RENEWABLE
ENERGY

Wisconsin Agricultural Biogas Casebook

JULY 2008 EDITION

Prepared for Focus on Energy
by Joe Kramer
Energy Center of Wisconsin

Map shows Wisconsin farms with operational digesters.

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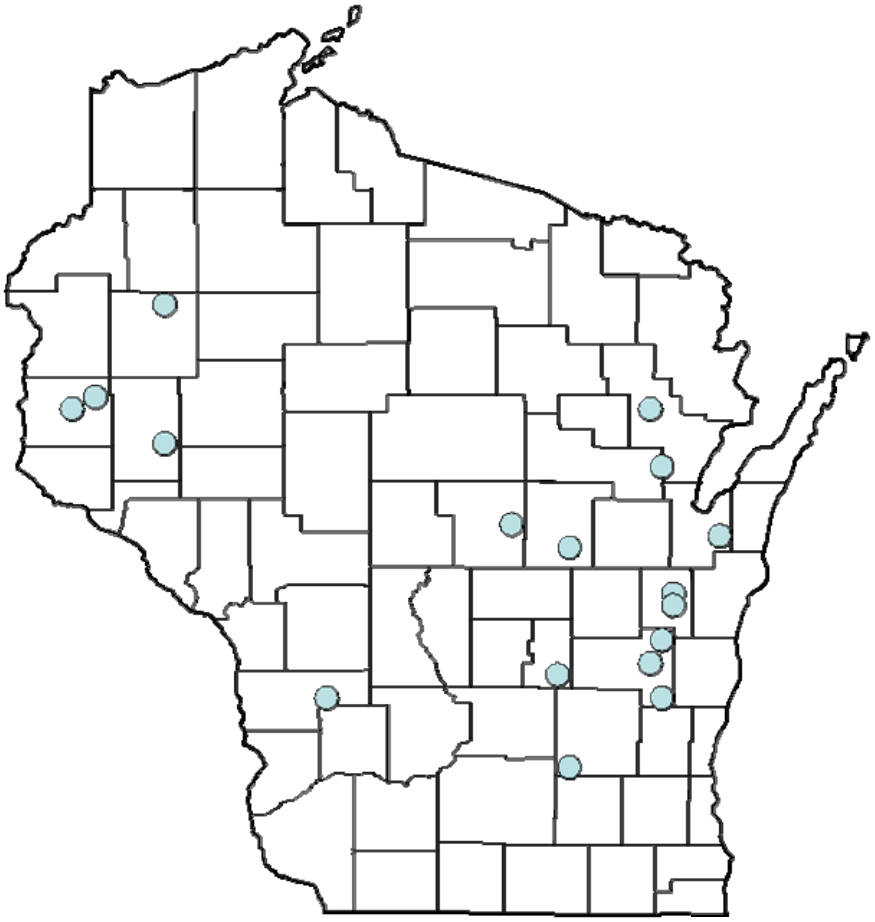

July 2008 Edition

Prepared for Wisconsin Focus on Energy – Renewables Program

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Common Abbreviations and Terms

Abbreviation	Meaning
AD	anaerobic digestion
ASBR	anaerobic sequencing batch reactor
CHP	combined heat and power
HRT	hydraulic retention time
RAS	return activated sludge
SRT	solids retention time
TPAD	temperature-phased anaerobic digester
Units	
AU	animal units
Btu	British thermal units
cfd (ft^3/day)	cubic feet per day
gpd	gallons per day
kW	kilowatt
kWh	kilowatt hours

Term	Definition
Acidogenic	acid producing
AgSTAR	a voluntary program jointly sponsored by the USEPA, US Department of Agriculture and the US Department of Energy, that encourages the use of biogas technologies at confined animal feeding operations that manage manures as liquids or slurries <http://www.epa.gov/agstar/index.htm>
Anaerobic Digestion (AD)	the biological, physical and or chemical breakdown of animal manure in the absence of oxygen
Anaerobic Sequencing Batch Reactor (ASBR)	a suspended growth reactor treating waste in four distinct phases over a 12-hour cycle, including digester feeding, digester mixing and gas production, biomass and solids settling, and liquid effluent discharge
Aquaponics	the symbiotic cultivation of plants and aquatic animals in a recirculating environment[1]
Biogas	the gas produced as a by-product of the anaerobic decomposition of livestock manure consisting of about 60-80 percent methane, 30-40 percent carbon dioxide, and trace amounts of other gases
Combined Heat and Power (CHP)	a system for producing electricity while capturing and using heat
Combined Phase	digestion phases are in the same vessel
Complete-Mix Digester	a controlled temperature, constant volume, mechanically

[1] This definition was taken from Wikipedia.com.

Term	Definition
	mixed vessel designed to maximize biological treatment, methane production and odor control as part of a manure management facility with methane recovery
Composting	a process of aerobic biological decomposition characterized by elevated temperatures
Construction Phase	the period during which the anaerobic digester is under construction
Covered Lagoon Digester	an anaerobic lagoon fixed with an impermeable, gas- and airtight cover designed to promote decomposition of manure and produce methane
Digestate	the liquid discharge of a manure treatment system
Digested Solids	the solids portion of digested materials
Digester	a vessel or system used for the biological, physical or chemical breakdown of animal manure
Hydraulic Retention Time (HRT)	average length of time any particle (liquid or solid) of manure remains in a manure treatment or storage structure. The HRT is an important design parameter for treatment lagoons, covered lagoon digesters, complete-mix digesters, and plug-flow digesters
Hydronics	a system for the circulation of heated liquid for various on-farm purposes
Induction Generator	a generator that will operate in parallel with the utility and cannot stand alone (induction generation derives its phase, frequency and voltage from the utility)
Influent	the materials entering the manure treatment system
Mesophilic	of, relating to, or being at a moderate temperature of about 100 degrees F
Methanogenic	methane producing
Microturbine	small-scale energy generation system that involves the direct combustion of gas and electricity generation in a single unit
Net Metering	an arrangement where distributed generation facilities can offset their associated load consumption and are compensated for any extra energy delivered to their electric provider as specified by their tariff
Operational Phase	biogas production is stabilized in the digester
Plug-Flow Digester	a constant volume, flow-through, controlled temperature biological treatment unit designed to maximize biological treatment, methane production, and odor control as part of a manure management facility with methane recovery
Psychrophilic	of, relating to, or being at a relatively low temperature of about 60 degrees F
Return Activated Sludge (RAS)	a process by which some of the digester bacteria are returned to the digester reducing the amount of energy

Term	Definition
	the biological system expends on growth of new bacteria as well as the reaction time required for digestion
Solids Retention Time (SRT)	average length of time any solid particle of manure remains in a manure treatment or storage structure. This is calculated by the quantity of solids maintained in the digester divided by the quantity of solids wasted each day (in digesters without RAS, HRT = SRT; in retained biomass reactors, the SRT exceeds the HRT).
Startup Phase	the digester is being fed manure, but biogas production is not yet stabilized
Struvite	a white crystalline substance consisting of magnesium, ammonium, and phosphorus in equal molar concentrations
Substrates	materials other than manure, bedding and wash water that is added to a digester for digestion
Synchronous Generator	a generator that can operate either isolated (stand-alone) or in parallel with the utility (i.e., it can run even if utility power is shut down). It requires a more expensive and sophisticated utility intertie to match generator output to utility phase, frequency and voltage.
Temperature-phased Anaerobic Digester (TPAD)	a controlled temperature, constant volume manure treatment system in which the manure treatment process is split into separate phases using different temperature ranges
Thermophilic	of, relating to, or being at a relatively high temperature of about 130 degrees F
Two Phase	acidogenic and methanogenic digestion phases occur in separate vessels

Introduction and Methodology

Anaerobic digestion of livestock manure is a manure treatment option with benefits. Raw manure is processed using a heated, oxygen free container, allowing digestion that began in the cow's stomach to continue and be enhanced. Products of anaerobic digestion of livestock manure include a combustible gas (i.e. biogas), liquid effluent, and digested solids. The gas is often used for energy generation (electricity and or heat). The liquid effluent is a low-odor fertilizer with characteristics closer to commercial fertilizers that provide more flexibility to farmers in land application. This can often be substituted for the increasingly expensive commercial fertilizers. The phosphorus (P) rich digested solids are commonly used as bedding for cows, but also have value as soil supplements either on agricultural lands or for landscapers and greenhouses.

Wisconsin continues to be one of the leading states in operating farm-based anaerobic digester systems. The Wisconsin Agricultural Biogas Casebook includes brief case studies of farm-based anaerobic digesters installed in Wisconsin. This report gives a snapshot with some history of the 17 operating anaerobic digester systems in Wisconsin as of June 2008. This information is presented to give those interested in digesters some insight into how these systems are working in Wisconsin. In addition, digester owners have generously shared experiences, ideas and innovations that may prove invaluable to those evaluating similar options for their farms.

The sources chosen for information in compiling these case studies are:

1. digester owners – information on farm characteristics, operation, and experiences
2. technology providers – digester designs and characteristics, assumptions about the farm that went into designing the digesters, biogas utilization systems
3. utility representative – energy generation, power purchase agreements, interconnection issues

Sources were interviewed over the period of March 2008 through July 2008. Digester owners were given the opportunity to review draft versions of their case study write-ups to improve accuracy. Electricity generation information was requested from utilities (with the owners' prior written consent) for the previous 18 months for all systems that have utility power purchase agreements. This information was ultimately obtained for 12 of the 15 systems generating electricity from biogas.

This casebook represents an early step in a larger and ongoing effort to provide coordinated and consistent digester performance information to the general public using uniform methods. The Association of State Energy Research and Technology Transfer Institutions (ASERTTI), USDA Rural Development and EPA AgSTAR program have worked together to produce a standardized performance protocol.[2] Information gathered in this casebook is broader in scope and generally lacks independent third party verification (application of the protocol to these systems was well beyond the scope of this project). Focus on Energy (Focus) has instituted contracting measures in their grant

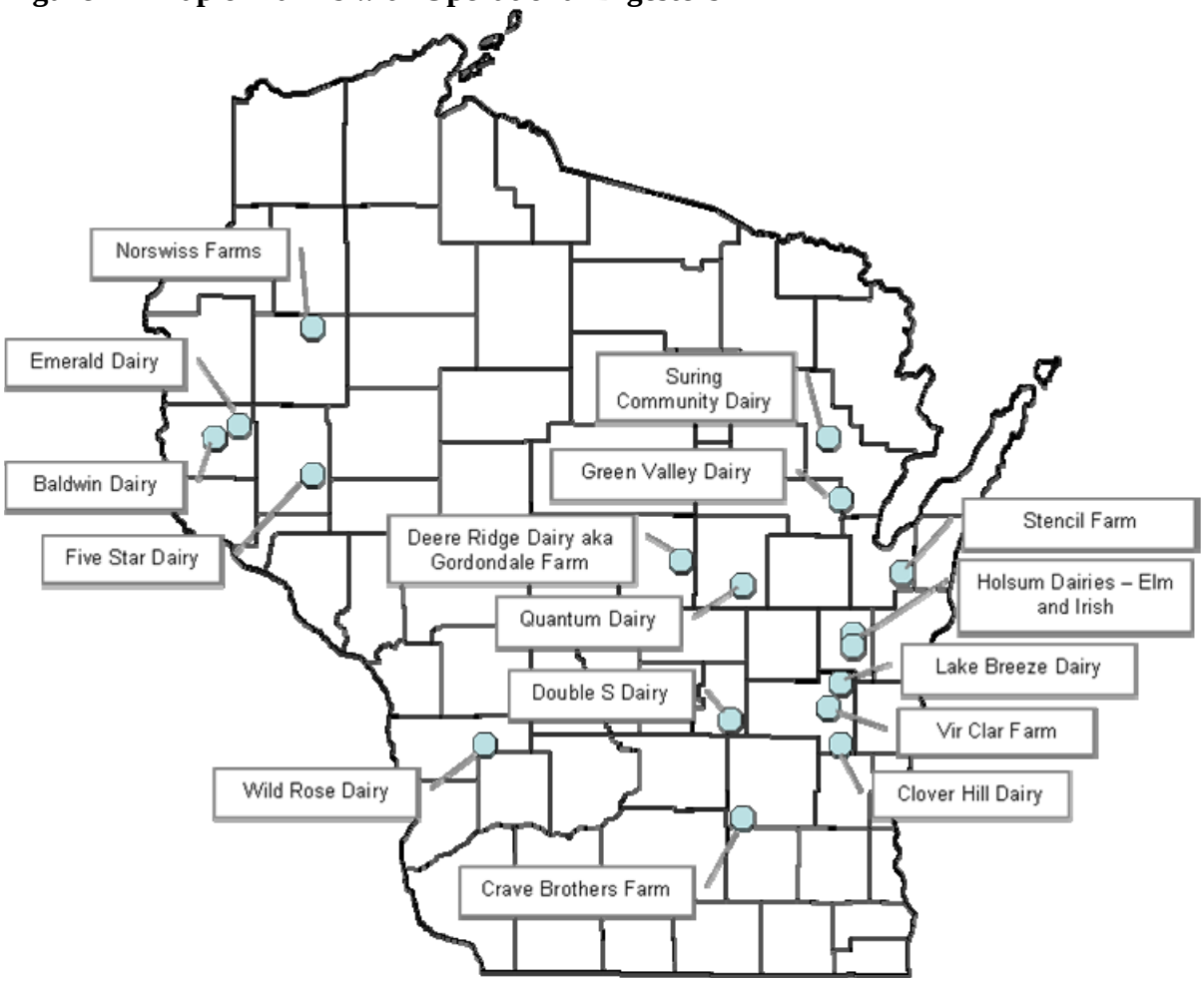
[2] A copy of the current protocol and additional information can be obtained from the ASERTTI Web site at: http://www.asertti.org/programs/digester/index.html.

language to enable monitoring and collection of more detailed information for current grant recipients which will make it easier to include more elements of the protocol for these systems in future editions of the casebook. Current plans are to include greater detail on system economics and biogas production, and to include consistent protocol adherent data whenever possible.

Summary Information

As of July 2008, there were 17 farms with operating anaerobic digester systems in Wisconsin. This number includes five farms that have two digesters bringing the total digesters in the state to 22. All of the operational systems are on dairy farms.[3] The farms with digesters are spread throughout the state. Figure 1 below shows a map of the general locations for these farms.

Figure 1 – Map of Farms with Operational Digesters



Additional information on the farms including number of animals feeding the digester, how manure is collected and type of bedding used is listed in Table 1 on the following page.

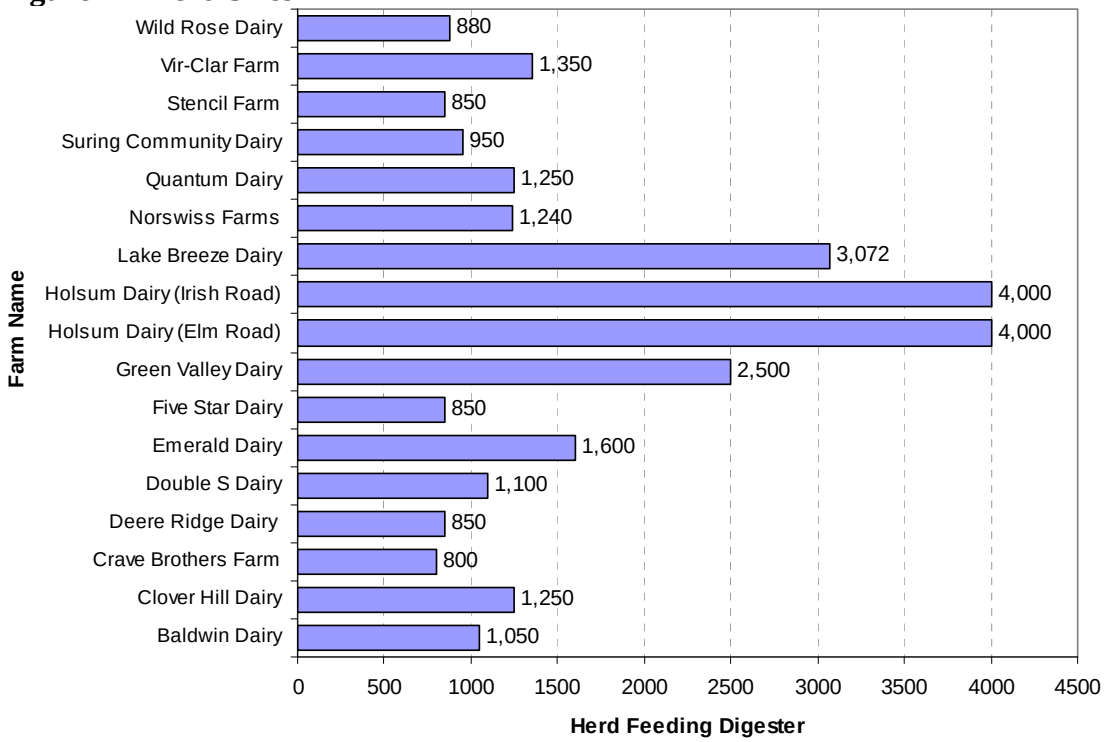
[3] Maple Leaf Farms, a duck farm in Franksville, Wisconsin, was the only non-dairy livestock operation with an anaerobic digester. They closed their Wisconsin operations in May of 2008.

Table 1 – Farm Details

Farm name	Locality	Herd Feeding Digester	Collection Type	Collection Frequency	Bedding Type
Baldwin Dairy	Baldwin	1,050	scrape	4x a day	digested solids
Clover Hill Dairy	Campbellsport	1,250	scrape	continuous	digested solids
Crave Brothers Farm	Waterloo	800	gravity flow to pit	continuous	digested solids
Deere Ridge Dairy (aka Gordondale Farms)	Nelsonville	850	scrape	3x a day	digested solids
Double S Dairy	Markesan	1,100	scrape	3x a day	digested solids
Emerald Dairy	Emerald	1,600	scrape	3x a day	digested solids
Five Star Dairy	Elk Mound	850	scrape	3x a day	digested solids
Green Valley Dairy	Green Valley	2,500	scrape	3x a day	digested solids
Holsum Dairy (Elm Road)	Hilbert	4,000	scrape	3x a day	digested solids
Holsum Dairy (Irish Road)	Hilbert	4,000	scrape	3x a day	digested solids
Lake Breeze Dairy	Malone	3,072	flush	hourly	sand
Norswiss Farms	Rice Lake	1,240	scrape	3x a day	digested solids
Quantum Dairy	Weyauwega	1,250	scrape	3x a day	digested solids
Stencil Farm	Denmark	700-1,000	scrape	hourly	digested solids
Suring Community Dairy	Suring	950	scrape	continuous	digested solids
Vir-Clar Farm	Fond du Lac	1,350	scrape	continuous	digested solids
Wild Rose Dairy	La Farge	880	scrape	3x a day	kiln-dried sawdust

Figure 2 illustrates the herd sizes on farms with operating digesters.

Figure 2 – Herd Sizes



Herd sizes for operational digester systems range from about 800 to 4,000 head. The AgSTAR Handbook gives a minimum number of dairy cows and steers of about 500 for successful use of an anaerobic digester.[4]

There are several system types being installed and a total of seven different digester design companies with active systems in Wisconsin. Table 2 below lists some details on individual systems and design companies, and Table 3 shows the number of systems for each company installed in Wisconsin.

Table 2 – Digesters and Designers

Dairy Name	Type of Digester(s)	System Designer	Temperature	Operational
Baldwin Dairy	modified mixed plug-flow	Bob Komro	mesophilic	2006
Clover Hill Dairy	mixed plug-flow	GHD, Inc.	mesophilic	2007
Crave Brothers Farm	complete mix	Clear Horizons, LLC	mesophilic	2007
Deere Ridge Dairy	mixed plug-flow	GHD, Inc.	mesophilic	2002
Double S Dairy	mixed plug-flow	GHD, Inc.	mesophilic	2004
Emerald Dairy	mixed plug-flow	GHD, Inc.	mesophilic	2006
Five Star Dairy	complete mix	Microgy, Inc.	thermophilic	2005
Green Valley Dairy	complete mix (x2)	Biogas Direct, LLC	mesophilic	2007
Holsum Dairy (Elm Road)	mixed plug-flow (x2)	GHD, Inc.	mesophilic	2007
Holsum Dairy (Irish Road)	mixed plug-flow (x2)	GHD, Inc.	mesophilic	2004
Lake Breeze Dairy	mixed plug-flow (x2)	GHD, Inc.	mesophilic	2006
Norswiss Farms	complete mix	Microgy, Inc.	thermophilic	
Quantum Dairy	mixed plug-flow	GHD, Inc.	mesophilic	2005
Stencil Farm	plug-flow	RCM Digesters, Inc.	mesophilic	2002
Suring Community Dairy	complete mix	American Biogas Co., Inc.	mesophilic	2006
Vir-Clar Farm	complete mix (x2)	Biogas Direct, LLC	mesophilic	2004
Wild Rose Dairy	complete mix	Microgy, Inc.	thermophilic	2005

Table 3 – Total Systems for Designers

Digester Type	Designer	Farms	Digesters
Mixed plug-flow, mesophilic	GHD, Inc.	8	11
Modified mixed plug-flow, mesophilic	Komro International	1	1
Plug-flow	RCM Digesters, Inc.	1	1
Complete mix, thermophilic	Microgy, Inc.	3	3
Complete mix, mesophilic	Biogas Direct, LLC	2	4
Complete mix, mesophilic	American Biogas Co., Inc.	1	1
Complete mix, mesophilic	Clear Horizons	1	1
Total		17	22

[4] The AgSTAR Handbook can be downloaded at: http://www.epa.gov/agstar/resources/handbook.html. Technological and practice innovations may make digester use an economic and technical possibility for farms with smaller herd sizes.

The most common choice for digester owners to use their biogas is to run it through an engine generator set to generate electricity for sale. Table 4 lists the biogas uses and information on the equipment.

Table 4 – Biogas Uses

Farm name	Biogas utilization	Type of prime mover	Generator Manufacturer and Capacity
Baldwin Dairy	flared	none	none
Clover Hill Dairy	electricity and heat	engine generator set, synchronous	Guascor MGG-355, upgraded to 300 kW
Crave Brothers Farm	electricity and heat	engine generator set, synchronous	Deutz, (spark ignited), 230 kW
Deere Ridge Dairy	electricity and heat	engine generator set, induction	Caterpillar 140 kW net, NG natural gas rated
Double S Dairy	electricity and heat	engine generator set, induction	Caterpillar 200 kW
Emerald Dairy	upgrade gas to pipeline quality and sale	biogas conditioning for sale into pipeline	none
Five Star Dairy	electricity and heat	engine generator set, synchronous, but not operated to stand alone*	Waukesha 775 kW, 750 kW net
Green Valley Dairy	electricity and heat	engine generator set, synchronous	Caterpillar 600 kW, ordered a second engine
Holsum Dairy (Elm Road)	electricity and heat	two engine generator sets, synchronous	Guascor 2 sets at 600 kW each, 1200 kW total net
Holsum Dairy (Irish Road)	electricity and heat	2 engine generator sets, induction	Deutz 500 kW and Caterpillar 200 kW
Lake Breeze Dairy	electricity and heat	2 engine generator sets, synchronous	Caterpillar 300 kW x2 (600 kW)
Norswiss Farms	electricity and heat	engine generator set, synchronous, but not operated to stand alone*	Jenbacher JGS316 GS-B.L. (made in Austria) 848 kW production engine
Quantum Dairy	electricity and heat	engine generator set, induction	Caterpillar 300 kW turbo charged
Stencil Farm	electricity and heat	engine generator set, synchronous	Caterpillar 3306 140 kW, 123 kW net
Suring Community Dairy	electricity and heat	engine generator set, synchronous	Dreyer & Bosse 250 kW, 230 kW net, engine is dual fuel using 20% diesel
Vir-Clar Farm	electricity and heat	engine generator set, synchronous	Caterpillar/SEVA, 350 kW
Wild Rose Dairy	electricity and heat	engine generator set, synchronous, but not operated to stand alone*	Waukesha 775 kW, 750 kW net

* The engine generator sets owned by Dairyland Power at Five Star, Norswiss, and Wild Rose dairies are synchronous systems which can be set up with a transfer switch so that they can continue to supply power to the farm during a system outage. These sets, however, are used primarily to provide voltage support in local distribution networks and are therefore configured to shut down in the event of a system outage.

Farm-scale biogas systems in Wisconsin have a total installed generation capacity of about 7.3 megawatts. In addition to the farms generating electricity, one farm is currently flaring the biogas and another is selling it to a third party. Owners of these two

operations are part of a group that has plans to install a gas pipeline linkage to allow them to upgrade their biogas and inject it into the natural gas distribution system as renewable natural gas. Additional information on these efforts is included in the case studies of Baldwin and Emerald dairies.

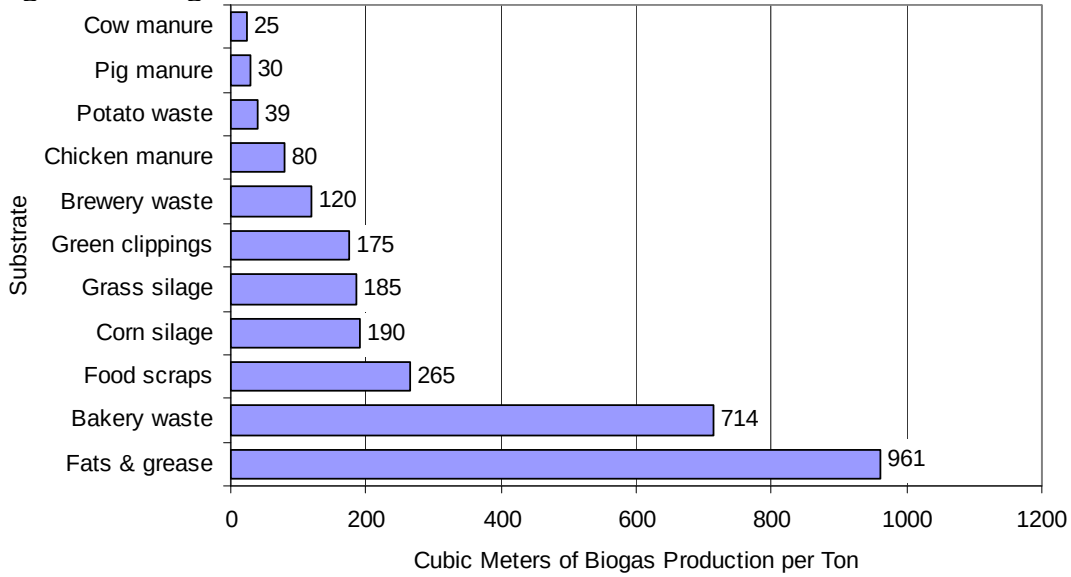
Eight digester owners are adding other substrates to their digesters in addition to the usual manure, bedding and wastewater. Some systems, such as those installed by Microgy, have inclusion of off-farm food wastes, and the resulting increase in biogas production is an integral part of their business models. Table 5 below lists farms that have reported addition of other feedstocks.

Table 5 – Other Wastes Being Digested

Farm name	Other Waste Added
Crave Brothers Farm	whey and other wastes added (some seasonal)
Five Star Dairy	industrial food-waste grease
Holsum Dairy (Elm Road)	waste substrates from 3 food processing industries
Holsum Dairy (Irish Road)	waste substrates from 3 food processing industries
Lake Breeze Dairy	corn syrup added as needed to supplement manure fuel value.
Norswiss Farms	industrial food-waste grease
Vir-Clar Farm	bunker waste, moldy feed, whatever not eaten by the cows (on-farm wastes)
Wild Rose Dairy	industrial food-waste grease

Figure 3 gives an estimate of the biogas production potential from various substrates. Manure is one of the lowest potential biogas producers.

Figure 3 – Biogas Generation Potential of Substrates

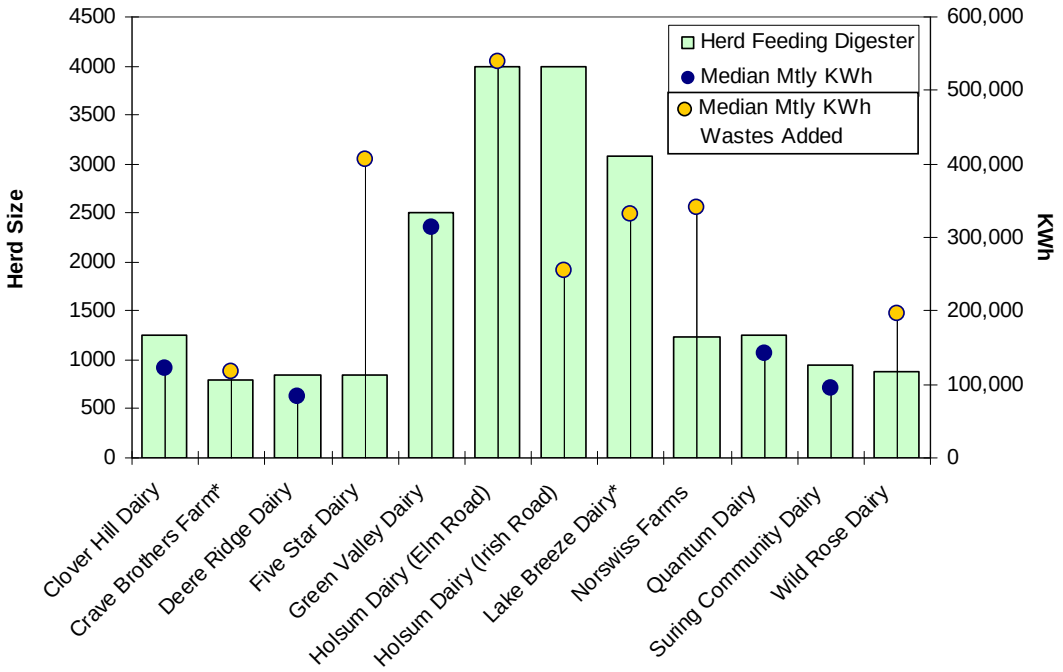


Source: Data derived from www.biogas-energy.com, © 2007 Biogas Energy, Inc., translated from: Basisdaten Biogas Deutschland, Marz 2005,: Fachagentur Nachwachsende Rohstoffe e.V.

Biogas generation information was not available for many of the systems in this report due to the lack of gas metering on older systems. Newer systems include biogas metering and this statistic is expected to be included in future editions of this casebook.

Each system that is generating electricity has a purchase agreement with their servicing utility and, therefore, with the owner's permission, a consistent measure of electricity generated was obtained from the utility. Figure 4 shows the average herd sizes and the median kWh of electricity generated from biogas over the 18 month period of January 2007 through June 2008. The median measure was chosen to give an indication of what "typical" monthly generation looks like. Medians were calculated based only on months in which the digester and energy generation equipment were operational (some systems only came on line recently and others had significant engine downtimes). Monthly generation profiles for individual systems are included in the case studies.

Figure 4 – Herd Sizes and Median Monthly Electricity Generation



* Crave Brothers Farm has only one year of generation data. Lake Breeze Dairy has only 16 months of generation data.
Note : The yellow dots are for digesters that regularly or periodically add wastes other than manure and wastewater to their digesters.

In general, those farms that add additional substrates to be co-digested with the manure see proportionally higher energy generation; these are represented on the graph by the yellow dots. There are two exceptions for this data. Holsum Dairy Irish Road has undersized energy generation equipment (relative to their herd size) and is therefore not able to use all the biogas they produce for electricity production. Lake Breeze Dairy is adding off farm wastes to compensate for inconsistent manure addition due to construction projects on the farm. More details on these operations are included in the case studies.

Table 6 shows some details about the business models for the digester installations and utility contracts.

Table 6 – Business Models and Utility Contract Types

Farm name	Business Model	Utility	Utility Contract Type
Baldwin Dairy	farm owns digester, plans to sell biogas	St Croix Electric Cooperative	na
Clover Hill Dairy	farm owns all, sells electricity to utility	We Energies	sell all
Crave Brothers Farm	Clear Horizons owns digester and energy generation, farmer buys solids back from CH, We Energies buys electricity.	We Energies	buy excess
Deere Ridge Dairy	farm owns digester and sells biogas to utility, utility owns and operates generator on site	Alliant Energy	sell biogas
Double S Dairy	farm owns all, sells electricity to utility	Alliant Energy	sell all
Emerald Dairy	farm owns digester, sells biogas to third party	St Croix Electric Cooperative	none, contract sales of biogas to a third party
Five Star Dairy	Microgy built, operates and maintains digester, Dairyland buys biogas and owns/operates genset and scrubber, sells elec to member coops, gas sales and carbon credits buy down debt for farmer on digester	Dairyland Power Cooperative	biogas sales to Dairyland Power, output goes into Dairyland system and is made available to member coops
Green Valley Dairy	farm owns all, sells electricity to utility	We Energies	sell all
Holsum Dairy (Elm Road)	farm owns all, sells electricity to utility	Wisconsin Public Service	sell all
Holsum Dairy (Irish Road)	farm owns all, sells electricity to utility	Wisconsin Public Service	sell all
Lake Breeze Dairy	farm owns all, sells electricity to utility	We Energies	sell all
Norswiss Farms	Microgy built, operates and maintains digester, Dairyland buys biogas and owns/operates genset and scrubber, sells elec to member coops, gas sales and carbon credits buy down debt for farmer on digester	Dairyland Power Cooperative, Barron Electric Cooperative	biogas sales to Dairyland Power, output goes into Dairyland system and is made available to member coops
Quantum Dairy	farm owns all, sells electricity to utility	We Energies	sell all
Stencil Farm	farm owns all, sells electricity to utility	Wisconsin Public Service Corporation	sell all
Suring Community Dairy	farm owns all, sells electricity to utility	Wisconsin Public Service	sell all
Vir-Clar Farm	farm owns all, sells electricity to utility	Alliant Energy	sell all
Wild Rose Dairy	Microgy built, operates and maintains digester, Dairyland buys biogas and owns/operates genset and scrubber, sells elec to member coops, gas sales and carbon credits buy down debt for farmer on digester	Dairyland Power Cooperative	biogas sales to Dairyland Power, output goes into Dairyland system and is made available to member coops

Case Studies

This section includes brief case studies of operational systems in Wisconsin. As of this writing, all farm-based anaerobic digester systems in Wisconsin were on dairy operations.

Baldwin Dairy – Baldwin, Wisconsin

Farm Name:	Baldwin Dairy	**Location:**	Baldwin
Farm Type:	dairy	**Herd Size:**	1,050 head (milking)
Collection Method:	scrape	**Bedding Type:**	digested solids
Digester Type:	modified mixed plug flow	**Design Temperature:**	100 deg F
Digester Notes:	not available		
Design Capacity:	1,200 head	**Date Operational:**	2006
Design HRT:	not available	**Current HRT:**	22 days
Design Solids %:	not available	**Current Solids %:**	8%
Biogas Use:	heat and flared, plans to upgrade and sell	**Utility Contract:**	none
Installed Capacity:	not applicable	**Prime Mover Brand:**	not applicable
Solids Separation:	yes, screw press	**Solids Use:**	bedding, sell about 20%
Ownership:	farm owns digester		
Digester Designer:	Komro International, LLC	**Utility:**	St. Croix Electric Coop.

Baldwin Dairy is located in Baldwin, Wisconsin, in central St. Croix County. It has a current milking herd size of about 1,050 Holsteins. This herd and milking operation produce about 30,000 gallons of manure and water per day at about eight percent solids, which is scrape collected four times per day and preheated prior entering the digester. They use a Fan screw press solids separator post digestion. Figure 5 below shows some of the barns at Baldwin Dairy. The former manure storage system for the farm was a covered anaerobic lagoon.

Figure 5 – Baldwin Dairy

Photo courtesy of Agri-Waste Energy, Inc.

Digester. A description of the digester from the designer was not available. The owner provided the following information. Manure is added to the digester four times per day. The digester is a modified mixed plug flow digester that operates in the mesophilic temperature range with liquid jet mixing. Liquid is sucked out on the bottom and re-injected on the sides. They are also returning activated sludge from the last stage to improve digestion efficiency by keeping more active bacteria in the system. The system is designed to use heat from the effluent to help pre-heat the manure going in. This is the first system of this type designed by Komro International. Influent (manure and wash-water) is pumped into the digester four times per day. The hydraulic residence time (HRT) is currently about 21 days, and the operating digester temperature is between 95 and 100 degrees F.

Outputs and Uses.
The owner reports that the system is putting out nearly 130,000 cubic feet per day (CFD) of biogas. They built their own biogas boiler to help heat the digester, and the rest is currently flared. The system produces 20-30 tons of digested solids per week at about 67 percent moisture. They are selling 20 percent of this to neighboring farms for use as bedding. The rest they use on farm for bedding. They are evaluating options for building a biogas pipeline from Baldwin and another local dairy to transport biogas to an upgrading facility near the natural gas pipeline injection point. The facility will use water column technology. This project is expected to move forward if financing is approved. During the summer of 2008 they began building a greenhouse complex to use biogas from the digester. They expect to use biogas for heat, and to eventually add absorption chilling and possibly electricity generation. Some possible uses for the greenhouses include aquaponics so they could grow algae for biodiesel production and tilapia (i.e., an edible fresh water fish capable of thriving in warm nutrient rich water).

History and Comments.
The owners were early adopters of anaerobic digestion technology when they installed covered lagoons at this and the Emerald Dairy in 1998 and 1999 respectively. When they did not get the digestion quality or biogas production they wanted, due to the cooling of the lagoons in cold months, the owners opted to replace them with heated systems. The owner had no additional comments on this system.

Information Sources.

John Vrieze – Baldwin Dairy

Clover Hill Dairy – Campbellsport, Wisconsin

Farm Name:	Clover Hill Dairy	**Location:**	Campbellsport
Farm Type:	dairy	**Herd Feeding Digester:**	1,250 head (1,100 milking)
Collection Method:	scrape	**Bedding Type:**	digested solids
Digester Type:	mixed plug-flow	**Design Temperature:**	100 deg F
Digester Notes:	two-stage, below grade concrete tank, u-shaped, gas-induced mixing, RAS		
Design Capacity:	1,050 head	**Date Operational:**	2007
Design HRT:	20 days	**Current HRT:**	not available
Design Solids %:	8-9%	**Current Solids %:**	6%
Biogas Use:	electricity and heat	**Utility Contract:**	yes
Installed Capacity:	300 kW	**Prime Mover Brand:**	Guascor
Solids Separation:	yes, screw press	**Solids Use:**	bedding, sold, land applied
Ownership:	farm owns digester and energy generation		
Digester Designer:	GHD, Inc.	**Utility:**	We Energies, Inc.

Clover Hill Dairy is located in Campbellsport, Wisconsin, in southeastern Fond du Lac County. They have a herd size of 1,250 Holsteins, and use digested solids for bedding. Manure is scrape-collected continuously throughout the day. The volume of manure and liquids produced daily for treatment is not available, but has an average solids content of about six percent. The farm's former manure storage system was a lagoon and slurrystore.

Digester.

The owner decided to install a mixed plug-flow digester designed by GHD, Inc. of Chilton, Wisconsin. The system is a U-shaped, below grade, concrete structure with a fixed concrete cover. Figure 6 below is a schematic of their standard design.

Figure 6 – GHD Digester Design Schematic

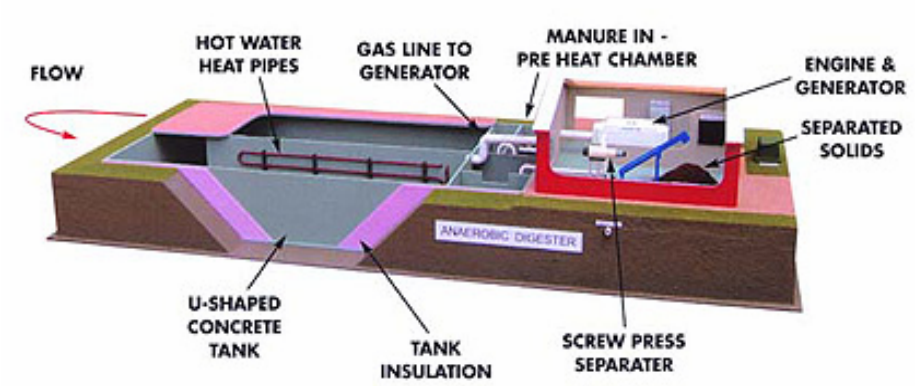


Image courtesy GHD Inc.

Manure and wastewater enter and exit on the same end of the digester (i.e., on the right end of the diagram), making a 180 degree turn at the enclosed end (i.e., left end). The design theoretically will allow expansion of the digester by extending the structure on the

enclosed end. The central shared wall holds hot water piping that heats the manure and helps conserve heat in the system by reducing outside surface area of the structure. The structure includes two distinct phases or digestion zones and is described as a two-phase system in which manure from the first phase flows directly into the second. The digester operates in the mesophilic range (design temperature of about 100 degrees F) and returns activated sludge. The design HRT is 20 days. The biogas is reintroduced into the digester along the bottom and the gas percolation through the manure provides passive mixing of the contents.

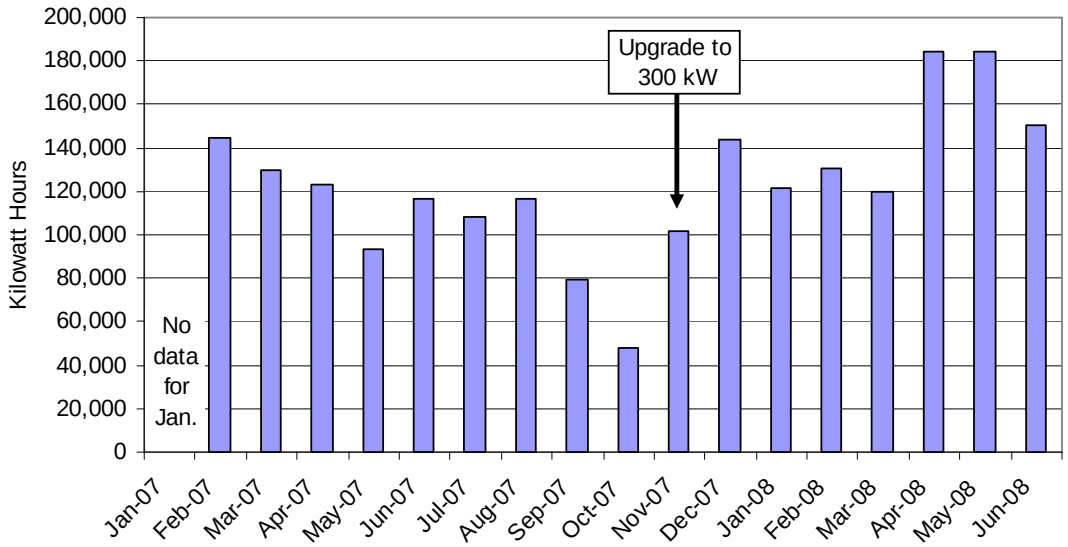
Outputs and Uses.

Biogas is treated with a passive hydrogen sulfide removal system and a chilling unit for condensate removal. It is then run through a 300 kW Guascor engine generator set (pictured in Figure 7 below) to produce electricity.

Figure 7 – Guascor 300 kW Engine Generator Set

Figure 8 on the following page shows the recent generation history for this system.

Figure 8 – Clover Hill Electricity Generation History



Waste heat from the water jacket and exhaust is captured and used for heating the digester, milk house, parlor and lanes. They are looking for other uses for heat as well. They do not have a boiler backup system to heat the digester when the engine is not operating.

They use a Bauer and Ireland brand screw press and produce about 100 tons of digested solids per week. The farm uses about 70 tons for both bedding and field application, and sells about 30-35 tons per week for $20 per ton to a dairy farm for bedding. Their solids storage area is shown in Figure 9.

Figure 9 – Digested Solids from Clover Hill Digester

The farm retains ownership of the carbon credits and has signed on with the Pure Farm Energy® Producer Network of farm energy project owners.[5]

History.
The digester was installed in 2006 and was operational in early 2007. The owner reported that construction and contracting went "smoothly." But the power purchase agreement with the utility was problematic and time-consuming. It took a while to get

[5] The Pure Farm Energy® Producer Network is an aggregator and certifier of carbon credits for farm energy project owners. http://www.agrefresh.org/401.html

the purchase and interconnect details worked out. They originally had a smaller engine generator set but after two to three months realized they were producing enough biogas to use a 300 kW system. They are also getting more usable heat from the energy generation than they expected and are still exploring ways to use it effectively. They are pleased with the large reduction in odor from the lagoon and land application of digested manure. The owner noted that they can also apply the effluent on to growing crops without burning or other adverse effects, which is not possible with raw manure.

Information Sources.
Joseph Bonlender – Clover Hill Dairy
Chris Bonlender – Clover Hill Dairy
Melissa VanOrnum – GHD, Inc.
Randy Jerome – We Energies, Inc.

Crave Brothers Farm – Waterloo, Wisconsin

Farm Name:	Crave Brothers Farm	**Location:**	Waterloo
Farm Type:	dairy	**Herd Size:**	800 head (milking)
Collection Method:	gravity flow to pit	**Bedding Type:**	digested solids
Digester Type:	complete mix	**Design Temperature:**	99 deg F
Digester Notes:	above ground steel tank, proprietary mixing tech, remotely managed via Web		
Design Capacity:	900 head (phase 1)	**Date Operational:**	2007
Design HRT:	25 days	**Current HRT:**	not available
Design Solids %:	12%	**Current Solids %:**	11-14%
Biogas Use:	electricity and heat	**Utility Contract:**	yes, buy excess
Installed Capacity:	230 kW	**Prime Mover Brand:**	Deutz
Solids Separation:	yes, screw press	**Solids Use:**	bedding, composted and sold as soil supplement
Ownership:	designer owns digester and energy generation		
Digester Designer:	Clear Horizons, LLC	**Utility:**	We Energies, Inc.

Crave brothers operate a dairy farm and specialty cheese production facility in Waterloo, Wisconsin, in southwestern Dodge County. They have 800 head of milking cows producing about 26,000 gallons of manure per day and use digested solids for bedding. Manure gravity-flows and drops through a slotted floor to a collection pit. They also add about 2,500 gallons of whey and other waste products from their cheese operations per day with some seasonal variation. Their former manure storage system was a pit.

Digester.
The Crave Brothers Farm partnered with Clear Horizons, LLC to have a digester installed. This is the first system of its kind built by Clear Horizons for a livestock operation. It can be monitored and operated remotely by PC using a Web interface. The digester is an above ground mesophilic complete mix stainless steel tank system. As a complete mix digester it does not require return of activated sludge because, by design it retains bacteria. The target operating temperature is 99 degrees F, and it has an HRT of 25 days. Operating their own system, Clear Horizons has been able to reasonably maintain these target parameters. Figure 10 below shows a schematic of the Clear Horizons system.

Figure 10 – Schematic of Clear Horizons System

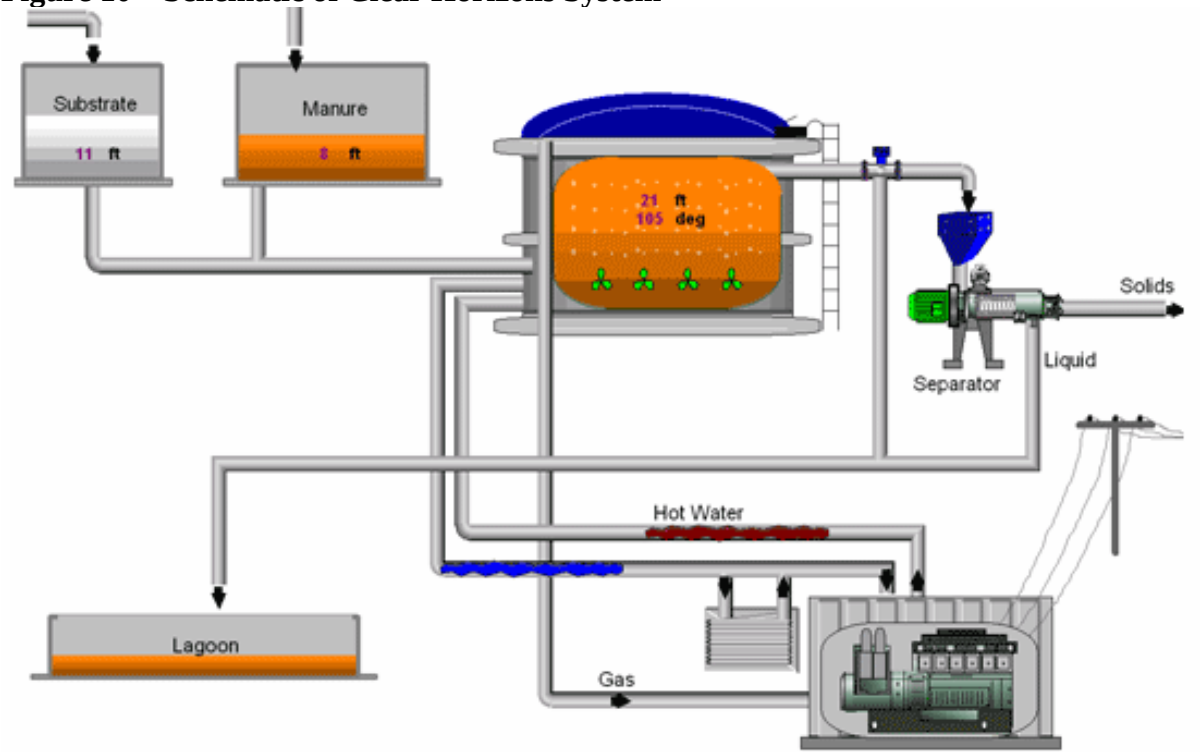


Image courtesy of Clear Horizons LLC.

The business model for this digester is Clear Horizons develops, owns, operates and maintains the digester, and generation equipment. It has rights to the products and credits associated with the digestion and energy generation. The farm buys solids back from Clear Horizons for bedding and retains the nutrient-rich liquid for field application. Figure 11 shows the digester.

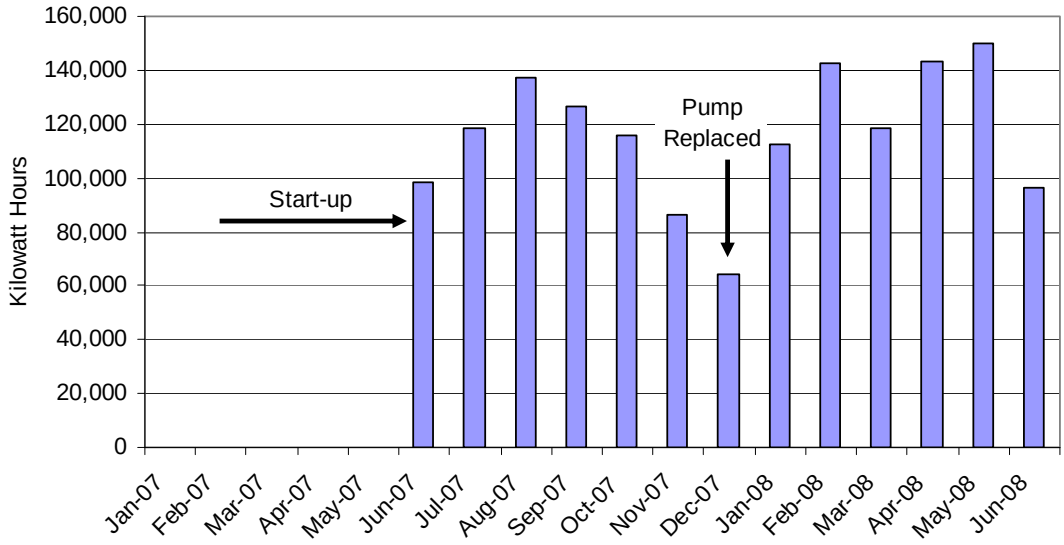
Figure 11 – Clear Horizons Digester at Crave Brothers Farm

The Clear Horizons digester uses a patented mixing technology. The external mixer mounting apparatus is pictured in Figure 12.

Figure 12 – Clear Horizons Mixer

Outputs and Uses.
The digester produces biogas which is treated with passive hydrogen sulfide removal and a chilling unit for condensate removal. It is then fed into a 230 kW Deutz synchronous spark-ignited engine generator set. Electricity is used to power the digester system with excess sold to We Energies. Heat captured from the engine generator set is used for digester heating, substrate tank heating, and heating of pumping and separation rooms at the site. Clear Horizons has a portable LP gas boiler that is designed mainly for startup of systems, but is also available for digester heating when engines are undergoing maintenance or repair. Figure 13 below shows the monthly gross energy generation for the Crave Brothers system.

Figure 13 – Electricity Generation for Crave Brothers System



Solids are separated using a Vincent KP-10 screw press solids separator. Clear Horizons produces a trademarked Energro potting mix using digested fiber, perlite and vermiculite, which it markets in bags. The sales of bedding to the farm and Energro amount to about two thirds of the income generated from the digester. Figure 14 on the following page shows the bagged commercial potting mix product.

Figure 14 – Digested Solids Potting Mix

History and Comments.
This is the first system Clear Horizons has produced after researching other plants in Wisconsin and Germany. Their goal was to have a system that can be remotely operated (via an Internet-linked workstation) and to maximize the long term rate of return. Dan Nemke of Clear Horizons suggested that as a first of its kind system, they probably had a little longer learning curve than future systems will. They are doing extensive real-time monitoring of the systems to optimize operation.

Karl Crave (also representing Crave Brothers Farm) notes that Clear Horizons has done full-scale testing of multiple substrates to verify biogas production. They have also further developed composting methods and products to improve the quality of the digested fiber

Mr. Crave had a "great group" of local contractors and construction and start-up went smoothly. In five months, the project went from groundbreaking to consistently producing electricity. The farm is now able to focus more effort on their prime businesses: livestock and cheese operations. The option to pass on manure management duties to Clear Horizons was very welcome. As owners of the digester and the energy generation, Clear Horizons also handled utility power purchase and interconnect negotiations, as well as politics and permitting associated with the project.

Sources.
Dan Nemke – Clear Horizons, LLC
Karl Crave – Clear Horizons, LLC

Deere Ridge Dairy / Gordondale Farms – Nelsonville, Wisconsin

Farm Name:	Deere Ridge Dairy / Gordondale Farms	**Location:**	Nelsonville
Farm Type:	dairy	**Herd Size:**	850 head (milking)
Collection Method:	scrape	**Bedding Type:**	digested solids
Digester Type:	mixed plug-flow	**Design Temperature:**	100 deg F
Digester Notes:	two-stage, below grade concrete tank, u-shaped, gas-induced mixing, RAS		
Design Capacity:	750 head	**Date Operational:**	2002
Design HRT:	20 days	**Current HRT:**	22 days
Design Solids %:	8-9%	**Current Solids %:**	not available
Biogas Use:	electricity and heat	**Utility Contract:**	yes
Installed Capacity:	140 kW	**Prime Mover Brand:**	Caterpillar
Solids Separation:	yes, screw press	**Solids Use:**	bedding and land applied
Ownership:	farm owns digester, utility owns energy generation		
Digester Designer:	GHD, Inc.	**Utility:**	Alliant Energy, Inc.

Deere Ridge Dairy or Gordondale Farms is an 850 Holstein dairy operation in Nelsonville, Wisconsin in eastern Portage County. Some 30,000 gallons of manure, bedding and milking parlor wastes are generated per day and scrape-collected at two hour intervals. They use digested solids for bedding and their former manure storage system was a pit.

Digester.

Deere Ridge Dairy installed the first farm-scale digester designed by GHD, Inc. in 2001. It is a below-grade, U-shaped mixed plug-flow digester, with a fixed concrete cover. It uses biogas-induced mixing and return of activated sludge. The digester has two distinct digestion phases within the main chamber. Figure 15 below shows the digester and the adjacent equipment building.

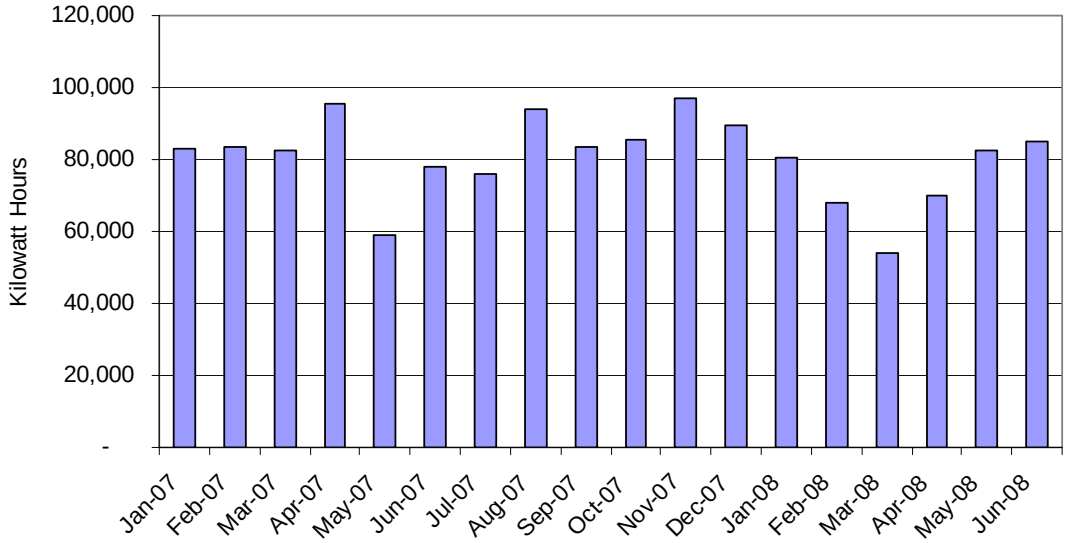
Figure 15 – Deere Ridge Dairy Digester

Photo courtesy of GHD, Inc.

The digester has a design operating temperature of 100 degrees F, and a target influent solids content of eight to nine percent. The design hydraulic residence time is 22 days. They do solids separation after digestion with a Fan brand screw press.

Outputs and Uses.
Biogas from their digester is treated with a water trap. It is sold to Alliant Energy and run through their on-site Caterpillar 140 kW (net) engine generator set. Alliant Energy is responsible for the operation and maintenance of the energy generation equipment. Figure 16 shows the monthly kW hours of electricity generated from January 2007 through June 2008.

Figure 16 – Deere Ridge Dairy Electricity Generation



Captured heat from the engine (via water jacket and exhaust) is used to heat the digester and milking parlor, and for facility water heating. They do not have a backup boiler for digester heat on site in the event the engine should be down for repairs or maintenance. However, they have the option of having GHD bring in a boiler if needed.

All digested solids are used for bedding on the farm. The owners were unsure of the quantity produced. Figure 17 on the following page shows the cows with digested solids bedding.

Figure 17 – Cows and Digested Solids Bedding

Photo courtesy of GHD, Inc.

History and Comments.
This installation originally came about because the farm owners were building a new dairy facility and were aware of the benefits of anaerobic digestion. Alliant Energy was also interested in a pilot project using biogas. The two parties talked with GHD, Inc. and agreed to have the first GHD digester installed on their farms. To reduce the financial risk for the farm, Alliant Energy agreed to supply, operate and maintain the engine generator set.

The digester has been operating as it is supposed to and they feel it is a good fit for the farm. Gale Gordon said he is surprised more digesters have not been built given the obvious advantages. For example, phosphorus (P) is concentrated mostly in the solids. After digestion, screw press solids separators take out about half the solids, and settling can remove most of the rest. The concentrated P in the lighter-weight solids can give the farm more flexibility in land application over greater distances and on fields that can use it. This added control helps farmers work within their nutrient management plans. He feels very strongly that digester designs should be as simple as possible.

Sources.
Gale Gordon – Deere Ridge Dairy / Gordondale Farms
Melissa VanOrnum – GHD, Inc.
Duane Hanusa – Alliant Energy, Inc.

Double S Dairy – Markesan, Wisconsin

Farm Name:	Double S Dairy	**Location:**	Markesan
Farm Type:	dairy	**Herd Size:**	1,100 head (milking)
Collection Method:	scrape	**Bedding Type:**	digested solids
Digester Type:	mixed plug-flow	**Design Temperature:**	100 deg F
Digester Notes:	two-stage, below grade concrete tank, u-shaped, gas-induced mixing, RAS		
Design Capacity:	1,200 head	**Date Operational:**	2004
Design HRT:	20 days	**Current HRT:**	not available
Design Solids %:	8-9%	**Current Solids %:**	not available
Biogas Use:	electricity and heat	**Utility Contract:**	yes
Installed Capacity:	200 kW	**Prime Mover Brand:**	Caterpillar
Solids Separation:	yes , screw press	**Solids Use:**	bedding and land applied
Ownership:	farm owns digester and energy generation		
Digester Designer:	GHD, Inc.	**Utility:**	Alliant Energy, Inc.

The Double S Dairy has 1,100 milking Holsteins and is located in Markesan, Wisconsin, in southern Green Lake County. The farm produces about 33,000 gallons of manure, wastewater and bedding for treatment every day. Manure is scrape-collected three times per day. They use digested solids for bedding and a Fan screw press for solids separation. Figure 18 is a photo of their solids separation operation. Their former manure storage system was a lagoon.

Figure 18 – Double S Dairy Solids Separator

Digester.
In 2002, the owners installed a mixed plug-flow digester designed by GHD, Inc. The system is a standard GHD design, U-shaped, mesophilic, with gas-induced mixing and return of activated sludge. It is a concrete structure, built below grade, with a fixed concrete cover. The owners are unsure how frequently influent is added to the digester. The digester is operating near its designed temperature of 100 degrees F, and has an HRT of about 20 days.

Outputs and Uses.
Biogas produced is dehumidified with a water trap, and run through a 200 kW Caterpillar engine generator set to produce electricity and heat. The system operates as an induction generator; it cannot operate in stand-alone mode. Figure 19 shows the engine generator set.

Electricity is sold to Alliant Energy through a sell-all purchase agreement that includes ownership of environmental attributes from generation.

Figure 19 – Double S Dairy Engine Generator Set

Captured heat is used for digester, milking parlor, and shop heating. They also use this heat in the summer and into the fall to heat their swimming pool.

They produce about three to four semi-loads of digested solids per week and use about half for bedding. The rest are land spread on the farm.

History and Comments.
Their system became operational in 2004. They switched from sand bedding to digested solids, and from flush collection to scrape so that farm operations would work more smoothly with the digester. Owner Dan Smits feels their digester has given them significant odor reduction, and that these systems are very "environmentally positive." They have one of the earlier systems and it requires significant maintenance, and it "is not a money-making machine." He adds that systems are getting more refined over the years and are constantly being improved. One thing they would do differently if starting over would be to spread out the buildings and structures more.

Sources.
Dan Smits – Double S Dairy
Melissa VanOrnum – GHD, Inc.

Emerald Dairy – Emerald, Wisconsin

Farm Name:	Emerald Dairy	**Location:**	Emerald
Farm Type:	dairy	**Herd Size:**	1,600 head
Collection Method:	scrape	**Bedding Type:**	digested solids
Digester Type:	mixed plug-flow	**Design Temperature:**	100 deg F
Digester Notes:	two-stage, below grade concrete tank, u-shaped, gas-induced mixing, RAS		
Design Capacity:	1,600 head	**Date Operational:**	2006
Design HRT:	20 days	**Current HRT:**	not available
Design Solids %:	8-9%	**Current Solids %:**	8%
Biogas Use:	upgrade, sell to 3M	**Utility Contract:**	no
Installed Capacity:	not applicable	**Prime Mover Brand:**	not applicable
Solids Separation:	yes, screw press	**Solids Use:**	bedding, some sold
Ownership:	farm owns digester and gas upgrade equipment		
Digester Designer:	GHD, Inc.	**Utility:**	St. Croix Electric Coop.

Emerald Dairy is a 1,600 head Holstein dairy in Emerald, Wisconsin, in eastern St Croix County. The dairy produces about 45,000 gallons of manure, bedding and wastewater per day. Manure is scrape-collected three times per day and averages about eight percent solids content. They use digested solids for bedding, and their former storage system was a anaerobic covered lagoon.

Digester.
They replaced an older covered lagoon digester with a GHD, Inc. digester in 2005. The digester, which became operational in 2006, is a U-shaped mixed plug-flow system, with gas induced mixing and return of activated sludge. It is a below-grade concrete structure with a fixed concrete cover. Figure 20 shows the digester behind the adjacent gas processing facility.

Figure 20 – Emerald Dairy Digester and Gas Cleanup Building

Photo Courtesy of Agri-Waste Energy, Inc.

The digester has a design HRT of about 20 days and an operating temperature of 100 degrees F. Influent is pumped in to the digester four times per day. The farm also separates solids from the effluent stream using a Fan screw press to produce the digested solids used for bedding. Additional solids separation is achieved using an ISS system[6] that cleans up the water to a dischargeable level.

Outputs and Uses.

Biogas produced by the digester is run through a moisture trap and iron sponge to remove hydrogen sulfide. Then it is upgraded into compressed natural gas using water column technology. The CNG is then shipped using a tube tanker to a pipeline injection point. Figure 21 shows the equipment inside the on-farm gas processing facility at Emerald Dairy.

Figure 21 – Biogas Processing Facility at Emerald Dairy

The CNG is injected into a natural gas pipeline and sold to 3M, Inc. Some biogas is also used to heat the digester itself using a Bryan brand boiler. Figure 22 below shows a tube tanker used to haul the CNG, and the location where injection occurs.

Figure 22 – Tube Tanker Truck at Injection Point

Photo courtesy of Agri-Waste Energy, Inc.

[6] ISS stands for Integrated Separation Solutions of Madison, Wisconsin, which has provided an advanced filtration system for the dairy.

Effluent from the digester is stored in a lined lagoon before being land applied.

The farm produces about 38 tons of digested solids per week at about 67 percent moisture. They use these for bedding in higher proportions than at typical dairies because they use deep beds at Emerald. They sell 10-20 percent of the solids they produce to other farms.

History and Comments.
Both Emerald and Baldwin dairies had installed covered lagoon digesters in 1999 and 1998 respectively. When these systems did not provide an adequate level of digestion, they were replaced with heated systems. The digester at Emerald has allowed the owner to arrange an innovative sales contract with the company 3M, Inc. which was interested in using renewable fuel. They installed gas cleanup and upgrading equipment on the farm and are temporarily using tube tanker trucks to move the biogas to the injection point. Pending approval of financing, the owner plans to partner with another large dairy (Jon-De Dairy) to build a gas distribution pipeline to allow biogas to be piped from Baldwin, Emerald and the third dairy to the injection point. The plan is to move the gas upgrading equipment to the injection point so the biogas from all three farms can be processed with it.

The owner of Baldwin Dairy is also exploring other innovations for use of dairy operation byproducts. These include growing tilapia and algae in nutrient rich water, and making biodiesel from the algae.

Sources.
John Vrieze – Emerald Dairy
Melissa VanOrnum – GHD, Inc.

Five Star Dairy – Elk Mound, Wisconsin

Farm Name:	Five Star Dairy	**Location:**	Elk Mound
Farm Type:	dairy	**Herd Size:**	850 head (milking)
Collection Method:	scrape	**Bedding Type:**	digested solids
Digester Type:	complete mix	**Design Temperature:**	125 deg F
Digester Notes:	above ground cylindrical tank, carbon steel, thermophilic, fixed steel cover		
Design Capacity:	800-1,200 head	**Date Operational:**	2005
Design HRT:	20 days	**Current HRT:**	20 days
Design Solids %:	6-8%	**Current Solids %:**	not available
Biogas Use:	electricity and heat	**Utility Contract:**	yes
Installed Capacity:	750 kW	**Prime Mover Brand:**	Waukesha
Solids Separation:	yes, screw press	**Solids Use:**	bedding, give away for gardeners
Ownership:	farm owns digester (designer operates and maintains), utility owns energy generation		
Digester Designer:	Microgy, Inc.	**Utility:**	Dairyland Power Cooperative

Five Star Dairy, located in Elk Mound, Wisconsin in east-central Dunn County, has 850 milking cows. The owner planned to add anaerobic digestion when he was building this new dairy in 2000. The daily volume of manure and other liquids requiring treatment is not available. Manure is scrape-collected three times per day and they use a Fan screw press for solids separation after digestion. Their former manure storage system was a lagoon.

Digester.
Five Star Dairy entered into an agreement with Microgy, Inc. and Dairyland power to have an anaerobic digester installed on the farm. Under this agreement they sell biogas to Dairyland Power for electricity generation. Figure 23 (on the following page) shows the digester installed at Five Star Dairy.

Under this agreement, Microgy installed the digester with no cash outlay from the farm owner. The farm owner pays off the debt on the digester through biogas sales to Dairyland Power. Microgy operates and maintains the digester. Dairyland Power has an engine generator set at the farm and generates green electricity for sale to its member cooperatives.

The Microgy system is a complete-mix above ground, carbon steel tank. It operates in the thermophilic range with a target temperature of 125 degrees F. The design HRT is 20 days, and as a complete mix system it has an inherent retention of activated sludge. The Microgy systems are designed to include addition of off-farm food wastes, preferably high fat wastes such as greases and oils. The systems and business model are designed around the co-digestion of such wastes and the resultant high level of biogas production. Five Star Dairy includes a storage tank for delivered food processing wastes (visible in Figure 23 as the smaller cylindrical tank on the lower right). A mixture of manure and about ten percent food wastes is batched into the digester every half hour. Solids are

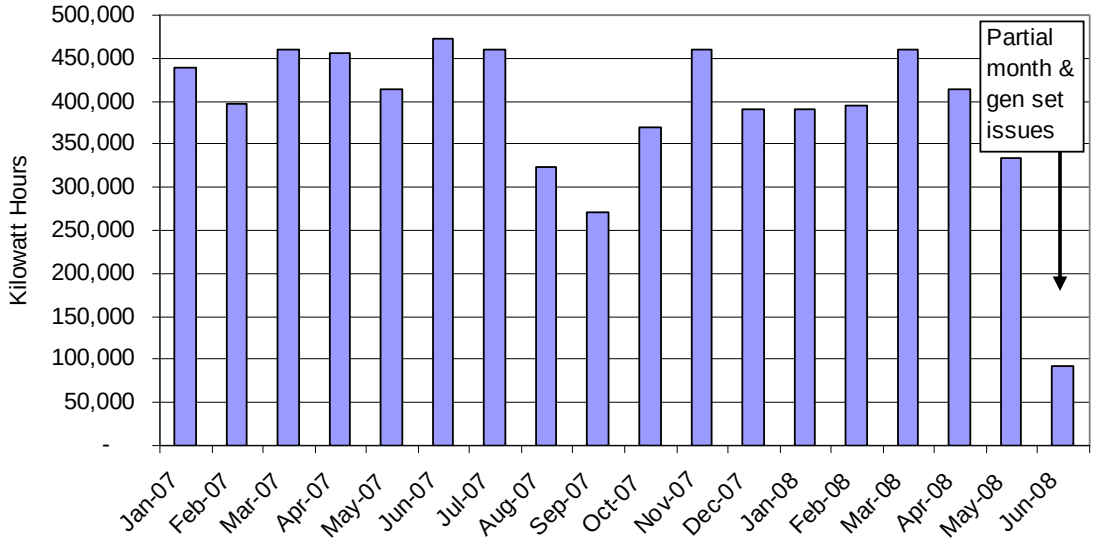
separated out after digestion. Most of these are used for bedding and some are given away to local gardeners.

Figure 23 – Microgy Digester at Five Star Dairy

Photo courtesy of Microgy, Inc.

Figure 24 below shows the last 18 months of electricity produced from biogas in monthly kWh totals.

Figure 24 – Dairyland Power Electricity Generation at Five Star Dairy



History and Comments.

The digester at Five Star Dairy was the first establishment of the farm/Microgy/Dairyland Power business model in Wisconsin. Therefore, there was a large amount of negotiation and legal assistance needed to iron out the details. Once the contract was established, the

other two systems (Norswiss and Wild Rose) were able to copy the business model. The owner, Lee Jensen, is happy with the resulting arrangement and feels it is a good deal for all the parties involved. He also noted that biogas production has been close to normal throughout the energy monitoring period covered in Figure 24, and variation has been due to engine generator set issues.

Mr. Jensen feels having the digester has been a great thing for the farm, the image of his operation and for the community. They have a good product, low odor, and good fertilizer. They are getting growing interest from the community in the manure solids for gardening. They are currently giving these away and are building substantial goodwill with their neighbors.

Their manure has noticeably lower odor. As an additional control measure, they are installing a cover on their lagoon (where effluent from the digester is stored) and will monitor the gas coming off that to see if it is usable.

Mr. Jensen notes that the system is very well metered. Because of this, he noticed that his operation is using much more water than the other two farms, and he knows that if they pay more attention to controlling water use they can reduce costs. He has also learned that you can move liquids farther and more efficiently with slow hydraulic pumps. He says having many spots where you can open up the flow lines for cleanout is important and they must be cleared regularly. To help keep the lines clear, they have put in filters and also have the local septic truck come out and clear them out with suction and a pig. He stresses the key to making gas is consistent flow.

Sources.
Lee Jensen – Five Star Dairy
Mike Casper – Microgy, Inc.
John McWilliams – Dairyland Power Cooperative

Green Valley Dairy – Green Valley, Wisconsin

Farm Name:	Green Valley Dairy	**Location:**	Green Valley
Farm Type:	dairy	**Herd Size:**	2,500 head
Collection Method:	scrape	**Bedding Type:**	digested solids
Digester Type:	complete mix (x2)	**Design Temperature:**	102 deg F
Digester Notes:	above ground cylindrical tank, flexible membrane cover		
Design Capacity:	2,500 head	**Date Operational:**	2007
Design HRT:	22 days	**Current HRT:**	not available
Design Solids %:	not available	**Current Solids %:**	8%
Biogas Use:	electricity and heat	**Utility Contract:**	yes
Installed Capacity:	600 kW	**Prime Mover Brand:**	Caterpillar
Solids Separation:	yes, screw press	**Solids Use:**	bedding, sold to farms
Ownership:	farm owns digester and energy generation		
Digester Designer:	Biogas Direct, LLC	**Utility:**	We Energies, Inc.

Green Valley Dairy is a 2,500 head (2,100 milking) dairy operation in Green Valley, in eastern Shawano County, Wisconsin. They scrape-collect manure three times per day, and produce about 83,000 to 105,000 gallons of manure per day. When milking parlor wash water is added the influent stream has about eight percent solid matter. The farm uses digested solids for bedding. The dairy is undergoing an expansion in summer 2008 (see History and Comments section for more details). Their former manure storage system was a lagoon.

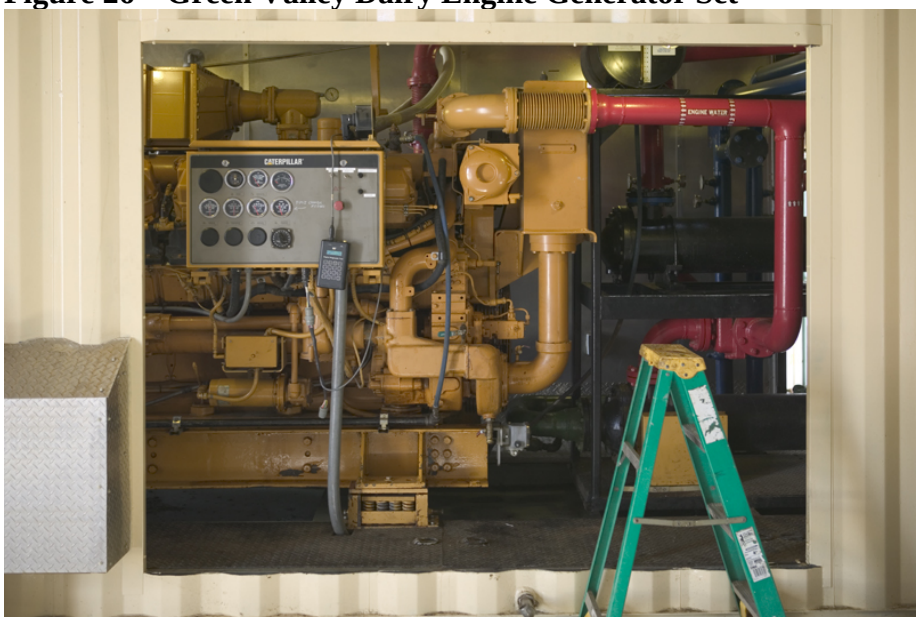
Digester.
The owners chose to install two Biogas Direct digesters for manure treatment. Figure 25 below shows the digesters.

Figure 25 – Biogas Direct Digesters at Green Valley Dairy

The digesters are complete mix above ground tanks with a flexible dual membrane cover that can expand to accommodate some limited biogas storage. Biogas is held in the inner membrane and there is a layer of air between the membranes. It is a mesophilic system with an operating temperature of 102 degrees F and an HRT of 22 days. As a complete mix system the digesters retain activated sludge during normal operation. The manure undergoes some pre-heating before entering the digesters, and is fed into the digester continuously. They do not add any off farm wastes to the digesters.

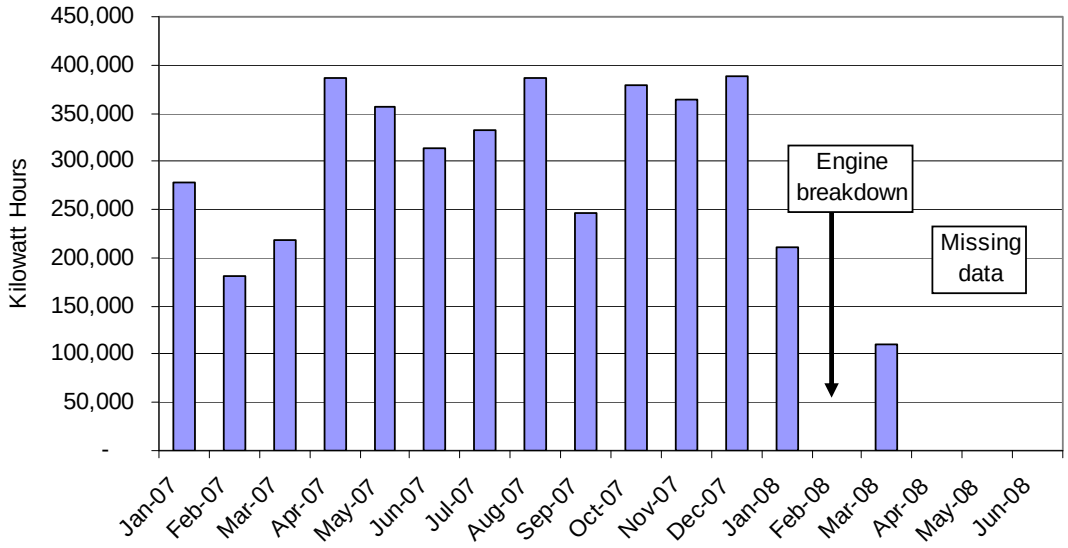
Outputs and Uses.
Biogas from the digesters is dehumidified using a condensate trap and chiller with oxygen addition. It is then used to generate electricity and heat. Electricity is sold to We Energies under a "sell all" contract. The farm owns a Caterpillar 600 kW engine generator set (see Figure 26) but plans to add generation capacity as part of their summer 2008 expansion.

Figure 26 – Green Valley Dairy Engine Generator Set



Their generator is synchronous and can run in stand-alone mode. Figure 27 on the following page shows the electricity production from January 2007 through June 2008.

Figure 27 – Green Valley Dairy Generation History



Heat is captured from the engine with a water jacket and from the exhaust. Currently all the recovered heat is used for heating the digester and bringing the manure up to temperature. They added a remote heat exchanger and they also have a cast iron Columbia boiler that can run on biogas for digester heat and pre-heating. Sometimes they supplement the heat with the boiler as well.

They use a Fan solids separator to separate digested solids for bedding. The farm generates about 120 tons per week of digested solids. They use half that on the farm and sell the other half to neighboring dairies. They are in the process of remodeling and will change from using mattresses (with which the cows end up kicking a lot of bedding into the aisles) to deep beds. They hope this switch will allow them to reduce their bedding use down to about 30 tons per week.

They have been producing more biogas than they could use and have ordered a second engine. After some fine tuning of engine settings, the current generator has been reportedly operating as high as 605 kW of gross output from biogas.

History and Comments.
Co-owner Guy Selsmeyer said they have experienced very good biogas production and have generally had more biogas than they could use – they flare the excess. They found that they got better digestion if they pre-heated the manure. They added a remote heat exchanger to be used for pre-heating and found that about 75 percent of the Btus they use for digester heat goes into that phase.

They are going through an expansion during the summer of 2008. They plan to add a new barn, 500 cows, a third digester and an additional 600 kW engine generator set. The owners are designing and building this third digester on their own and hope to have it running by the end of 2008.

Mr. Selsmeyer stressed that it is very important to have a backup boiler to provide heat to the digester, especially if the farm is using solids for bedding. During a recent engine breakdown (which they suspect was caused by a wiring issue) they were able to keep the digester up to temperature and continue production of good quality bedding until the engine was up and running again. Also, during below zero days, when ice crystals form in the manure, it can take significant extra heat to bring it up to digester temperature. Having additional boiler capacity is very useful at those times.

Sources.
Guy Selsmeyer – Green Valley Dairy
Michael Zander – Energies Direct, LLC (formerly with Biogas Direct, LLC)
Pat Keily – We Energies, Inc.

Holsum Dairy, Elm Road – Hilbert, Wisconsin

Farm Name:	Holsum Dairy, Elm Road	**Location:**	Hilbert
Farm Type:	dairy	**Herd Size:**	4,000 head
Collection Method:	scrape	**Bedding Type:**	digested solids
Digester Type:	mixed plug-flow (x2)	**Design Temperature:**	100 deg F
Digester Notes:	two-stage, below grade concrete tank, u-shaped, gas-induced mixing, RAS, fixed concrete covers		
Design Capacity:	4,000 head	**Date Operational:**	2007
Design HRT:	22 days	**Current HRT:**	20-22 days
Design Solids %:	8-9%	**Current Solids %:**	not available
Biogas Use:	electricity and heat	**Utility Contract:**	yes
Installed Capacity:	1200 kW (600 kW x2)	**Prime Mover Brand:**	Guascor
Solids Separation:	yes, screw presses	**Solids Use:**	bedding, sold to farms
Ownership:	farm owns digester and energy generation		
Digester Designer:	GHD, Inc.	**Utility:**	Wisconsin Public Service

Holsum Dairy has two separate farms both of which have digesters and are characterized in this casebook. The Elm Road dairy has about 4,000 head of Holsteins and is located in Hilbert, Wisconsin in Calumet County. Total volume of manure produced is not available. They use solids for bedding and scrape collect the manure three times per day. Their former manure storage method was in ponds.

Digester.

Having worked with GHD digesters at their other dairy, the dairy owner decided to install two GHD, Inc. designed digesters at this facility as well. The systems were installed in 2006-2007 and became operational in 2007. Figure 28 shows one end of a digester near the generator shed. These are U-shaped mixed plug-flow digesters with passive gas-induced mixing. The structures are concrete and below grade with fixed concrete covers. They operate in the mesophilic temperature range with a target operating temperature of 100 degrees F. The system has a design HRT of 22 days. In practice, they are seeing the temperature range between 95 and 100 degrees, and estimate a 22 day HRT. The GHD system has return of activated sludge to help maintain the bacteria colonies. Frequency of the manure addition to the digester was unavailable. They also add about one to one and a

Figure 28 – Holsum Digester and Equipment Shed

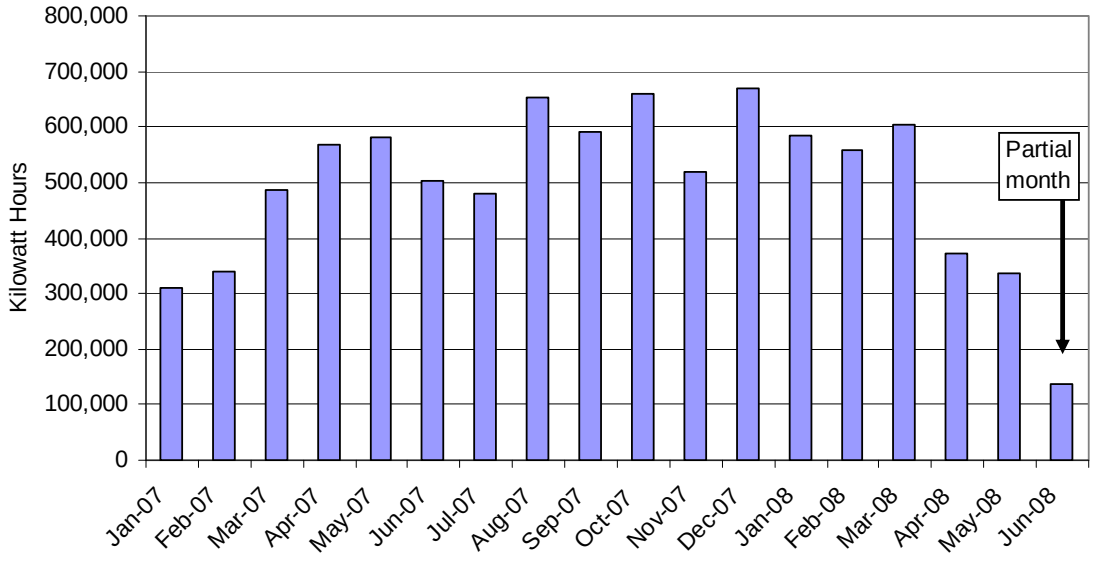
half semi loads per day of non-farm food processing industry wastes from three industries to their influent stream and receive an undisclosed tipping fee.

Outputs and Uses.

The produced biogas is dehydrated by running it through a condensate trap and chiller, then run through two engine generator sets to generate electricity. They have two 600 kW Guascor engine generator sets. Figure 29 shows Holsum's engine generator sets. They have a contract to sell all the electricity they generate to Wisconsin Public Service Corporation. Figure 30 shows the last 18 months of electricity generation for the Elm Road dairy.

Figure 29 – Holsum Engine Generator Sets at Elm Road

Figure 30 – Elm Road Electricity Generation History



Heat recovered from the engine generator sets is used for heating the digester, milking parlor, office, shop, and holding and transfer areas. They have a dual fuel boiler (brand unknown) for backup heat that can run on either diesel or biogas.

The farm uses two Fan screw presses to separate the solids from the digestate. The farm produces about 16 semi loads of solids per week and uses about one third on the farm. The other two thirds are sold to other dairies.

History and Comments.
The owner chose not to share any comments or history details other than to note that the layout for this system was somewhat different from their Irish Road dairy (see the following case study). They arranged the buildings differently, having an engine generator building further away from the radiators and heat exhaust.

Sources.
Kenn Buelow – Holsum Dairy
Melissa VanOrnum – GHD, Inc.
Joe Sinkula – Wisconsin Public Service Corporation

Holsum Dairy, Irish Road – Hilbert, Wisconsin

Farm Name:	Holsum Dairy, Irish Road	**Location:**	Hilbert
Farm Type:	dairy	**Herd Size:**	4,000 head
Collection Method:	scrape	**Bedding Type:**	digested solids
Digester Type:	mixed plug-flow (x2)	**Design Temperature:**	100 deg F
Digester Notes:	two-stage, below grade concrete tank, straight, gas-induced mixing, RAS, fixed concrete covers		
Design Capacity:	4,000 head	**Date Operational:**	2004
Design HRT:	22 days	**Current HRT:**	20-22 days
Design Solids %:	8-9%	**Current Solids %:**	not available
Biogas Use:	electricity and heat	**Utility Contract:**	yes
Installed Capacity:	700 kW (500 kW + 200 kW)	**Prime Mover Brand:**	Deutz and Caterpillar
Solids Separation:	yes, screw presses	**Solids Use:**	bedding and sold to farms
Ownership:	farm owns digester and energy generation		
Digester Designer:	GHD, Inc.	**Utility:**	Wisconsin Public Service

Holsum Dairy on Irish Road is one of two Holsum dairies with digesters in Hilbert, Wisconsin, in Calumet County. The Irish Road dairy, the older of the two, has 4,000 head of Holsteins (milking proportion unknown). The daily volume of manure produced is unknown. They use scrape collection three times per day and use digested solids for bedding. Their former manure storage method was in ponds.

Figure 31 – Holsum Dairy Irish Road Digesters

Digester.
Holsum Dairy was one of the early dairies in Wisconsin choosing anaerobic digestion for manure treatment. They installed two GHD designed digesters in 2001-2. Figure 31 shows the top of the digesters with flare. These systems are unlike the typical GHD digesters in that they are straight (laid out end to end) rather than U-shaped. The digesters are mixed plug-flow systems using biogas for mixing. They operate in the mesophilic range with a target temperature of 100 degrees F and have a design HRT of 22 days. They use return of activated sludge. The structure is concrete below grade and has a fixed concrete cover. Manure mixed with food industry waste is added to the digesters three times a day. The one to one and a half semi-loads per day off farm wastes are byproducts

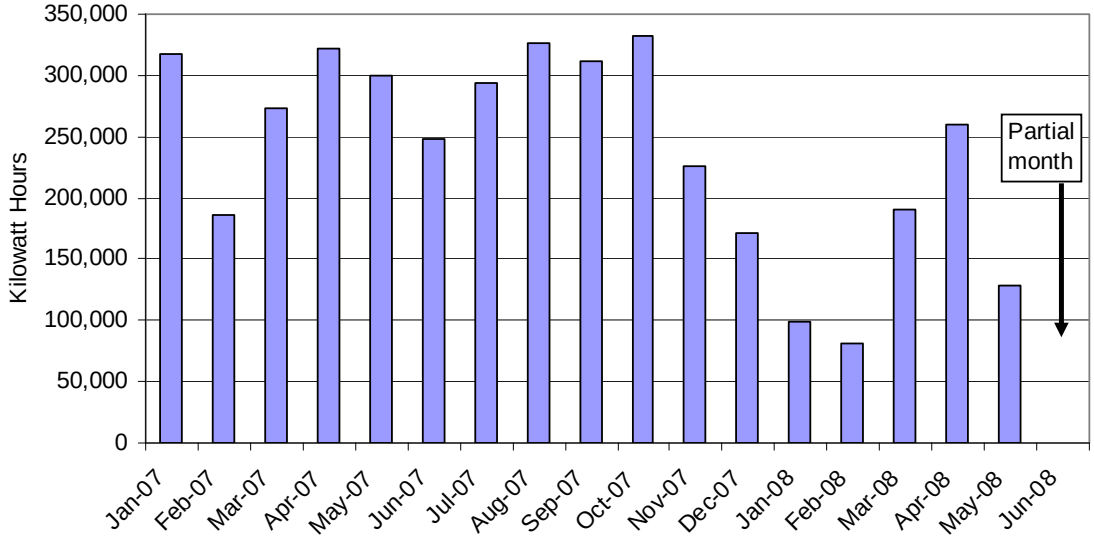
from three area food processing industries for which the farm receives tipping fees. The manure and other wastes are not pre-treated in any way.

Figure 32 – Holsum Dairy Irish Road Engine Generator Set

Outputs and Uses. Biogas produced from the digester is fed through a condensate trap and chiller then used in two engine generator sets – a Deutz 500 kW and a Caterpillar 200 kW. Figure 32 shows the Cat engine generator set. Electricity produced from these is sold to Wisconsin Public Service Corporation under a "sell-all" agreement. The generators are not capable of operating in stand-alone mode (i.e., they are induction generators). Waste heat from the engines and exhaust is captured and used for the digester, milking parlor, office, and holding and transfer areas. They also have a backup boiler (make unknown) that can use either diesel or biogas to provide supplemental heat to the system.

Figure 33 shows the electricity production from Irish Road from January 2007 through June 2008

Figure 33 – Holsum Dairy Irish Road Electricity Generation History



The dairy produces about 16 semi-loads of digested solids per week. It uses one third on the farm and sells two thirds to other dairies.

History and Comments.
The owner stressed the importance of keeping the electronic equipment separate from the engine generator and solids separation areas. He said the systems were standard GHD digesters and installation was "pretty straightforward."

Sources.
Kenn Buelow – Holsum Dairy
Melissa VanOrnum – GHD, Inc.
Joe Sinkula – Wisconsin Public Service Corporation

Lake Breeze Dairy – Malone, Wisconsin

Farm Name:	Lake Breeze Dairy	**Location:**	Malone
Farm Type:	dairy	**Herd Size:**	3,072 head
Collection Method:	flush	**Bedding Type:**	sand
Digester Type:	mixed plug-flow (x2)	**Design Temperature:**	100 deg F
Digester Notes:	two-stage, below grade concrete tank, u-shaped, gas-induced mixing, RAS		
Design Capacity:	2,900 head	**Date Operational:**	2006
Design HRT:	22 days	**Current HRT:**	not available
Design Solids %:	8-9%	**Current Solids %:**	8-9%
Biogas Use:	electricity and heat	**Utility Contract:**	yes
Installed Capacity:	600 kW (300 kW x2)	**Prime Mover Brand:**	Caterpillar
Solids Separation:	yes, screw press	**Solids Use:**	stockpiling
Ownership:	farm owns digester and energy generation		
Digester Designer:	GHD, Inc.	**Utility:**	We Energies, Inc.

Lake Breeze Dairy is a 3,072 head (2,550 milking) Holstein dairy in Malone, Wisconsin, in northeastern Fond du Lac County. They use flush collection of their manure and use sand for bedding. Their farm processes produce about 120,000 gallons of material for treatment per day. Their former manure storage system was in ponds.

Digester.
Because the farm uses sand bedding and flush collection, some additional treatments are required before the manure reaches the digesters. To remove the sand bedding the manure stream flows through one of two alternating sand settling lanes. The lane used is switched daily so the idle one can be scooped out. The sand is stored so bacteria cultures die off and it can be re-used. After the sand settling lanes, the manure stream goes into a mechanical rotary screen solids separation system. The liquid from this stage goes into a settling tank and the fine solids that settle out of this are re-mixed with the separated solids from the mechanical screen. This combination, approximating a solids composition of eight to nine percent, is fed into the digester while the clarified liquid is sent to a lagoon. The clarified undigested liquid is re-used for the flush collection system. The owners decided to install two GHD anaerobic digesters to treat their manure. The digesters are shown in Figure 34.

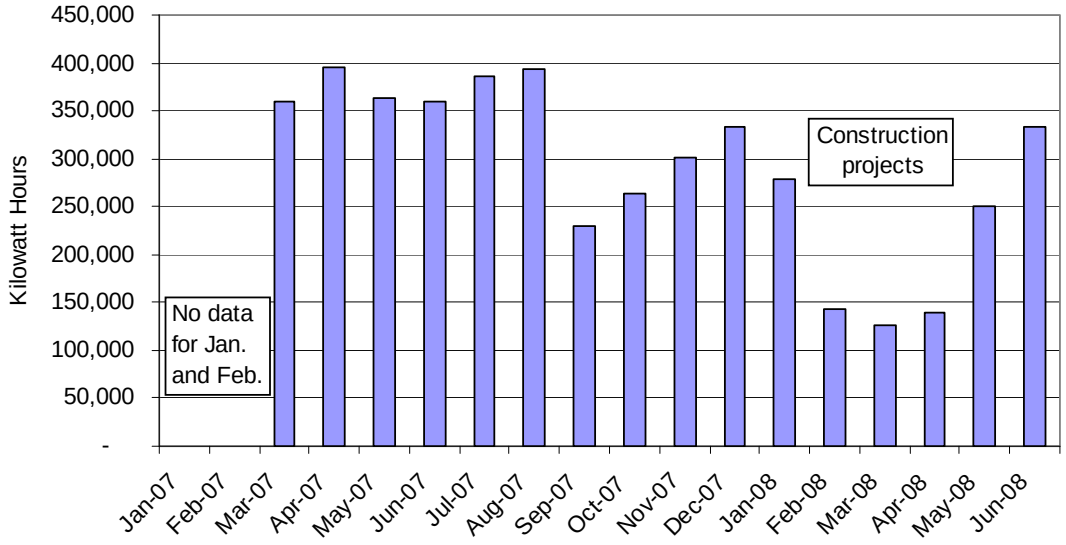
Figure 34 – Digesters at Lake Breeze Dairy

The digesters are side-by-side mixed plug-flow systems that are U-shaped. They operate in the mesophilic temperature range with a target of 100 degrees F. They use biogas for mixing and have return of activated sludge. They are below grade concrete structures with fixed concrete covers.

During the spring and summer of 2008 various construction projects (including installation of sand settling lanes) have interfered with the normal flow of manure to the digester making daily digester feeds smaller and variable. The owners have supplemented the input stream with varying amounts of purchased corn syrup from an Oshkosh ethanol plant to support biogas production.

Outputs and Uses.
Biogas produced by the digesters is conditioned using a condensate trap and chiller. Then it is fed into two Caterpillar 300 kW capacity engine generator sets that are capable of operating in stand-alone mode (i.e., synchronous generation). Electricity produced is sold to We Energies under a sell-all type of contract. Waste heat captured from engine water jackets and exhaust is used to heat the digester. Figure 35 shows the electricity production over the last 18 months.

Figure 35 – Lake Breeze Dairy Electricity Generation History



After digestion, solids are pulled out using Anderson brand screw presses. Figure 36 shows the solids separators used after digestion and the solids separation area. They tried using the solids for bedding but had some incidence of mastitis so switched to sand. These solids are currently being stockpiled because they do not have a ready market for them.

History and Comments.
The owners installed the anaerobic digesters to reduce odor from the farm (about which they had received some complaints). Brian Gerrits of Lake Breeze Dairy said that they

researched options and saw anaerobic digestion as fairly expensive one, but were encouraged by the benefits. Once the digesters were in they did not get the level of odor control they expected. Their water has a lot of sulfates in it which contribute to hydrogen sulfide (H_2S) formation. They also noticed openings in the final section of the digester where manure is pumped to the screw press. They closed these and experienced a reduction in odor. They are now adding ferric chloride to the effluent when it goes from the screw presses to the lagoon for H_2S control. They tried adding ferrous chloride to the influent but that did not work well.

Figure 36 – Digested Solids Separation Area

Their sand removal lanes are reportedly working well, but they expect to periodically need to clean sand out of the digester as it builds up over time.

Maintenance of their system was more expensive than they thought. The feasibility study also did not give the amount of parasitic load (i.e., energy needed to run the manure handling and treatment system) for pumps and agitation equipment which was especially high due to the flush collection and associated systems. Still, they feel that power generation from their overall system is "pretty good."

Some anaerobic digester experts contend that the practices of flush collection and sand bedding are incompatible with most anaerobic digesters (or at a minimum, present a reduced chance for successful implementation).[7] The coordination of these systems clearly involved some fine-tuning and compromises, but both designer and farm owners feel the sand separation and digester system are working well. Mr. Gerrits pointed out that it is important to have farm reps and digester design reps work well together in order to work out these issues. In retrospect, he feels they could have spent more time on design and layout of the manure handling systems. This may have allowed them to avoid some pumps and use gravity more.

Contacts.
Brian Gerrits – Lake Breeze Dairy
Melissa VanOrnum – GHD, Inc.
Randy Jerome – We Energies, Inc.

[7] For example, see the Agricultural Utilization and Research Institute "Self-Screening Checklist" at: http://www.auri.org/research/digester/digchck.pdf. This identifies each as "key issues."

Norswiss Farms – Rice Lake

Farm Name:	Norswiss Farms	**Location:**	Rice Lake
Farm Type:	dairy	**Herd Size:**	1,240 head (1,180 milking)
Collection Method:	scrape	**Bedding Type:**	digested solids
Digester Type:	complete mix	**Design Temperature:**	125 deg F
Digester Notes:	above ground cylindrical tank, carbon steel		
Design Capacity:	800-1,200 head	**Date Operational:**	2006
Design HRT:	20 days	**Current HRT:**	not available
Design Solids %:	6-8%	**Current Solids %:**	not available
Biogas Use:	electricity and heat	**Utility Contract:**	yes
Installed Capacity:	848 kW	**Prime Mover Brand:**	Jenbacher
Solids Separation:	yes,	**Solids Use:**	bedding
Ownership:	farm owns digester (designer operates and maintains), utility owns energy generation		
Digester Designer:	Microgy, Inc.	**Utility:**	Dairyland Power Cooperative, Barron Electric

Norswiss Farms is a 1,240 head dairy farm with mostly Holsteins and some Swiss cows. The dairy is located in Rice Lake, Wisconsin, in northern Barron County. The daily manure production amount is not available. Manure is scrape-collected three times per day to a center gravity-flow system from which it is pumped to the digester. The farm uses digested solids for bedding. Their former manure storage system was a lagoon.

Digester.
The farm owner chose to work with Microgy and Dairyland Power to have a digester installed on his farm. Figure 37 shows the Norswiss digester and the surrounding structures.

Figure 37 – Norswiss Farms Digester

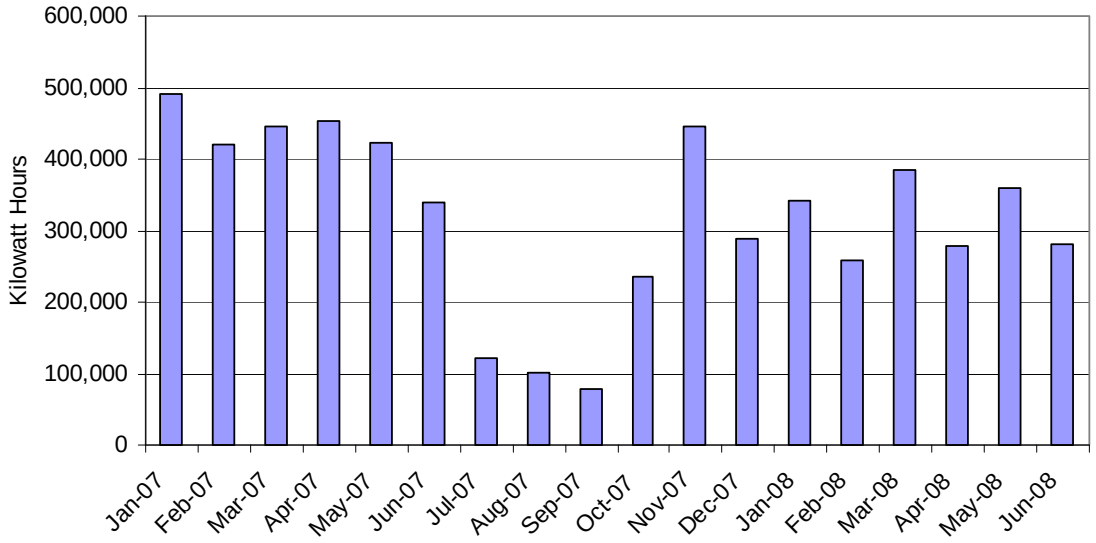
Photo courtesy of Microgy, Inc

The Microgy digester is an above-ground carbon steel cylindrical complete mix tank. It operates in the thermophilic temperature range with a target of 125 degrees F. The digester has an HRT of 20 days. Next to the digester is a 50,000 gallon tank in which the off farm food wastes, primarily grease, are stored. These wastes are pumped into the digester every half hour and are limited to about 10 percent of the total volume in the digester. The farm puts all farm waste liquids into the digester including waste milk and footbath water.

Under this business model, Microgy installs the digester, which is owned by the farm, with no cost outlay from the farm. Dairyland Power installs an engine generator set on the farm as well. Microgy operates and maintains the digester and sells biogas to Dairyland Power. The proceeds from these sales pay down the farm's debt on the digester. Dairyland Power generates green electricity with the biogas and sells it to its member cooperatives. Important to the model is the co-digestion of off-farm food processing wastes – preferably high fat greases and oils. These boost biogas production and produce more income to pay down the debt.

Outputs and Uses.
The biogas produced by the digester is scrubbed with a Biothane brand scrubber. It then is used to run a Jenbacher 848 kW engine generator set owned, operated and maintained by Dairyland Power. The system is synchronous, but is set to shut down in the event of power failure. As a synchronous generator the utility relies on it to provide voltage support for their distribution system. Figure 38 shows the electricity production history for Norswiss.

Figure 38 – Electricity Production History at Norswiss Farms



Dairyland Power gets renewable energy credits for the electricity generated, and the farm gets carbon credits for methane emissions avoided by using an anaerobic digester. Sales of these carbon credits also go toward paying down the debt on the digester.

The farm also has a backup boiler that runs on biogas to provide heat to the digester in the event the engine is down. Recovered heat is used for digester heating only.

Effluent from the digester goes through a Fan brand screw press solids separator which runs constantly. The liquid fraction is pumped into the storage lagoon seen at the top of the photo. They produce about 55 yards of solids per day and use all of it on the farm as bedding on mattresses.

History and Comments.
Andreas Heer, the farm owner, said that once digested, the manure is more liquid with relatively lowered chemical oxygen demanding compounds (COD). They can use it on their hayfields which they cannot do with raw manure. They have been able to eliminate fertilizer purchases for hay, bean and alfalfa fields which the owner sees as a very good benefit.

The digester took a bit longer than predicted to build due to some permitting delays and some problems with out of state contractors. But, Mr. Heer said that this did not negatively affect the farm operation. He says the digester and business arrangement is working well for them – they had no cash outflow and are now saving money on bedding and fertilizer. The availability of these solids has allowed them to do heavy bedding (6-12 inches) on mattresses for much better cow comfort and performance, and they have had low somatic cell counts. They are avoiding the expense of using sawdust which would otherwise be costing them $1,800 every 6 days, and is sometimes hard to find.

Sources.
Andreas Heer – Norswiss Farms
Mike Casper – Microgy, Inc.
John McWilliams – Dairyland Power Cooperative

Quantum Dairy – Weyauwega, Wisconsin

Farm Name:	Quantum Dairy	**Location:**	Weyauwega
Farm Type:	dairy	**Herd Size:**	1,700 head
Collection Method:	scrape	**Bedding Type:**	digested solids
Digester Type:	mixed plug-flow	**Design Temperature:**	100 deg F
Digester Notes:	two-stage, below grade concrete tank, u-shaped, gas-induced mixing, RAS		
Design Capacity:	1,250 head	**Date Operational:**	2005
Design HRT:	22 days	**Current HRT:**	18 days
Design Solids %:	8-9%	**Current Solids %:**	11%
Biogas Use:	electricity and heat	**Utility Contract:**	yes
Installed Capacity:	300 kW	**Prime Mover Brand:**	Caterpillar
Solids Separation:	yes, screw press	**Solids Use:**	bedding, sold to farms or gardeners
Ownership:	farm owns digester and energy generation		
Digester Designer:	GHD, Inc.	**Utility:**	We Energies, Inc.

Quantum Dairy is a dairy in Weyauwega, in southern Waupaca County, Wisconsin. They have 1,700 head of milking Holsteins (their dry cows and replacements are kept off site) and are planning to expand to 2,100 head in the near future. The operation produces about 55,000 gallons per day of manure and liquids for treatment. This influent has a solids content of about 11 percent. They use scrape collection of manure three times per day, and use separated digested solids for bedding. Their former manure system was an open lagoon.

Digester.
The owners researched digester designs and chose GHD, Inc. to design and install their digester and energy generation systems. The digester was built in 2004-5 and became operational in 2005. Figure 39 shows the digester at Quantum Dairy.

Figure 39 – Quantum Dairy Digester

The digester is a U-shaped mixed plug-flow system with biogas induced mixing. It operates in the mesophilic temperature range with a target of 100 degrees F. It uses return of activated sludge and has a design HRT of about 22 days. The structure is

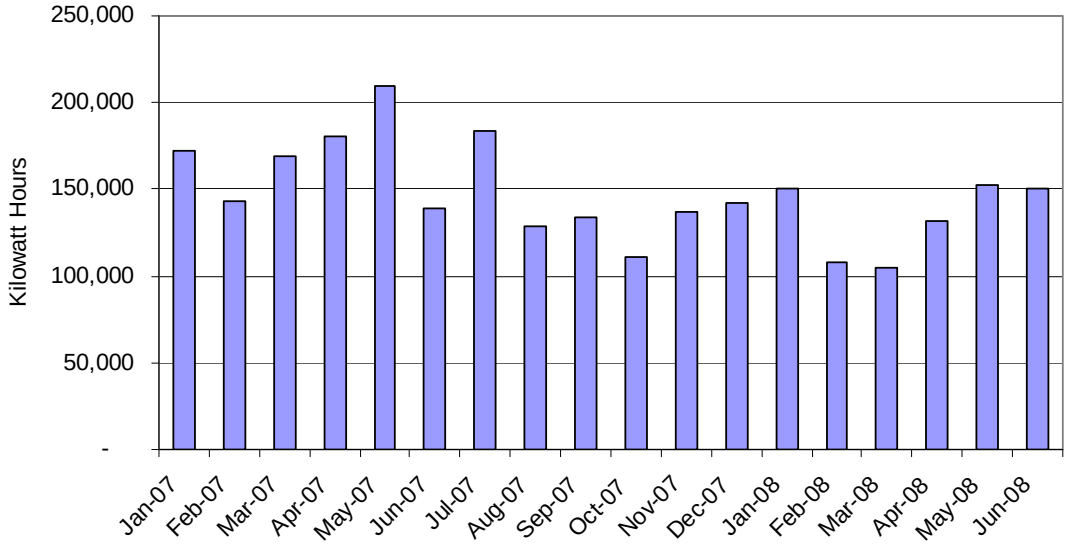
below-grade concrete with a fixed concrete cover. The farm owns the digester and energy generation and sells electricity to We Energies.

Figure 40 – Screw Press Solids Separator

Manure from the reception pit is pumped to the digester 12 times per day. Cows undergoing footbath treatment are at a separate barn so that liquid currently does not go through the digester (this will soon be included in the influent). After the digester, solids are separated out of the effluent stream with a Fan brand screw press solids separator pictured in Figure 40.

Outputs and Uses.
Biogas produced by the digester is sent through a condensate trap and chiller to remove moisture. It is then sent to a Caterpillar 300 kW turbo-charged engine generator set. Electricity is sold to We Energies under a sell-all contract. The generation history for Quantum is shown in Figure 41.

Figure 41 – Electricity Generation at Quantum



Note: These generation numbers are net of parasitic load.

Heat is recovered and used to heat the digester, two parlors, the engine generator set building, the shop and the house.

The dairy creates about 133 tons (about 400 yards) of digested solids per week, about 75 percent of which they use on the farm. The remainder is sold to other dairies for bedding and occasionally to gardening businesses. They are selling the solids for $15 ton or $5 per yard take away.

History and Comments.
GHD designed the digester, integration with the engine generator set, and associated structures. Richard Wagner of Quantum Dairy said they did the project when they only had 600 cows, but had planned to expand, so the digester was built to handle 1,200 to 1,500 cows. They are currently over the design capacity (at 1,700) and plan to push manure from as many as 2,100 cows through the system. They are planning to upgrade the engine generator set again (they have been awarded funding from Focus on Energy). They have already upgraded from their original 200 kW to their current 300 kW set, but it only runs well up to 270 kW. They hope to expand to a generation capacity of 400-450 kW. They have experienced some pinhole leaks in the digester. Mr. Wagner says one way to avoid these leaks is to operate at zero pressure. They have noticed that manure exiting the digester still has gas bubbles coming out and odor is still an issue (probably due to overloading of the digester which causes manure to move through more quickly). They capture these gases which contain hydrogen sulfide (H_2S), run them through a pipe and bubble them through water which converts the H_2S into liquid sulfuric acid. This is then sent to the lagoon.

Mr. Wagner noted that depending on staff, the job falls to someone to maximize the run-time of the engines. This can be demanding because they typically seem to shut down in the middle of the night.

Sources.
Richard Wagner – Quantum Dairy
Melissa VanOrnum – GHD, Inc.
Tom Young – We Energies, Inc.

Stencil Farm – Denmark, Wisconsin

Farm Name:	Stencil Farm	**Location:**	Denmark
Farm Type:	dairy	**Herd Size:**	1,300 head, (700-1,000 feed digester)
Collection Method:	scrape	**Bedding Type:**	digested solids
Digester Type:	plug-flow	**Design Temperature:**	100 deg F
Digester Notes:	straight plug-flow, below grade, flexible cover		
Design Capacity:	1,200 head	**Date Operational:**	2002
Design HRT:	20 days	**Current HRT:**	22-23 days
Design Solids %:	9-12%	**Current Solids %:**	varies
Biogas Use:	electricity and heat	**Utility Contract:**	yes
Installed Capacity:	123 kW	**Prime Mover Brand:**	Caterpillar
Solids Separation:	yes, screw press	**Solids Use:**	bedding
Ownership:	farm owns digester and energy generation		
Digester Designer:	RCM Digesters, Inc.	**Utility:**	Wisconsin Public Service

Stencil Farm in Denmark, Wisconsin, in eastern Brown County, has a herd size of around 1,300 Holsteins. Manure from between 700 and 1,000 head is regularly sent to the digester. They use digested solids for bedding and scrape collect the manure hourly. The volume, as well as the solids content of the manure sent to the digester varies depending on which barns it is coming from. Their former manure storage system was a lagoon.

Digester.
The Stencils installed a digester designed by RCM Digesters, Inc. in 2001-2, and the system became operational in 2002. The digester is a below grade, concrete, straight plug-flow system with a flexible cover. It operates in the mesophilic range with a target temperature of 100 degrees F. The system is designed to work best with manure solids concentrations of 9 to 12 percent.

Outputs and Uses.
Biogas produced by the digester is used to generate electricity and heat with a Caterpillar 123 kW (biogas rated) engine generator set. The electricity is used entirely on the farm, but they have the capability of selling excess to Wisconsin Public Service. Because the farm is not selling electricity, there is no generation data available.

Heat recovered from the engine is used entirely for the digester. The shop adjacent to the engine room receives some radiant heat from the engine.

Digested solids are separated out from the effluent using a Fan screw press type separator. All solids produced at the farm are used on the farm. They are looking at a press and tumbler system to produce solids from raw manure, heat it to 150 degrees F, and have solids ready for use in a day.

History and Comments.
The farm has had some trouble with the variability in solids content in their manure influent stream affecting digester performance. Dave Stencil said when their solids content is lower, they get some crusting, and it interferes with the heat exchangers making them less effective at bringing the manure up to temperature. He is checking into some modifications including some agitation that might make their system more tolerant of their variable manure input stream. Their primary goal is to generate bedding product.

He thinks the flexible cover on his digester offers insufficient insulation capability for cold Wisconsin winters, and that his digester's structural insulation may have been compromised over time. Their difficulties in maintaining the system temperature have affected digester performance.

As one of the earlier systems installed in Wisconsin, they were required to put in 16 inch thick concrete walls which made the system more expensive. They also had repeated problems with the engine and other safety features. Mr. Stencil stated that he has had a hard time getting local people to work on his system and at one point had a $14,000 overhaul (of the engine) that could have been avoided with a $600 repair. He pointed out that newer engines made for biogas are more efficient and can provide more energy output.

He says owning and maintaining a digester and energy generation equipment is challenging, and he knows farmers who have given up on their digesters. One reason he is considering redoing his system is that the modifications look pretty good on paper.

Sources.
Dave Stencil – Stencil Farm
Mark Moser – RCM Digesters, Inc.

Suring Community Dairy – Suring, Wisconsin

Farm Name:	Suring Community Dairy	**Location:**	Suring
Farm Type:	dairy	**Herd Size:**	950 head (810 milking)
Collection Method:	scrape	**Bedding Type:**	digested solids
Digester Type:	complete mix	**Design Temperature:**	100 deg F
Digester Notes:	above ground bolted stainless steel tank with dual membrane, flexible cover on floating concrete pad		
Design Capacity:	1,000 head	**Date Operational:**	2005
Design HRT:	22 days	**Current HRT:**	28 days
Design Solids %:	not available	**Current Solids %:**	7-8%
Biogas Use:	electricity and heat	**Utility Contract:**	yes
Installed Capacity:	230 kW	**Prime Mover Brand:**	Dreyer & Bosse
Solids Separation:	yes, screw press	**Solids Use:**	bedding, composting, other farms
Ownership:	farm owns digester and energy generation		
Digester Designer:	American Biogas Company, Inc.	**Utility:**	Wisconsin Public Service

Suring Community Dairy is a 950 head Holstein operation in Suring, Wisconsin in Oconto County. They use scrape collection continuously throughout the day. The daily production volume of manure is about 25,000 gallons. The manure and wastewater influent stream requiring treatment has an estimated solids content of seven to eight percent. They use separated solids for bedding and their former manure storage method was a lagoon.

Digester.
The farm owners chose to install a complete mix digester designed by American Biogas Company (AMBICO). The digester is an above ground, stainless steel complete mix tank with a dual membrane flexible cover, resting on a floating concrete pad. It operates in the mesophilic range with a target temperature of 100 degrees F, and an HRT of 22 days. Figure 42 shows the Suring Community Dairy digester.

Figure 42 – Suring Community Dairy Digester

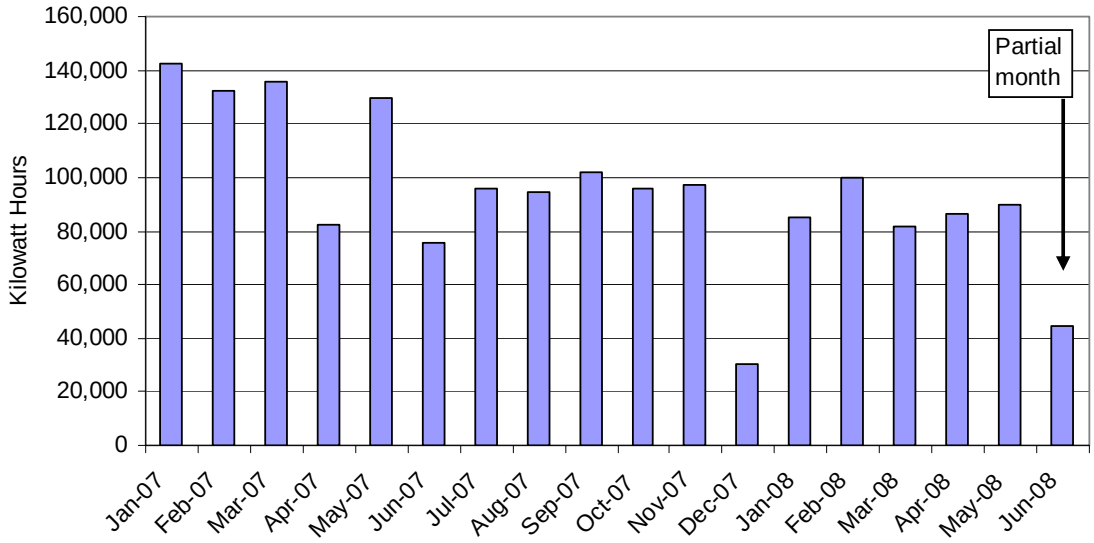
The farm feeds manure in every two hours. They are planning to adjust the schedule to pump more in during off hours to take advantage of lower time-of-day electricity rates. They do not do any kind of pre-treating of the influent. Currently, only manure, wastewater and bedding are sent into the digester. Small amounts of footbath water are sent through the digester as well.

Figure 43 – Suring Engine Generator Set

Outputs and Uses.
Biogas produced from the digester is sent through a passive hydrogen sulfide removal system and chilling unit for condensate removal. It is then fed into a 250 kW Dreyer and Bosse, dual fuel engine generator set. The engine uses 20 percent diesel and is synchronous (i.e., can run in stand-alone mode). Figure 43 shows the engine generator set.

Electricity produced on the farm is sold to Wisconsin Public Service Corporation under a sell all agreement. Figure 44 shows the electricity generation history for the dairy.

Figure 44 – Suring Community Dairy Electricity Generation History



Heat captured from the engine and exhaust is used to heat the digester and the shop building.

They separate solids from the effluent stream with two separators: a WEDA brand screw press solids separator, and a PTI (Press Technologies, Inc.) model. They have replaced one of each model so far due to failures. They produce between 80 and 100 yards of digested solids per week. They use 40 to 45 yards per week on the farm. Of the rest, they compost some and have some neighbors who are trying them out for bedding. They are also considering doing some drying and bagging solids as possible horse bedding, a market that is developing due to a growing shortage of sawdust. They have recently supplied some solids for landscapers and gardeners who appreciate the lower cost manure. They are also considering an option to supply solids to a pelleting operation for fuel production.

History and Comments.
Ray Leicht of Suring Community Dairy said the utility, digester designer, Focus on Energy, and the USDA Rural Development all worked well together to bring this project to life. The biggest hang-up they had was working with equipment manufactured in different countries (e.g., German engine, Japanese controllers) caused some delays in getting things to fit together properly.

Had he been more familiar with the demands of having a digester as part of their manure management system he would have located equipment differently. They planned to have substrates from off-farm brought in for co-digestion, but discovered that arranging this was not as easy as they thought it would be. One food producer was talking with them about some grease trap wastes and he found out from the Department of Natural Resources that using it may cause some permit issues related to their nutrient management. They continue to explore options for co-digesting some off farm substrates such as food waste and septage.

One energy and cost-saving measure they are implementing is to reroute effluent from the screw press back into the reception pit for pre-heating. This helps lower the energy needed to heat the manure up to digester target temperature by capturing heat from the effluent that would otherwise be wasted. They also plan to pump more manure into the digester during off hours to take advantage of the lower time-of-day electricity rates.

Sources.
Ray Leicht – Suring Community Dairy
Carsten Weber – American Biogas Company
Joe Sinkula – Wisconsin Public Service Corporation

Vir-Clar Farm – Fond du Lac, Wisconsin

Farm Name:	Vir-Clar Farm	**Location:**	Fond du Lac
Farm Type:	dairy	**Herd Size:**	1,350 head (1,200 milking)
Collection Method:	scrape	**Bedding Type:**	digested solids
Digester Type:	complete mix (x2)	**Design Temperature:**	100 deg F
Digester Notes:	above ground tanks, flexible membrane covers		
Design Capacity:	1,350 head	**Date Operational:**	2004
Design HRT:	33 days (oversized system)	**Current HRT:**	30 days
Design Solids %:	not available	**Current Solids %:**	not available
Biogas Use:	electricity and heat	**Utility Contract:**	yes
Installed Capacity:	350 kW	**Prime Mover Brand:**	Caterpillar/SEVA
Solids Separation:	yes, screw press	**Solids Use:**	bedding, farms and potting soil company
Ownership:	farm owns digester and energy generation		
Digester Designer:	Biogas Direct, LLC	**Utility:**	Alliant Energy

Vir-Clar Farm is a 1,350 head Holstein dairy, in Fond du Lac, Wisconsin, in eastern Fond du Lac County. They produce about 27,000 gallons of manure per day. They use digested solids for bedding and do continuous scrape collection. Their former system for manure storage was a storage tank.

Digester.
Vir-Clar Farm installed two Biogas Direct, LLC, digesters to treat their manure. These are above ground complete mix tank systems, with flexible dual membrane covers. The inside membrane holds biogas, and there is a layer of air between the membranes. They operate in the mesophilic temperature range with a target operating temperature of 100 degrees F. The design HRT is 33 days and they are currently at about 30 days. Figure 45 shows the digesters at Vir-Clar.

Figure 45 – Vir-Clar Farm Digesters

Manure is added to the digesters twice a day. They also digest other organics from the farm including bunker wastes, moldy feed, and whatever is not eaten by the cows. They mix the manure going into the digester with liquid coming from the solids separators. They avoid having footbath water go into the digester.[8]

Outputs and Uses.
Biogas from the digester is passed through a passive hydrogen sulfide removal system and chilling unit for condensate removal. It is then fed into a Caterpillar engine generator set that has been modified by the German company SEVA and has a 350 kW generating capacity. The engine generator set is containerized. Figure 46 shows a view of the inside of the container. The generator is synchronous and can operate in stand-alone mode. Electricity generated is sold to Alliant Energy under a sell-all contract. Electricity generation information was not available for this system.

Figure 46 – Engine Generator Set in Container

They do not have a backup boiler. Heat from the engine and exhaust is captured and used for heating the digester, water for calves, the separator room, and to provide in-floor heating in the calf barn.

The farm produces about 150 tons of digested solids per week. They use between 70 and 80 tons on the farm each week, and sell the rest to a small farm and to a potting soil facility who will buy all they can. They compost it and put it into their potting soil mix. Liquid digestate is stored in a storage tank under the cows before being land applied.

History and Comments.
Gary Boyke, owner of Vir-Clar Farm says they had a great experience with construction. They started building the digesters in the beginning of June 2004 and by mid-October they were filling them with manure. In November 2004 they were making electricity.

He thinks the system has paid for itself and is making them money. They are often making more gas than the engine can use and are looking for ways to improve production

[8] Copper sulfate, a common footbath treatment, is toxic to digester bacteria.

and get an even better return. One short-term option they are exploring is to use biogas to heat a new shop they are building.

One thing he would do differently is he would have arranged the structures differently to better use their 1.5 million gallon storage lagoon, and to more easily allow for growth of the farm.

Sources.
Gary Boyke – Vir-Clar Farm
Michael Zander – Energies Direct, LLC (formerly Biogas Direct, LLC)

Wild Rose Dairy – La Farge, Wisconsin

Farm Name:	Wild Rose Dairy	**Location:**	La Farge
Farm Type:	dairy	**Herd Size:**	1,050 head (880 milking)
Collection Method:	scrape	**Bedding Type:**	kiln-dried sawdust
Digester Type:	complete mix	**Design Temperature:**	125 deg F
Digester Notes:	above ground cylindrical tank, carbon steel		
Design Capacity:	800-1,200 head	**Date Operational:**	2005
Design HRT:	20 days	**Current HRT:**	20 days
Design Solids %:	6-8%	**Current Solids %:**	not available
Biogas Use:	electricity and heat	**Utility Contract:**	yes
Installed Capacity:	750 kW	**Prime Mover Brand:**	Waukesha
Solids Separation:	yes, screw press	**Solids Use:**	sold to dairies and organic farmers (export P)
Ownership:	farm owns digester (designer operates and maintains), utility owns energy generation		
Digester Designer:	Microgy, Inc.	**Utility:**	Dairyland Power Cooperative

Wild Rose Dairy is a 1,050 head dairy consisting of half Holsteins, and half Jersey/Holstein crossbreeds. The dairy is located in La Farge, Wisconsin, in southeastern Vernon County. They have 880 head milking from which about 33,000 gallons of manure per day is collected for treatment. They use scrape collection three times a day, and use kiln-dried sawdust for bedding. Their previous manure storage system is an earthen basin which now holds the liquid digestate.

Digester.
Wild Rose Dairy chose to have a Microgy digester installed. Under this business model Microgy installed their digester system on the farm with no cost outlay to the farm. The farmer owns the digester and Microgy operates and maintains it. Dairyland Power Cooperative installed energy generation (using biogas) equipment on the site and buys biogas from the farm. These biogas payments go to Microgy to pay down the farm's debt owed on the digester.

The Microgy system is an above ground carbon steel tank complete-mix digester with a fixed cover. It operates in the thermophilic range with a target temperature of 125 degrees F and an HRT of 20 days. The system is designed to include co-digestion of off-farm high fat food wastes to boost biogas production. About 1,100 gallons of manure mixed with food wastes are batched into the digester hourly. Figure 47 on the following page shows the digester and surrounding structures.

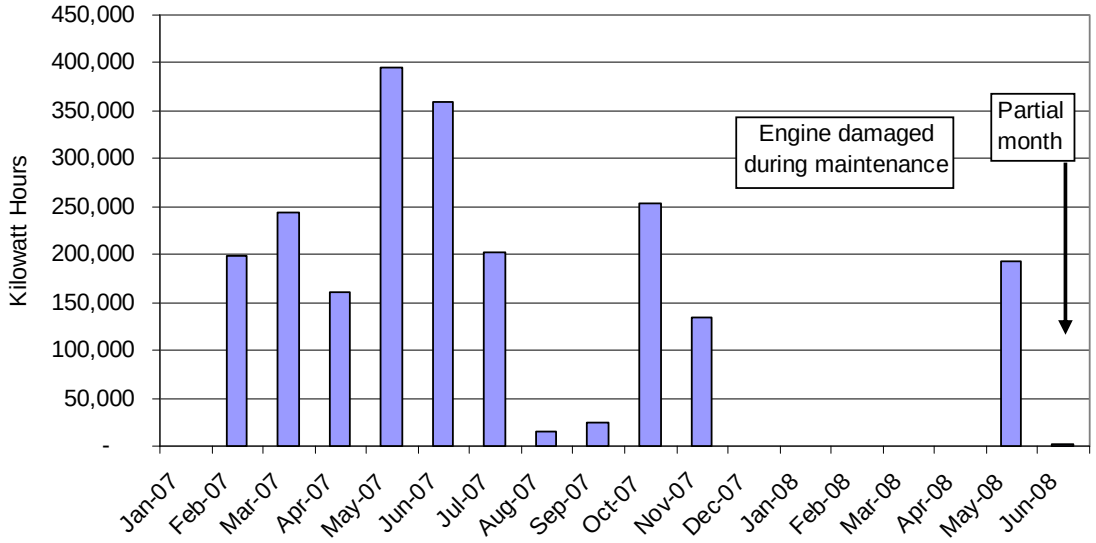
Figure 47 – Wild Rose Dairy Digester

Photo courtesy of Microgy, Inc.

Outputs and Uses.

Biogas produced by the digester is treated with a Biothane brand scrubber, water trap and dehumidifier. It is then used to run a Waukesha 750 kW (net) synchronous engine generator set owned, operated and maintained by Dairyland Power Cooperative. Dairyland buys the biogas and owns renewable energy attributes from the electricity generation. Figure 48 shows the electricity generation history for this location.

Figure 48 – Electricity Generation History for Wild Rose Dairy



Heat captured from the engine is used for the digester only. They have extra they could use but have not yet made the investment to do so. All recovered heat is pulled off the water jacket. They have a backup furnace that runs on LP.

They separate out solids and sell them for use off the farm. Changes in nutrient management requirements meant they had to reduce P application to their soils and this is how the owners decided to address this. This helps with their nutrient management by giving them some control over P application that would not be there without digestion. They are selling separated solids to other dairies for bedding and to organic farmers for fertilizer at about $20 per ton. They produce about five tons per day of these digested solids. In contrast, they use about 12.5 tons of sawdust for bedding every week (or nearly 2 tons per day).

History and Comments.
Mike Casper of Microgy (Dave Schroeder of Microgy is responsible for on-site maintenance and upkeep of the digester) says they experienced greater variability in biogas output from this system than the other two systems in Wisconsin, and they are still exploring why this occurred. One possible reason is that this system was not consistently being run at full load which may have affected the development and sustenance of bacteria cultures. When run at full loading, the system should have outputs similar to Five Star and Norswiss.

Figure 49 – Structures and Piping at Wild Rose

Art Thelen the owner of Wild Rose Dairy says he likes having the digester very much. Microgy did a great job during construction and the start-up went smoothly. They have many tours so people can see what they are doing and how well the animals are being treated. He said "it is only right that the gas be put to use." He also noted that gas production has been more consistent than electricity generation.

One thing Mr. Thelen said he would do differently if starting over that is he would try to group functions into a smaller number of buildings to avoid having so many small buildings. For instance, he would put all pumps and sensors in one place to use the excess heat. Figure 49 shows some of the structures and piping. They have lots of extra heat year round.

Sources.
Art Thelen – Wild Rose Dairy
Mike Casper – Microgy, Inc.
John McWilliams – Dairyland Power Cooperative