiler, or a flare (for excess gas). During the farmstead layout processes, the decision was made to locate the biogas utilization equipment closer to the utility's electrical service connection instead of closer to the digester, because it was determined that there is less capital cost to lay biogas pipe and hot water heating loop pipe and pump the biogas across the farmstead than it was to pay for additional electrical lines. (This, however, does not mean it is cheaper overall, due to operating costs.)

From a biogas-to-electrical energy conversion standpoint, initially biogas was intended to be used to fire four 28-kW Capstone microturbines. However, extreme difficulties were experienced by the farm associated with cleaning and pressurizing biogas to meet the inlet requirements of the Capstone units, which resulted in their removal without achieving any significant electricity generation.

In 2006 the decision was made to install one 70-kW Ingersoll-Rand (IR) microturbine designed for low energy fuels. An arrangement is in place between the farm and IR, in which the farm sells conditioned biogas to IR who in turn owns and operates the microturbine and sells electricity to the farm and to New York State Electric and Gas (NYSEG). The farm owns and operates an iron sponge biogas clean-up unit to reduce the hydrogen sulfide to approximately less than 50 ppm; only the biogas used by the IR microturbine is cleaned. Farm experience to date shows that the iron sponge media lasts about six months.

The system includes a heat exchanger to recover combustion heat from the microturbine exhaust and use it to assist in meeting the digester heating demand.

A portion of the biogas is used to fire a 1.5 million Btu boiler which provides heat for the hot water heating system used to heat the digester. There is an automatic control located on the boiler that keeps hot water flowing to the digester at 124°F in order to keep the digester operating at the target temperature of 100°F.

Biogas not used by the microturbine or the boiler is flared by a power flare.

Economics

Table 1. Initial capital costs for NHV Farm

Component	Cost ($)
Digester	350,000
Electrical and Heating Systems	
- Microturbines	136,000
- Boiler and Piping	50,000
Subtotal	***186,600***
Solids and Liquids Separation	
- Separator	46,613
- Separator Building	42,387
Subtotal	***89,000***
Liquid Storage	315,000
Others	43,800
Total Capital Cost	**984,400**

Lessons Learned

DDI/New Hope View digester managers report the following lessons have been learned as a result of operating their anaerobic digester.

Digester placement

The placement of the digester on the farm was a highly debated topic prior to construction. The microturbine and control room were located closer to the existing electrical infrastructure, and pipe was installed a long distance instead of electric conductors. Because of this, the hot water must be pumped across the farm to heat the digester, and significant heat and energy is wasted in the transport process. Better operation and energy efficiency can be achieved if a digester and its power generation equipment are located closer to each other.

Heavy snow load can collapse the flexible cover on the digester if it falls faster than it can melt. Shoveling the snow off will allow the cover to re-inflate.

Temperature control

Temperature control of the digester is critical. Air locks in the heat pipes can prevent proper circulation of hot water inside the digester to heat the incoming manure to 100°F and to keep it at that temperature throughout the 20-day retention time. Temperature gauges, if working properly would help in diagnosing a heat loss problem. It is therefore imperative that temperature gauges are calibrated and working properly. Groundwater impingement on the bottom of the digester can take a significant amount of heat away from the digester making it hard to heat. When flows to the digester are reduced, the amount of heat to the digester needs to be adjusted since heat will not be needed for incoming manure. Without adjustment, higher temperatures than desired may result.

Although heat recovered from the electrical generation system can be supplied continuously for on-farm demands, during sharp cold snaps, in-floor heating may not prevent the pipes from freezing.

Odor control
Odor control can be achieved by a digester system. The odors are negligible when the volatile acid levels leaving the digester are below 500 ppm. As the digester experiences difficulties with temperature control or retention time the volatile acids leaving the digester may be higher and odors may occur.

Flow gutter
The flow gutter often has too many solids to flow steadily, and must be flushed with milking center wastewater. The problem is acquiring clean water to do this with, since the wastewater from the foot baths contains copper sulfate, which decreases microbe activity in the digester.

Crust in the digester
The plug-flow digester relies on the proper moisture content of the influent. Dairy manure as produced will not separate into floatable solids and settleable solids very easily. When extra moisture is added, the floatable and settleable solids separate inside the digester leaving a floating crust and a deposit. As these two portions of the digester get larger they will decrease the usable volume in the digester and decrease the hydraulic retention time. Lower retention times will decrease biogas production and fail to reduce the odors in the effluent.

Foam in the digester
Foaming can occur when operational and management changes are made, such as: the diet of the cows, the temperature of the digester or additions of other organic loading. Foam flowing out from the digester creates a mess, but spraying water over it can control the foaming. A water source and spray device near the effluent tank is useful.

As foaming occurs it often flows into the biogas collection and transport pipe. The digester head space biogas pressure-control system consists of water buckets that maintain the proper water-level to sustain biogas pressure. Providing a drain for the pipe chases and a solid bottom and water supply makes clean up easier. Removing the top of the pipe chase allows easy access and good ventilation for those working in the area. Also, if preventable, the manure influent pipe should not be located in the same pipe chase as the biogas exiting the digester.

Solids separation
Solid-sales marketing needs to be done in order to sell separated manure solids. The separated digested solids are homogeneous, dark in color, and have good tilth. When the digester was constructed, demand for compost or manure solids was not evident in the market, and transportation costs narrowed the market area to relatively near the farm. Currently however, more interest is being generated in the use of separated manure solids, and if a stable and reliable market can be found, the revenue collected from this by-product would be a valuable asset in the economic performance of the digester.

Gas composition & scrubbing
Conditioning biogas before sending to the compressors and microturbine is critical. Hydrogen sulfide and water vapor in biogas present the potential for corrosion - the compressor may have

sensitive components that will corrode. The biogas scrubber, with iron-coated bark as the operative cleaning device was installed to remove hydrogen sulfide.

Flare

There is a 3" pipe to transfer excess gas to the gravity flare. When gas was not being used for heating or electricity generation, the pipe was too small and a blow out in the pipe chase occurred. Keeping the gravity flare lit during windy conditions for high and low biogas flows is difficult. Two automatic spark ignition systems are needed to provide a spark where a flammable mixture of biogas and oxygen is present. The decision was made to change to a power flare, due to the windy conditions and highly variable biogas flows.

Previous Testing Results

New Hope View's anaerobic digester system, along with six others in New York 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. Five of the seven systems currently being monitored were also monitored in the past, including New Hope View. The following data was taken from an interim monitoring report written in 2007; the complete report is available on line at www.manuremanagement.cornell.edu and can also be obtained by contacting us.

Waste stabilization results

Samples of influent and effluent 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.

Biogas and energy production results

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. DDI used biogas to fire a boiler and any excess biogas was flared. The average daily biogas production 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 recorded values are shown. The electrical energy generated, purchased, sold, displaced, and used is 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. Electricity production sold by DDI to Niagara Mohawk was 100-kWh; this is not shown in the table.

Table 2. Anaerobic Digester Performance at New Hope View

Constituent	Statistic	Influent Constituent Concentration	Effluent Constituent Concentration	Change in concentration
pH (Std. units)	Avg.	7.48	7.68	--
	St. Dev.	0.47	0.23	
	CI	0.18	0.08	
	n	28	28	
TS (percent)	Avg.	9.81	7.25	26.2%
	St. Dev.	1.55	1.56	
	CI	0.58	0.58	
	n	28	28	
TVS (percent)	Avg.	8.21	5.81	29.3%
	St. Dev.	1.40	1.47	
	CI	0.52	0.55	
	n	28	28	
Volatile acid as Acetic acid (mg/kg)	Avg.	3,688	1,658	55.0%
	St. Dev.	1,005	1,416	
	CI	402	566	
	n	24	24	
COD (mg/kg)	Avg.	103,496	88,232	14.7%
	St. Dev.	66,317	12,620	
	CI	25,014	47,760	
	n	27	27	
DCOD (mg/l)	Avg.	22,797	17,711	22.3%
	St. Dev.	1,877	7,520	
	CI	3,028	2,890	
	n	26	26	
MAP (cfu/gram)	Avg.	330	1.5	99.1%
	St. Dev.	0.6	0.3	
	CI	0.4	0.2	
	n	17	15	
F. Coli. (mpn/gram)	Avg.	590	3.5	99.7%
	St. Dev.	0.9	0.9	
	CI	0.5	0.5	
	n	27	24	
TKN (mg/kg)	Avg.	3,682	3,717	-1.0%
	St. Dev.	641	928	
	CI	238	344	
	n	28	28	
NH_3-N (mg/kg)	Avg.	1,866	2,294	-22.9%
	St. Dev.	423	454	
	CI	157	168	
	n	28	28	
ON (mg/kg)	Avg.	1,815	1,815	21.6%
	St. Dev.	613	613	
	CI	227	227	
	n	28	28	
TP (mg/kg)	Avg.	561	556	0.9%
	St. Dev.	105	126	
	CI	39	47	
	n	28	28	

Table continued on next page

Constituent	Statistic	Influent Constituent Concentration	Effluent Constituent Concentration	Change in Constituent concentration
OP (mg/kg)	Avg.	298	325	-9.0%
	St. Dev.	92	84	
	CI	34	31	
	n	28	28	
K (mg/kg)	Avg.	2,425	-	-4.3%
	St. Dev.	341	-	
	CI	193	-	
	n	12	-	
Cu (mg/kg)	Avg.	50		--
	St. Dev.	19	-	
	CI	18	-	
	n	4	-	

Table 3. Electrical energy generated, purchased, sold, displaced and used at NHV from 1/04 to 5/05

	Monthly metered biogas (ft^3)	Average biogas CO_2 content (%) [1]	Monthly energy generated, purchased, sold, displaced, utilized (kWh)
Average	673,419	35.4	Produced: 0 Purchased: 54,848 Sold: 0 Displaced: 0 Farm used: 54,848
Range	3,101 1,242,700	32 50	Produced: 0 Purchased: 45,671 to 65,804 Sold: 0 Displaced: 0 Farm used: 45,671 to 65,804
Standard Dev.	386,110	--	--
Number samples	17 months	241	17 months

[1]Estimated CH_4 concentration is estimated by 100 – [CO_2]

<u>Results from current monitoring project</u>

The monitoring of New Hope View is continuing, following the Association of State Energy Research & Technology Transfer Institutions (ASERTTI) protocol, developed to standardize monitoring and reporting of anaerobic digestion systems.

Per the ASERTTI protocol, a pump test was conducted at the farm (10/10/2007) by pumping manure from the influent pit to a tanker truck and counting the number of strokes. Density of the manure was also determined. The results showed the Houle piston pump in the influent pit to have a volumetric pump efficiency of 83% when pumping influent to the digester.

Who to Contact

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[1]"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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