Agricultural Biogas Casebook – 2004 Update

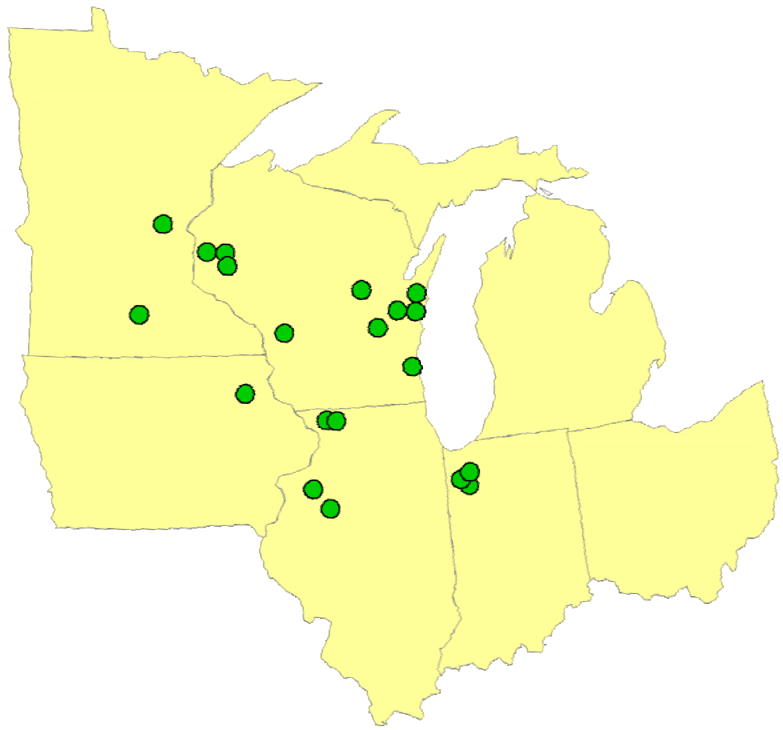

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Table of Contents

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The author has made every attempt to obtain and document all relevant, available information on these systems. Opinions expressed in this casebook do not necessarily reflect those of project funders or advisors. Advisors' comments, experience and insights have increased the quality and usefulness of this casebook. Any remaining errors or omissions are the author's alone.

Abbreviations and Definitions

Abbreviations	
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
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 process heat
Combined Phase	digestion phases are in the same vessel
Complete-Mix Digester	a controlled temperature, constant volume, mechanically mixed vessel designed to maximize biological treatment, methane production, and odor control as part of a manure management facility with methane recovery

Term	**Definition**
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 air-tight 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
Ecalene™	a fuel additive produced from methane using the Power Energy System™, licensed and sold by Power Energy, Inc.
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
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 agreement with a utility that states the utility will purchase the net energy generated by a distributed generation system
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
Return Activated Sludge (RAS)	a process by which some of the digester bacteria are returned to the digester reducing the amount of energy the biological system expends on growth of new bacteria as well as the reaction time required for digestion

Term	Definition
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
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
Two Phase	the digestion phases occur in separate vessels

CHAPTER 1

INTRODUCTION AND METHODOLOGY

Introduction and Background

A number of factors continue to move livestock owners toward use of anaerobic digestion (AD) systems for manure. Important considerations include: economies of scale for livestock operations, encroachment of residential developments on traditional farming lands, and a need for additional profit centers on the farm. Some larger operations are finding that in order to secure permits or local approvals to build or expand their facilities they must include some means of manure treatment with odor control such as an AD system. In addition, as the number of operational systems grows, and farmers become aware of (and often can visit) examples of stable, successful systems, barriers to adopting these systems are dissolving.

The purpose of this casebook is to provide a picture of on-farm AD systems in the Great Lakes states.[1] These systems are characterized including information on technologies, practices, inputs, outputs and owner experiences. This information will help those currently considering AD systems to make informed choices and benefit from the experiences of others.

Those interested in more information on manure management systems and anaerobic processes should visit the US Environmental Protection Agency's AgSTAR program site (<www.epa.gov/agstar>). This site contains numerous downloadable reference materials including the AgSTAR Handbook (Roos, Martin and Moser 2004) and the US Department of Agricultural Natural Resource Conservation Service Biogas Interim Standards (USDA NRCS 2003). Also available on that site are the "Industry Directory for On-Farm Biogas Recovery Systems" and "Funding On-Farm Biogas Recovery Systems: A Guide to Federal and State Resources" which includes information on potential funding sources for biogas projects. For more information on biogas system development opportunities in the Great Lakes states, contact your state biomass program representative. Contact information for these representatives can be found on the State Biomass Contacts page on the Great Lakes Biomass State-Regional Partnership Web site (<http://www.cglg.org/biomass/>).

Structure and Methodology

The casebook contains brief profiles of on-farm biogas systems in the Great Lakes states. This information was gathered primarily through personal interviews with owners or system operators. On many systems, supplemental information on designs, equipment and other operational specifics was also obtained through personal communication with designers and representatives from servicing utilities, as well as through published reports.

The casebook is structured as follows:

- introduction and methodology, description of retired or idle systems
- summary and comparative information on profiled farms and systems
- individual case studies.

Interviews were conducted over a period from March through June 2004. Existing farm-scale digester systems and those under construction during that period were profiled. These profiles

[1] In the spring of 2002 the Council of Great Lakes Governors Great Lakes Regional Biomass Energy Program, with support from Alliant Energy, commissioned production of a casebook documenting experiences of livestock owners using AD systems in the Great Lakes states. Resource Strategies, Inc. (RSI) researched these systems and produced a casebook in September 2002 (Kramer 2002). The first casebook is available at <www.cglg.org/biomass>.

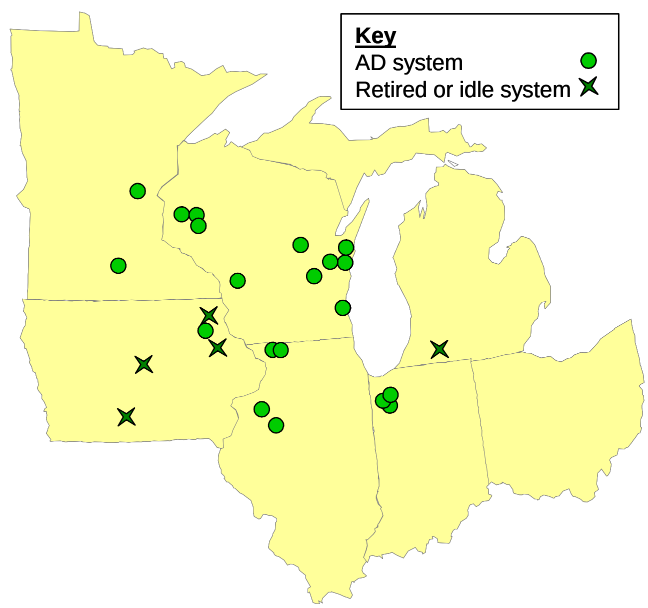
represent snapshots of current situations for the profiled operations. The reader should note that short-term performance data may not reflect actual long-term performance and great care should be taken to consider all aspects of a farm's situation. For those few cases in which operational data were available to provide a more long-term picture of performance, that information is included in the profile. A large number of systems were not equipped with gas gauges which provide a preferred baseline measure of digester performance. Some of these had removed gauges because they became corroded and impeded gas flow causing problems with the engine operation.

In order to examine different aspects of the profiled systems, it was sometimes necessary to look at subsets of farms or digesters. For example, when looking at cows per kW of installed energy generation capacity we must exclude the swine and duck operations, and those dairies without energy generation equipment installed. For each data presentation that uses a subset of the profiled systems, that subset is carefully described.

Due to the limited resources available for this project, it was not possible to verify all information gathered or to visit and inspect systems in person. Information included in digester profiles is as-submitted by participating livestock owners, managers, system designers, and utility representatives. Verification of submitted information using these sources was done whenever possible.

Digesters Idle or Retired

A number of digesters described in the 2002 casebook were not being used at the time of this study. The graphic to the right shows the locations of new or operational systems as well as those that are no longer being used. These systems are described as either retired or idle based on whether they are likely to be re-activated in the near term. Of the five digesters that were retired or idle, three were because of change in farm ownership or production (one of these digesters had run successfully for over 20 years), one was due to design and practice issues, and one was because of funding depletion and complications arising from an experimental system. The cases are described briefly below.



Crawford Farm – retired
The anaerobic sequencing batch reactor (ASBR) installed as a demonstration project at Crawford Farms in Nevada, Iowa, was abandoned after numerous mechanical and structural problems. Because of electrical problems and component failures (some resulting from a lightning strike), the ASBR required excessive owner daily attention. The digester could be redesigned and re-started, but there are currently no plans to do so (Crawford 2004, Sung No Date).

Fairgrove Farms – retired
The plug-flow digester at Fairgrove Farms, near Sturgis, Michigan, was retired in September 2002 after about 21 years of successful operation. The farm ceased operating as a dairy at that time and therefore did not have the manure production needed to feed the digester (Pueschel 2004).

Northeast Iowa Community College – retired
The plug-flow digester for Northeast Iowa Community College, in Calmar, Iowa, has been inoperative since March 2003. They had several design and piping problems including freezing, clogging and blowouts. The use of wood shavings for bedding contributed to mat formation within the plug. They do not plan to start the digester again (Koester 2004).

Futura Dairy – idle
The mixed plug-flow loop digester at Futura Dairy in Central City, Iowa, was inactive at the time of the survey. The farm had ceased operating as a dairy and was reported to be up for sale. This system is classified as "idle" because it is possible the buyers of the farm may run a dairy and re-start the digester. Farm contacts were not available to confirm this information.

White Stone Farms (formerly Bell Farms/Swine USA) – idle
The complete-mix digester at White Stone Farms in Thayer, Iowa, was idle as of March 2004. The farm had two ownership changes after the digester was installed and the current owners feel they do not have the knowledge needed to properly manage the system. They are currently consulting with an engineer to see how they could use the digester. They expect it to require a full system clean-out, replacement of several parts, and training or hiring a staff person to manage it (Eenhuis 2004).

CHAPTER 2

SUMMARY INFORMATION

This section provides an overview of the systems examined and information collected. Information regarding operation and experiences was obtained from the farm owner or manager whenever possible. Details regarding digester design and related equipment were gathered from the designers, and information on the energy generation equipment was acquired from the servicing utility, the designer or the farm owner as needed. In most cases, the farm profile is compiled from information from those three sources with some corroboration. When conflicting information was given, the farm owners' information was used.

Case studies of farms that were under construction at the time of the survey are abbreviated due to lack of operational experience or performance data. The sole system in startup phase has more available information but lacks operational experiences due to its stage of development. Systems that are operational have the most extensive profiles.

Of the previous casebook project participants, two owners have chosen not to have their operations publicly profiled at this time. The four digesters on these two farms were operational at the time of contact, but other details are not available. Therefore, those systems are included in our overall listing of installed systems (Table 1 only), but updated profiles are not included in this edition of the casebook.

Table 1: Farms and Digesters in the Region – by Status

Farm Name	Farm Type (Head Feeding Digester) [a]	State	Digester Type Category
Construction			
Boss Dairy No. 4	dairy (3,400)	IN	mixed plug-flow loop (x2)
Five Star Dairy	dairy (910)	WI	complete-mix
Hunter Haven Farms	dairy (1,000)	IL	mixed plug-flow loop
Scheidairy Farms	dairy (1,000)	IL	mixed plug-flow loop
Wild Rose Dairy	dairy (900)	WI	complete-mix
Startup			
Fair Oaks Dairy	dairy (3,200)	IN	vertical plug-flow (x4)
Operational			
Apex Pork	swine finishing (8,300)	IL	heated mixed covered lagoon
Baldwin Dairy	dairy (1,100)	WI	covered lagoon
Double S Dairy	dairy (1,100)	WI	mixed plug-flow loop
Emerald Dairy	dairy (1,600)	WI	covered lagoon
Gordondale Farms	dairy (875)	WI	mixed plug-flow loop
Haubenschild Farms	dairy (840)	MN	plug-flow
Herrema Dairy (formerly Boss)	dairy (3,750)	IN	mixed plug-flow loop (x2)
Maple Leaf Farms	duck (500,000)	WI	complete-mix
New Horizons Dairy (formerly Inwood)	dairy (1,400)	IL	plug-flow (x2)
Northern Plains Dairy [b]	dairy (3,000)	MN	plug-flow (x2)
Stencil Farm	dairy (1,000)	WI	plug-flow
Tinedale Farms	dairy (2,400)	WI	complete-mix (formerly TPAD)
Top Deck Holsteins	dairy (675)	IA	plug-flow
Wholesome Dairy [b]	dairy (3,000)	WI	mixed plug-flow (x2)
Total: 20 farms	**Farms: dairy=18, swine=1, duck=1**		**Total Digesters: 28**

a. Farms going through expansions at or near the time of the survey are listed at their predicted post-expansion size. The number listed is the population feeding the digester, not necessarily the farm herd population.
b. Updated information on this system was not available. Therefore, an updated case study for this system is not included in this edition of the casebook.

Farm and Design Characteristics

Table 1, on the preceding page, lists the farms in the Great Lakes states with existing digesters or with digesters under construction, excluding those listed as retired or idle in the previous section.

Digesters in this casebook are described using the following characteristics: combined phase or two phase, operating temperature range, basic digester type category, and cover type. The following table lists the digesters profiled in this casebook and the appropriate characteristics.

Table 2: Profiled Digester Types and Categories

Farm Name	**Phases**	**Temperature**	**Type**	**Cover**	**Year Built**
Apex Pork (swine)	combined phase	mesophilic	heated mixed covered lagoon	flexible	1998
Baldwin Dairy	combined phase	psychrophilic	covered lagoon	flexible	1998
Boss #4 Dairy	two phase [a]	mesophilic	mixed plug-flow loop (x2)	fixed	2004
Double S Dairy	two phase	mesophilic	mixed plug-flow loop	fixed	2001-2
Emerald Dairy	combined phase	psychrophilic	covered lagoon	flexible	1999
Fair Oaks Dairy	combined phase	mesophilic	vertical plug-flow (x4)	fixed	2004
Five Star Dairy	combined phase	thermophilic	complete-mix tank	fixed	2004
Gordondale Farms (dairy)	two phase	mesophilic	mixed plug-flow loop	fixed	2001
Haubenschild Farms (dairy)	combined phase	mesophilic	plug-flow	flexible	1999
Herrema Dairy	two phase	mesophilic	mixed plug-flow loop (x2)	fixed	2002
Hunter Haven Farms (dairy)	two phase	mesophilic	mixed plug-flow loop	fixed	2004
Maple Leaf Farms (duck)	combined phase	mesophilic	complete-mix tank	fixed	1988
New Horizons (dairy)	combined phase	mesophilic	plug-flow (x2)	flexible	2001-2
Scheidairy Farms (dairy)	two phase	mesophilic	mixed plug-flow loop	fixed	2004
Stencil Farm (dairy)	combined phase	mesophilic	plug-flow	flexible	2001-2
Tinedale Farms (dairy)	combined phase	mesophilic	complete-mix (converted TPAD) [b]	fixed	2001
Top Deck Holsteins (dairy)	combined phase	mesophilic	plug-flow	fixed	2002
Wild Rose Dairy	combined phase	thermophilic	complete-mix tank	fixed	2004

a. These digesters were classified as combined phase in the previous casebook but the designer suggested that "two-phase" was a more accurate description since the digester contains separate chambers for the digestion phases.
b. Temperature-phased anaerobic digester.

The profiled systems include some new variations on digester types. Table 3 lists the 16 dairies with digesters profiled in this casebook, and brief descriptions of the installed systems.

Table 3: Count of Profiled Dairy Digesters by Type

Farms	**Digester Descriptions**	**Digesters**
2	psychrophilic covered lagoon	2
3	mesophilic plug-flow with flexible cover	4
1	mesophilic plug-flow with fixed cover	1
6	mesophilic two-phase mixed plug-flow loop with fixed cover	8
1	mesophilic vertical high-rate plug-flow tank	4
1	mesophilic complete-mix adapted from temperature phased AD	1
2	thermophilic complete-mix tank	2
Total = 16		Total = 22

This casebook uses the following definitions for digester temperature ranges (as defined by Lusk 1998).[2]

- psychrophilic <68° F
- mesophilic 95° to 105° F
- thermophilic 125° to 135° F

The profiled digesters include 17 that are described by the designers as "plug-flow" systems and variants, and five described as "complete-mix" or variants. Table 4 lists some design and operational specifications for these systems, grouped by subtype.

Table 4: Digester Subtypes and Operational Specifications

Plug-Flow Type	**Design Solids Content**	**Target Temp. (° F)**	**RAS** [a]	**Hydraulic Residence Time (HRT)**
standard, straight	9-14%	98-105	no	20 days (one digester is 14 days)
mixed, loop	8-10%	100-101	yes	20 days, SRT>20 days
vertical tank	3-7% [b]	95-98	yes	6 days, SRT=18-24 days
Complete-Mix Type	**Design Solids Content**	**Target Temp. (° F)**	**RAS**	**Hydraulic Residence Time (HRT)**
covered lagoon (swine)	2.5-10% [c]	na (mesophilic)	no	18-20 days
tank (duck)	1-2.5%	na (mesophilic)	yes	7-10 days
tank (former TPAD)	9-10%	100	no	20 days
tank (thermophilic)	6-8%	135	no	20 days

a. Return activated sludge refers to a process by which some of the digester bacteria are reintroduced to the digester reducing the amount of biological energy expended on propagation and increasing the energy available for gas production.
b. Although this is the target range for the digesters on the profiled farm, the designer maintains that this design will work with virtually any solids concentration likely to occur on a dairy farm.
c. This is the range given by USDA NRCS in its practice standards for complete-mix systems (USDA/NRCS 2003).

Digester Performance

Profiled digesters were nearly all reported to be functioning as intended.[3] The owners reported little or no digester down-time for the 12 profiled farms with stabilized digestion systems. Those reporting biogas production fluctuations or other digestion issues during their operational histories gave one or more of the following as contributing factors:

- inadequate heat to digester due to engine trouble or maintenance
- water pipe break affected solids content of influent
- anti-freeze leak in a barn killed much of the bacteria when manure put in the digester, and
- sanitizing footbath sent into digester depleted bacteria population.

[2] Alternative definitions of these ranges do exist. The German Biogas Association defines them as psychrophilic 50° to 77° F, mesophilic 86° to 95° F, and thermophilic 120° to 140°F (da Costa Gomez no date).
[3] The sole exception is the Tinedale Farms digester which was designed as a TPAD system but is now being run as a complete-mix (i.e., mesophilic only) system.

Biogas Applications

The large majority of anaerobic digester systems either use or plan to use the biogas to generate electricity. Recovered heat from the electricity generation is used for heating the digester and other applications. The details on biogas uses, equipment and heat applications are listed in Table 5 below.

Table 5: Biogas Uses and Equipment

Farm Name	Biogas Use	Utilization Equipment	Heat Applications
Apex Pork	heat	boiler	digester
Baldwin Dairy	none	flare	na
Boss #4 Dairy	electricity, heat	2 Waukesha 350 kW (biogas rated) engine-generator sets, synchronous	digester, water
Double S Dairy	electricity, heat	Caterpillar 200 kW (biogas rated) engine-generator set with option for turbo (+60 kW) replacing Hess 200 kW, induction	digester, parlor floor, all offices, floor in shop
Emerald Dairy	none	flare	na
Fair Oaks Dairy	electricity, heat	2 Waukesha 375 kW (biogas rated) engine-generator sets, induction	digester
Five Star Dairy	electricity, heat	Waukesha 775 kW engine-generator set (750 kW net) designed for biogas, induction	digester, may heat barn floors and collection pits to prevent freezing
Gordondale Farms (dairy)	electricity, heat	Caterpillar 3406 135 kW (biogas rated) engine-generator set, induction	digester, dairy parlor, holding area, offices, engine room, pad for milk tankers, maybe adsorption/absorption refrig unit
Haubenschild Farms (dairy)	electricity, heat	Caterpillar 3406 retrofitted 135 kW (biogas rated) engine-generator set, induction	digester, parlor, alleyway, store hot water in 180 gal tank reserve - used for the other functions
Herrema Dairy	electricity, heat	2 Hess 350 kW (biogas rated) engine-generator sets, induction	digester, hope to use for floor heat in barn, alleyway
Hunter Haven Farms (dairy)	electricity, heat	Caterpillar 200 kW (biogas rated) engine-generator set, induction	digester, hot water, in floor heating
Maple Leaf Farms (duck)	electricity, heat	Hess/Daewoo 200 kW (biogas rated) engine-generator set, operates as induction, also back-up boiler	digester, offices, lab, utility bldg (when engine working), boiler digester only
New Horizons (dairy)	electricity, heat	2 Caterpillar 3406 130 kW (biogas rated) engine-generator sets, induction	digester, hot water, hydronics system
Stencil Farm (dairy)	electricity, heat	Caterpillar 3306 140 kW (biogas rated) engine-generator set, induction	digester
Scheidairy Farms (dairy)	electricity, heat	Caterpillar 200 kW (biogas rated) engine-generator set, induction	digester, hot water, in-floor heating
Tinedale Farms (dairy)	electricity, heat	Waukesha 375 kW (biogas rated) engine-generator set, low NOx, induction	digester, have excess now but not likely to use for anything else
Top Deck Holsteins (dairy)	electricity, heat	Waukesha 100 kW (biogas rated) engine-generator set, induction, 30 kW Capstone microturbine	currently digester only, would use for parlor, hot water for pipeline washing, parlor cleaning, floor heat in alley
Wild Rose Dairy	electricity, heat	Waukesha 775 kW engine-generator set (750 kW net) designed for biogas, induction	digester

Nearly all the farms in this casebook have chosen engine-generator sets to use their biogas. These sets range in capacity from 100 kW to 750 kW (biogas rating). One system uses a boiler to generate heat only. Another has a 30 kW microturbine in addition to an engine-generator set.

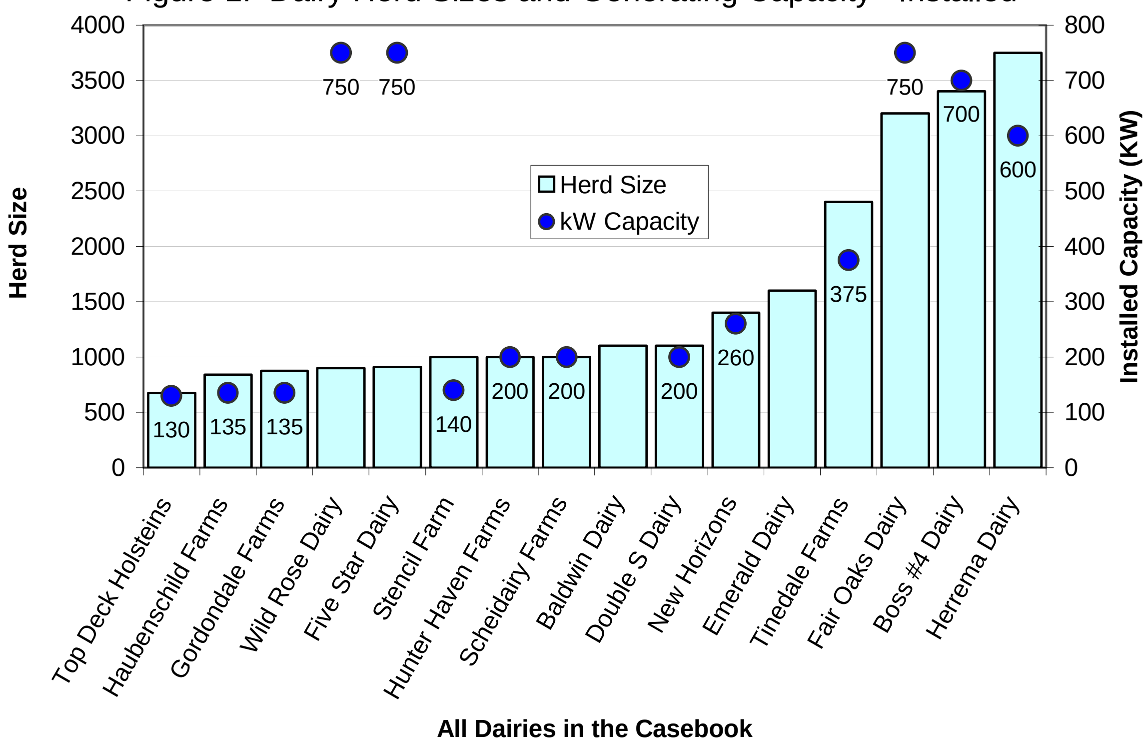
Generating and either using and or selling electricity is often seen as one of the primary means of recovering installation costs. For many of the systems profiled in this casebook, problems with generating equipment have meant lower than expected electricity production. Dairies and energy generation systems are examined in more detail below.

Profiled Dairies and Installed Capacities

There are 16 dairy operations with digesters in this edition of the casebook. Together these digesters will process waste from approximately 30,750 dairy cattle and have 5.325 MW of installed generating capacity. The amount of generating capacity installed at each farm should logically reflect expectations regarding the biogas outputs and capabilities of the digestion system installed (i.e., installing too much excess capacity can be costly and installing too little can result in lost opportunities to use biogas). Generating capacity represents the theoretical maximum amount of energy the system could generate. In practice, all engines, even when functioning properly, require some down-time for regular maintenance. Therefore, this maximum is never reached for extended periods of time.

Herd sizes for this group ranged from 675 to 3,750 head. Figure 1 below illustrates the herd sizes for the dairies profiled in this casebook, ranked smallest to largest, and the kW of generating capacity they have installed.

Figure 1: Dairy Herd Sizes and Generating Capacity [a] Installed

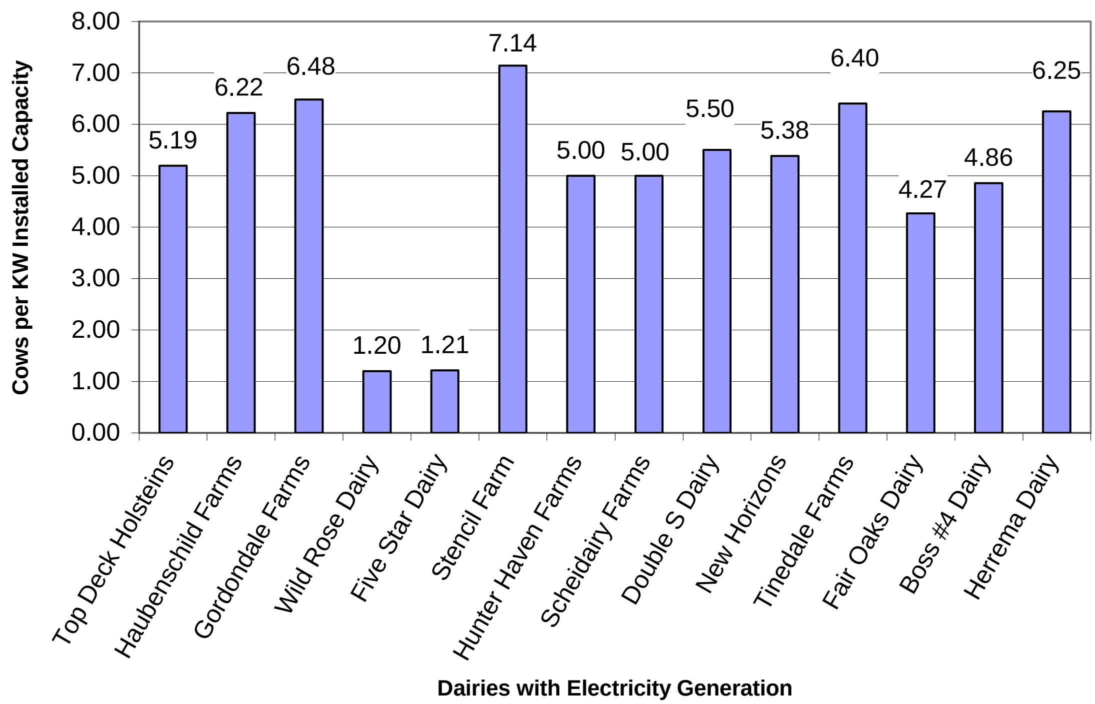


a. Generating capacity should not be confused with actual performance. For information on systems performance see the Systems Performance section later in this chapter.

As the figure suggests, the relative generating capacity installed for these dairies tends to correspond to the relative herd size. The graph also shows some notable exceptions. Five Star and Wild Rose dairies (both still under construction as of this writing) in Wisconsin each have under 1,000 head but plan to have 750 kW installed capacity. The owners of these systems plan to include high-fat food-grade wastes as part of their influent streams. These added substrates, along with efficiencies the manufacturer maintains are provided by this digestion technology, account for their high expectations for biogas production.

To illustrate the difference in the profiled systems, Figure 2 below shows the cows per kW of installed electricity generation capacity for each system.

Figure 2: Cows per Kilowatt of Installed Capacity [a]



Farm Name	Herd Size	kW Installed Capacity [a]	Purchasing Utility	Contract
Top Deck Holsteins	675	130	Alliant Energy	yes
Haubenschild Farms	840	135	East Central Energy	yes
Gordondale Farms	875	135	Alliant Energy	yes
Wild Rose Dairy	900	750	Dairyland Power	yes
Five Star Dairy	910	750	Dairyland Power	yes
Stencil Farm	1,000	140	Wisconsin Public Service	yes
Hunter Haven Farms	1,000	200	ComEd	no
Scheidairy Farms	1,000	200	ComEd	no
Double S Dairy	1,100	200	Alliant Energy	yes
New Horizons	1,400	260	AmerenCILCO	no
Tinedale Farms	2,400	375	We Energies	yes
Fair Oaks Dairy	3,200	750	Jasper County REMC	yes
Boss #4 Dairy	3,400	700	Jasper County REMC	yes
Herrema Dairy	3,750	600	Jasper County REMC	yes

a. Generating capacity should not be confused with actual performance. Information on actual systems performance is covered in the next section.

The Five Star and Wild Rose systems have cows-per-kW ratios of 1.21 and 1.20 respectively, compared to the average for all other systems of 5.64. Another notable system is the group of Fair Oaks Dairy digesters designed by Dennis Burke, with a cows-per-kW installed capacity ratio of 4.27. The owners of this system plan to constantly feed in natural gas to keep the engines running at full capacity regardless of how much biogas is produced. The farm and its affiliates plan to use all of the electricity produced.

Systems Performance

Ten profiled operational systems had energy generation equipment installed to use the biogas. Comparing performance of these systems directly is problematic for the following reasons:

- few systems have recorded data on biogas production
- several owners reported serious problems with their energy generation equipment

A number of digester systems had trouble with their engine/generator sets. Engine breakdowns not only limited the availability of long-term performance measures, but, in some cases, disrupted digestion processes by causing digester temperatures and biogas production to fluctuate.

Table 6 lists the farms with operational systems and reported performance issues.

Table 6: Biogas Use Experiences – Operational Systems with Energy Generation

Farm Name	**Biogas Utilization Equipment**	**Performance**
Apex Pork	Burnham boiler	no issues
Double S Dairy	Hess engine-generator set	repeated problems, recently replaced with Caterpillar engine-generator set
Gordondale Farms	Caterpillar 3406 engine-generator set	no engine issues, gas meter became corroded, obstructed flow, meter removed
Haubenschild Farms	Caterpillar 3406 engine-generator set	no issues (has run >41,000 hours without overhaul)
Herrema Dairy	Hess engine-generator set (x2)	repeated problems with both sets, never approached rated capacity, engines recently replaced (and now maintained) by manufacturer
Maple Leaf Farms	Hess engine-generator set	repeated problems, looking at other generation
New Horizons	Caterpillar 3406 engine-generator set (x2)	no major issues
Stencil Farm	Caterpillar 3306 engine-generator set	recent engine problems and overhaul
Tinedale Farms	Waukesha engine-generator set	repeated breakdowns caused by moisture and H_2S getting into cylinders
Top Deck Holsteins	Waukesha engine-generator set, Capstone microturbine	repeated (suspected age-related) problems with engine-generator set, no issues with microturbine

Biogas production records are probably the simplest baseline measurement of digester performance. The number of systems with any extended period of recorded biogas production was small. For systems without records of biogas production, the amount of electricity generated can also be used as a performance measure. Statistics on electricity generation, however, include other operational variables (such as engine-generator set maintenance and performance) that make them less directly representative of digester performance. Naturally, performance data covering longer periods are stronger indicators of system capabilities provided there are no unusual events over those periods. However, even with seemingly comparable information, direct comparison of these systems is far from straightforward due to operational and situational differences such as variation from design parameters, maintenance activities and addition of other substances or fuels. As the number of operational systems grows, the opportunities for direct comparisons will grow as well. Table 7 below lists the four operational systems that had performance data for a period of 6 months or longer.

Table 7: Digesters with Performance Data

Farm	Biogas Production/ Period of measure	Electricity Production/ Period of measure	CF/Cow/ Day	kWh/Cow/ Year
Gordondale Farms (dairy) [a]	na	876,051 kWh/ 12 months	na	1,208
Haubenschild Farms (dairy) [b]	86,000 cfd / 36 months	1,095,000 kWh/ 12 months	102	1,304
New Horizons (dairy) [c]	115,000 cfd/ 12 months	1,500,000 kWh/ 12 months	82	1,071
Tinedale Farms (dairy)	200,000 cfd/ 6 months	na	83	na

a. Monthly electricity production for this farm varied from 95,767 kWh (January 2004) to 17,520 (July 2003). This variation is attributed to equipment malfunctions, an anti-freeze leak that depleted the microbes, and engine availability during that period. The performance measure kWh/cow/year was made with the herd size during that period (i.e. 725 head) rather than the current herd size.

b. Electricity production for this farm is augmented by the addition of 10 ft^3 of propane to the gas stream per day. The owners indicated that the use of shredded newspaper for bedding may also be boosting biogas production.

c. This farm had a growing herd population over the measuring period, meaning this calculation, which uses the most recent herd number, likely understates the per-cow production rates. This farm also adds crop and food waste substrates to their digester on a daily basis which should increase biogas production and per-cow rates.

Costs of Digester Systems

Cost information on installed systems was available with varying levels of specificity. Again, comparisons across systems are not straightforward. Table 8 on the following page lists the cost figures as given by owners for installed systems. Some of the estimates given were itemized and presumably more-precise, whereas others were given as ball-park figures.

Table 8: Costs for Operational Systems

Farm Name	Total Cost to Make Operational	Cost Comments and Details	Total Cost per Head (and per AU [a]) (Grant Funds Included)
Apex Pork	$152,300	$66,700 for cover and gas collection equipment, $85,600 for boiler and gas handling equipment	$18 ($46) swine – based on current herd of 8,300 (3,320 AU)
Baldwin Dairy	$70,000	costs are for lagoon cover and gas collection equipment only	$57 ($45) based on design capacity of 1,100 (1,540 AU)
Double S Dairy	$500,000 (digester only)	engine-generator set costs were not available (paid by Alliant Energy)	$500 ($357) digester only – based on design capacity of 1,000 (1,400 AU)
Emerald Dairy	$125,000	costs are for lagoon cover and gas collection equipment only	$78 ($60) based on current population of 1,600 (2,080 AU)
Gordondale Farms	$520,000	digester cost $230,000, energy generation cost (Alliant Energy) $290,000	$650 ($464) digester $288, energy generation $362 and grid connection – based on design capacity of 800 (1,120 AU)
Haubenschild Farms	$355,000	owner set it up with extra wiring, plumbing and thicker walls for contingencies and experiments. Owner paid $77,500, and got $150,000 no-interest loan from MN Dept. of Agriculture, $50,000 grant from MN Dept. of Commerce, $37,500 grant from MN Office of Environmental Assistance, $40,000 AgStar in-kind services.	$444 ($317) based on design capacity of 800 cows (1,120 AU)
Herrema Dairy	na	na	na
Maple Leaf Farms	$804,000	$534,000 (digester cost converted to 2002 dollars) + $270,000 energy generation equipment costs. Got $65,000 from WI Dept. of Administration (toward the $270,000 cost)	$1.6 ($161) duck – based on current population of 500,000 (5,000 AU)
New Horizons	$1.526M	received grants totaling $226,000 from IL Dept. of Commerce and Community Affairs, and Division of Energy and Conservation	$763 ($545) based on design capacity of 2,000 (2,800 AU)
Stencil Farm	$500,000	na	$417 ($298) based on design capacity of 1,200 (1,680 AU)
Tinedale Farms	na	system involved a lot of R&D resulting in high costs	na
Top Deck Holsteins	$501,500	Iowa DNR and NRCS contributed $157,900, Alliant Energy paid $250,000 for the energy generation equipment and to connect the system to the grid, and Top Deck paid $93,600 for the digester	$743 ($548) based on current herd size of 675 (915 AU)

a. Animal units (AU) are calculated using Wisconsin Department of Natural Resources conversion factors as follows: milking cows = 1.4; cattle = 1.0; swine = 0.4; duck = 0.01. Dairy estimates may include both dairy cows and dry cattle. AU numbers used here represent animals feeding the digester only.

For dairies with operational systems including energy generation, the range of cost per cow given was from $417 to $763. The two dairies with covered lagoons reported much lower costs per cow with $57 and $78 per cow. These systems, however, did not use energy generation (they flared the biogas) and costs only include lagoon covers and gas collection equipment.

Benefits of Digester Systems

Owners reported numerous benefits to their operations from using anaerobic digestion. However, the benefits were sparsely recorded and often not quantified. The benefits described were not always separable and mutually exclusive and were often not easily monetized. Many of the systems profiled in this casebook did not have their benefits quantified in any way.

For the purpose of this section, only the benefits to the farm are discussed (i.e., environmental and local economic benefits are not covered). Owners of operational systems examined in this casebook offered the following comments on benefits they received from their AD systems.

Table 9: Benefits of Operational Systems

Farm Name	Annual Benefits Savings or Revenues
Apex Pork	odor reduction has stopped complaints
Baldwin Dairy	odor controlled, volume needing treatment reduced due to precipitation exclusion, easier handling of digested manure
Double S Dairy	$30,000 savings using digested solids for bedding
Emerald Dairy	odor controlled, volume needing treatment reduced due to precipitation exclusion, easier handling of digested manure
Gordondale Farms	$23,000 in biogas sales (based on kWh of electricity generated), $30,000 savings replacing commercial fertilizer with digested manure, $28,800 savings using digested solids instead of sand, reduced need for pest control in barns saving $5,000 per year, $2,000 in reduced propane use, herbicide savings (not yet calculated), less lime needed to balance pH in soil, significant odor control, extra heat allows use of warm flush flumes and daily scraping throughout the year
Haubenschild Farms	$66,000 in electricity sales and offsets, $50,000 savings replacing commercial fertilizer with digested manure, $30,000 savings in reduced herbicide use, $4,000 in reduced propane use, less stirring needed, better neighbor relations, improved operational flexibility
Maple Leaf Farms	odor reduction improved, continued operation despite encroaching residential development
New Horizons	$40,700 in electricity sales and offsets, process heat allows use of hydronics system, odor greatly reduced
Stencil Farm	electricity offsets, bedding cost savings, odor reduction, improved fertilizer quality of manure
Tinedale Farms	$75,000 saved using digested solids for bedding

Note: Operational systems are not listed here if the owners did not describe any benefits associated with those systems. This should not be interpreted as meaning they did not experience any benefits from using the AD system, only that they did not share this information for the casebook.

Electricity Sales. Electricity sales or offsets are often heralded as the primary benefits these systems can provide. For several of these systems, information on electricity sales was not available. This lack of information was often due to operational difficulties with generation equipment. Annual sales revenues and cost offsets ranged from $23,000 ($32/head) to $66,000 ($78/head). For these systems, benefits from use of digested solids for bedding and commercial fertilizer replacement often rivaled the benefits from energy generation.

Bedding. Using recovered digested solids for bedding was another source of cost savings for some digester owners. Annual savings estimates, based on the avoided costs associated with using other bedding materials, averaged about $32 per head and ranged from about $29,000 to $75,000. Some farms were using a combination of solids and other substrates for bedding.

A common concern of dairy owners in considering use of digested solids for bedding is that it might result in elevated somatic cell counts in their herds. Table 10 lists the somatic cell counts reported for farms using only digested solids for bedding.

Table 10: Digested Solids and Somatic Cell Counts

Farm	Herd Somatic Cell Count
Dairy 1	150,000 to 170,000
Dairy 2	260,000
Dairy 3	180,000 (was 120,000 with sand)
Dairy 4	250,000
Dairy 5	190,000

Some farms have seen an increase in somatic cell counts after switching to digested solids. Nevertheless, as a group, they have remarked that the cows prefer the solids to other bedding they have used, and that the cows are very clean when bedded with solids.

One dairy (not listed in the above group) has temporarily switched from using digested solids to using rice hulls at their veterinarian's request after they experienced some mastitis. The veterinarian believes elevated bacteria levels in the bedding occurred because they were not getting the solids dry enough (even after composting). They plan to switch to a combination of solids and rice hulls as their regular bedding material.

Commercial Fertilizer Replacement. Some characteristics of digested manure (i.e., improved nutrient availability, reduced acidity, reduced odor) allow owners to use it as a substitute for commercial fertilizers in some cases. Reported savings in avoided fertilizer purchases for this group ranged from $30,000 ($41/head) to $50,000 ($60/head) per year.

Odor Control. Nearly all the system owners mentioned odor reduction as an important benefit of their AD system. For new farms, some means of odor control is often either implicitly or explicitly required for the facility to be sited and built. Some owners of ongoing operations reported that the encroachment of residential developments near their farms have put increasing pressure on them over time (sometimes in the form of lawsuits) to reduce odor emissions. Because digested manure has much lower odor than raw manure, owners have more flexibility in when and where they field-apply it (i.e., they do not have to wait until the wind is blowing the right way or avoid applying it on weekends). Therefore, the seemingly simple benefit described as "odor reduction" actually encompasses:

- quality of life (both on and off farm)
- avoided lawsuits or complaints
- continuation of operation or ability to site facility
- increased operational flexibility

Other Benefits. Digester owners also reported benefits in the form of avoided herbicide purchases and applications, reduced need for pest control services for the barns, and less need for lime for field application. Other benefits such as the ability to use a heated flush flume or hydronics system and to continue regular scrape collection year round help improve efficiency and operational flexibility on the farm.

A better understanding and tracking of system costs and benefits is needed to provide meaningful estimates of system net effects. Some quantification of odor control, process improvements, and other seeming intangibles would allow a more accurate portrayal of the effect installation of an anaerobic digestion system has on farm welfare.

Business Models

Planned and actual installations of digester systems in the Great Lakes states have occurred in the form of several distinct business models. Some brief descriptions of these models are given below.

Farm Owns All. The most straightforward model, when the farm owns all the equipment and takes responsibility for all operations, has also been the most common. Under this model, the farm owner buys, manages and maintains the digester and the energy generation equipment. This option offers the most potential for gains from income generated and also offers the farm owner the most control over the system. However, this model also has the farm owner assuming all the risk and responsibilities for the systems as well as the full up-front cost. None of the farm owners interviewed who were operating under this model indicated they would prefer an alternative model.

Alliant Energy Model. Another model that has been used in Wisconsin and Iowa is to have the farm own the digester and have the servicing utility own and maintain the energy generation equipment. Alliant Energy has pioneered this model which takes on some of the risk and up-front expense that would have been shouldered by the farm. This model has the utility buying, installing and often maintaining the energy generation equipment (or paying the farm to do so). These are areas in which the utility has more expertise and resources than the farm does. Some drawbacks to this approach for the farm owner are a reduced earning potential from biogas generation (Alliant Energy's agreements involve purchase of biogas from the digester owner based on the amount of electricity generated) and lack of control over the energy generation system. In practice, some farm owners that have installed digesters under this type of agreement have said that if given the opportunity to do it again, they would own the energy generation equipment themselves.

Microgy/Dairyland Model. A new model has recently been used in Wisconsin by Microgy Cogeneration Inc. and Dairyland Power Cooperative. Under this model, Microgy installs a digester on a farm, then maintains it for the life of the project. Dairyland Power, the servicing utility for these projects, buys, installs and maintains the energy generation equipment on the farm. The farm owns the digester but pays no out-of-pocket costs (i.e., it is financed using 100 percent non-recourse financing), and income from the sales of biogas to Dairyland Power is earmarked to buy down the debt on the digester. Microgy estimates that the digester debt will be paid off after ten years of operation. Also, the farm owner has the option of buying down the debt earlier. This model is new and farm owner comments on it were not yet available.

Shared Facilities. Some other models have been proposed or implemented that may reduce barriers to AD system use or maximize shared resources or benefits from economies of scale. One example is a centralized digestion system. The first phase of this project was recently completed in the Port of Tillamook Bay, Oregon (Port of Tillemook Bay 2004). Although it is out of the Great Lakes region, this model could be used in the region. When completed, this group of digesters will be fed manure from about 4,000 dairy cattle from several nearby dairies. Manure will be collected by facility vehicles, transported to the digester, and some digested material will be returned to the farms. Variations on this centralized system model have been proposed in which the manure is piped into a centralized digester (Wall 2004), and in which biogas from multiple digesters is piped in to a centralized gas processing plant where it is processed into liquefied natural gas and resold (Mulder 2004). This model was not yet represented in the region, so farm owner comments on it were not available.

Shared Expertise. Rather than sharing facilities, another group of livestock owners have plans to share maintenance and trouble-shooting staff among several operations installing anaerobic digesters and energy generation. The proposed collaborative currently includes about 17 dairies with a combined herd of 50,000 head in Wisconsin and Michigan (Selsmeyer 2004). This model was still in the development phase and farm owner comments on it were not available.

Combined with Ethanol Production. Another model, yet to be implemented in the Great Lakes states, is to use the methane, heat or other products from a manure digester for industrial processes. An innovative example of this type of business model is being developed by Harrison Ethanol, LLC in Harrison County, Ohio. This project involves a large dairy and beef operation (permitted at 12,800 animal units) that will install six parallel mixed plug-flow digesters as a component of a small fuel grade ethanol plant. Plans are to use the methane as a fuel to generate electricity and recover "trickle down" energy from that process, and also use the cellulosic portion of the recovered digested solids as boiler fuel. The team developing this project has improved potable water recovery, increased methane percentage generation, and identified numerous opportunities for synergistic processes, and efficiency and design improvements. This project, the first of three similar systems proposed for Ohio, is expected to begin construction in September 2004. This model has yet to be used in the region, so farm owner comments were not yet available.

CHAPTER 3

CASE STUDIES

The farm profiles are grouped by development status: systems under construction, systems in startup, and operational systems. These terms are defined as follows for the purposes of this casebook.

Systems under Construction: AD projects which have broken ground but have not yet reached the stage where manure is added to the digester.
Systems in Startup: AD projects that have completed construction and are currently having manure added, but have not yet achieved stabilized biogas production.
Operational Systems: AD systems that have stabilized biogas production.

Systems Under Construction

Farm Name	Farm Type	Location	Digester Type
Boss Dairy No. 4	dairy	Fair Oaks, IN	mixed plug-flow loop (x2)
Five Star Dairy	dairy	Elk Mound, WI	complete-mix tank*
Hunter Haven Farms	dairy	Pearl City, IL	mixed plug-flow loop
Scheidairy Farms	dairy	Freeport, IL	mixed plug-flow loop
Wild Rose Dairy	dairy	La Farge, WI	complete-mix tank*

* Microgy Cogeneration Inc. proprietary design.

Systems in Startup

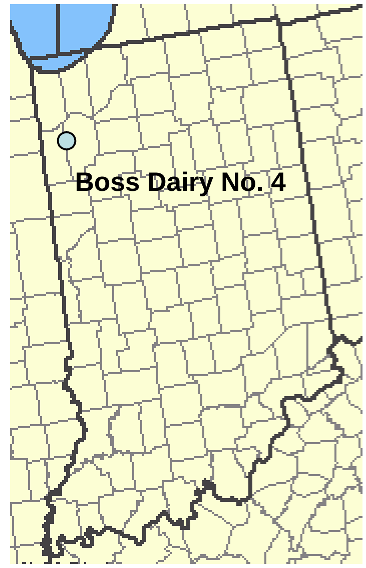
Farm Name	Farm Type	Location	Digester Type
Fair Oaks Dairy	dairy	Fair Oaks, IN	vertical plug-flow** (x4)

** Environmental Energy Corporation proprietary design.

Operational Systems

Farm Name	Farm Type	Location	Digester Type
Apex Pork	swine finishing	Rio, IL	heated mixed covered lagoon
Baldwin Dairy	dairy	Baldwin, WI	covered lagoon
Double S Dairy	dairy	Markesan, WI	mixed plug-flow loop
Emerald Dairy	dairy	Emerald, WI	covered lagoon
Gordondale Farms	dairy	Nelsonville, WI	mixed plug-flow loop
Haubenschilds Dairy	dairy	Princeton, MN	plug-flow
Herrema Dairy	dairy	Fair Oaks, IN	mixed plug-flow loop (x2)
Maple Leaf Farms	duck	Franksville, WI	complete-mix
New Horizons Dairy	dairy	Elmwood, IL	plug-flow (x2)
Stencil Farm	dairy	Denmark, WI	plug-flow
Tinedale Farm	dairy	Kaukauna, WI	complete-mix
Top Deck Holsteins	dairy	Westgate, IA	plug-flow

Systems under Construction



Boss Dairy #4 – Fair Oaks, Indiana

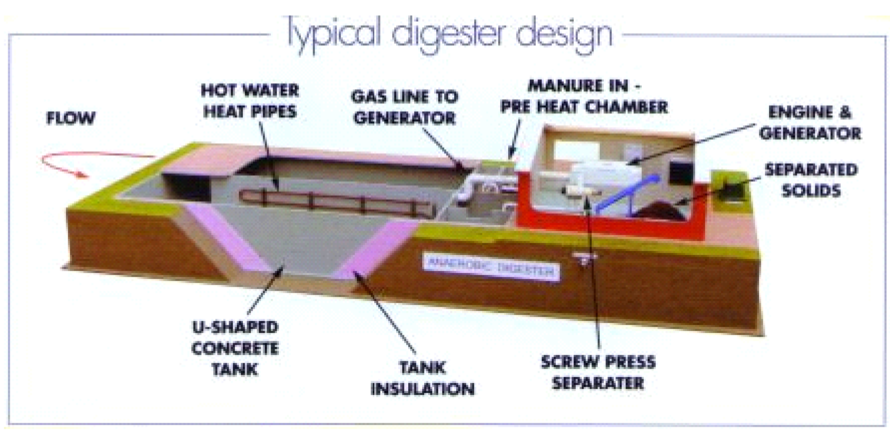
two-stage, mesophilic, mixed plug-flow loop, fixed cover

Boss Dairy #4 is a new dairy being built in Fair Oaks, Indiana. The dairy is planned to have a population of 3,400 milking cows. The owners will use scrape collection with skid steers and plan to use digested solids for bedding. They expect to produce about 120,000 gallons per day (gpd) of manure, bedding and wash water to be fed to the digester. They plan to do solids separation with Fan brand solids separators after digestion.

Farm Name:	Boss Dairy #4	**Location:**	Fair Oaks, IN
Farm Type:	dairy	**Herd Size:**	3,400 milking (predicted)
Collection Method:	scrape with skid steer	**Bedding Type:**	digested solids
Digester Type:	mixed plug-flow loop (x2)	**Design Temperature:**	100° F
Digester Notes:	two-stage, RAS, mesophilic, fixed cover, 2 digesters with shared wall		
Design Capacity:	3,400 milking	**Date Operational:**	na
Design HRT:	22 days	**Current HRT:**	na
Design solids %:	8-9%	**Current solids %:**	na
Biogas Use:	electricity, heat (700kW)	**Utility Contract:**	yes
Solids Separation:	yes, post digestion, Fan separator	**Solids Use:**	bedding
Farm Owns:	digester, energy generation	**Utility Owns:**	na
Digester Designer:	GHD, Inc.	**Utility:**	Jasper County REMC

Digester. They are installing two side-by-side two-stage (i.e., includes acidogenic and methanogenic chambers) mixed plug-flow digesters (a general design schematic is pictured at right). The digesters, designed by Steve Dvorak of GHD, Inc., will each hold approximately 1.3 million gallons and will share a heated wall. The U-shaped (or loop design) digesters will have gas-induced mixing (using a patented GHD process) and will also use return of activated sludge (RAS) to strengthen bacteria populations. The target operating temperature for these digesters is 100° F.

Graphic: Dvorak S, GHD Inc.



Biogas Use. They are installing two 350 kW Waukesha engine-generator sets that will be capable of operation independent of the utility grid (i.e., synchronous). They also plan to use the captured heat from the engines to heat the digester and heat water for farm use.

Revenues/Savings. They plan to use all the energy they produce on the farm replacing their payments for electricity at the retail rate. They also will avoid some bedding costs by using digested solids for bedding. Predicted amounts of electricity and bedding cost savings were not available.

Cost Estimates. The estimated costs for digesters and energy generation equipment are roughly $1,000,000 and $700,000, respectively, for a total of $1.7 million.

Information Sources.

Tony T. Boss – Boss Dairy #4
Steve Dvorak – GHD, Inc., <www.ghdinc.net>

Five Star Dairy – Elk Mound, Wisconsin

combined phase, thermophilic, complete-mix, tank

Five Star Dairy, in Elk Mound, Wisconsin, is a dairy operation with 820 milking cows and 910 head total. The dairy was built in 2000 with the intention of adding an anaerobic digester in the future. The amount of manure currently generated by the dairy and solids content are unknown. The owner saw use of an AD system as an important part of a progressive modern dairy operation. In addition to helping the dairy be environmentally friendly, he saw this AD system as a means to reduce some operating costs, reduce odor, and provide additional income streams for the farm. They use scrape collection of manure and sawdust bedding, but will eventually switch to digested solids. Five Star expects to add local food-grade waste to the manure input stream, and is currently evaluating local sources.

Farm Name:	Five Star Dairy	**Location:**	Elk Mound, WI
Farm Type:	dairy	**Herd Size:**	910 head (820 milking)
Collection Method:	scrape	**Bedding Type:**	sawdust, digested solids
Digester Type:	complete-mix tank, Microgy proprietary design	**Design Temperature:**	135° F
Digester Notes:	mixed above ground tank, flow from top to bottom, thermophilic		
Design Capacity:	800-1,200 head	**Date Operational:**	na
Design HRT:	20 days	**Current HRT:**	na
Design solids %	6-8%	**Current solids %:**	na
Biogas Use:	electricity, heat (750 kW)	**Utility Contract:**	yes
Solids Separation:	optional, post-digestion, class A	**Solids Use:**	na
Farm Owns:	digester (non-recourse financing)	**Utility Owns:**	energy generation
Digester Designer:	Microgy Cogeneration Systems	**Utility:**	Dairyland Power Coop

Digester. Five Star Dairy is installing a type of complete-mix tank digester to treat their manure. The system, a proprietary design by Microgy Cogeneration Systems, Inc., will use an above-ground cylindrical tank (the photo below shows the tank under construction), 40 feet in diameter and 40 feet tall. It will operate in the thermophilic range (135° F), and is designed to have manure flow from top to bottom. Mixing of the manure is accomplished by some undisclosed mechanism. The design HRT for the 770,000 gallon digester is 20 days. This space in the digester also houses the mixing equipment

Photo: Eastman D, Microgy Cogeneration Systems and some gas storage and therefore has a liquid storage capacity closer to 660,000 gallons. Actual HRT will be variable based on animal populations and practices. Microgy reports successful installation and operation of this system at 20 farms in Europe over the last 15 years,[4] but Five Star Dairy is its first application on a dairy farm in the United States.

Biogas Use. Dairyland Power will install a 775 kW (750 kW net) Waukesha engine-generator set, designed for biogas, to generate electricity. Dairyland will buy biogas from the digester at an undisclosed rate based on the cost of new coal-fired generation. Dairyland will own and maintain the energy generation assets, and will sell the "green power" generated to its customers. Further details regarding the utility contract are unavailable. Heat from the engine will be used to heat the digester and possibly to heat the barn floors and collection pits (to prevent freezing in winter).

Revenues/Savings. Projections of savings and revenues from this system were not available. Revenues from biogas sales will accrue to Five Star and will be earmarked to repay costs of the installation and equipment for the digester. The estimated payoff period is ten years. The benefit from electricity sales will accrue to Dairyland Power. Five Star expects to benefit from the use of process heat, digested solids, replacement of commercial fertilizer, and odor, weed seed, and pathogen reduction. The farm will also have the option of selling the separated solids as certified organic fertilizer. Five Star could possibly charge tipping fees for food wastes added to the digester.

Cost Estimates. The digester will be installed and maintained by Microgy, using 100 percent non-recourse funding for the farm. The predicted full payoff of this debt is 10 years of operation, the time period Microgy estimates it will take to pay off the digester cost through biogas sales to Dairyland Power. The farm has the option of paying down the debt earlier.

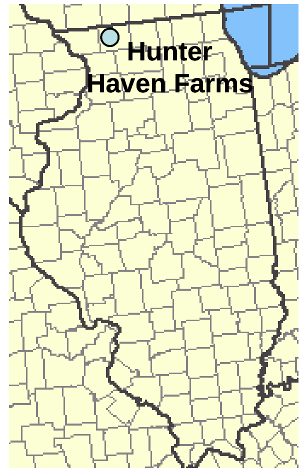
Information Sources.

Lee Jensen, Five Star Dairy
Dan Eastman, Microgy Cogeneration Systems, Inc., <www.microgy.com>
Neil Kennebeck, Dairyland Power Cooperative, <www.dairynet.com>

[4] Information was drawn from Microgy's Web site <http://www.microgy.com/technology.htm>.

Hunter Haven Farms – Pearl City, Illinois

two-stage, mesophilic, mixed plug-flow loop, fixed cover



Hunter Haven Farms is a 600 head dairy operation in Pearl City, Illinois. They are planning to expand to 1,000 head in the near future. The farm currently produces about 20,000 gpd of treatable materials (including manure, bedding and wash water) and will produce roughly 33,000 gpd after expansion. Manure is collected by scraping with a skid steer. The manure solids concentration is in the eight to ten percent range. They plan to separate solids out of the digested manure using a Fan brand solids separator and use these solids for bedding.

Farm Name:	Hunter Haven Farms	**Location:**	Pearl City, IL
Farm Type:	dairy	**Herd Size:**	600 head, expanding to 1,000
Collection Method:	scrape with skid steer	**Bedding Type:**	will use digested solids
Digester Type:	mixed plug-flow loop	**Design Temperature:**	100° F
Digester Notes:	two-stage, RAS, mesophilic, fixed cover		
Design Capacity:	1,000 head	**Date Operational:**	(predicted) late Sept. '04
Design HRT:	20 days	**Current HRT:**	na
Design solids %:	8-10%	**Current solids %:**	na
Biogas Use:	electricity, heat (200 kW)	**Utility Contract:**	not yet
Solids Separation:	yes, post digestion, Fan separator	**Solids Use:**	bedding
Farm Owns:	digester, energy generation	**Utility Owns:**	na
Digester Designer:	GHD, Inc.	**Utility:**	ComEd

Digester. Hunter Haven Farms chose to have a mixed plug-flow loop digester installed. The digester, designed by Steve Dvorak of GHD, Inc., will be a two-stage system (within the loop) with RAS and gas-induced mixing. The target operating temperature will be 100° F and it will have an HRT of 20 days (with a longer SRT due to the RAS). The digester dimensions will be 72' x 112' x 14', and it will have a volume of about 660,000 gallons.

Biogas Use. The owners plan to use the biogas generated by the digester to fuel a Caterpillar engine-generator set with a biogas rating of 200 kW. They do not yet have a contractual agreement with their servicing utility (ComEd) for the sale of electricity. They plan to use the process heat from the engine to heat the digester, water, and in-floor heating.

Revenues/Savings. Predicted revenues and savings for this system were not available.

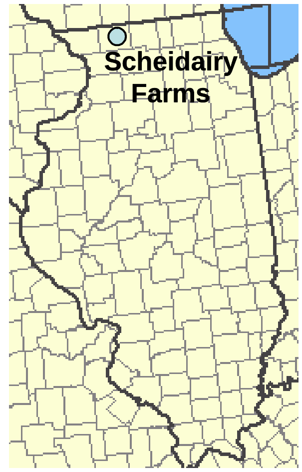
Cost Estimates. Cost estimates for this system were not available.

Information Sources.

Steve Dvorak – GHD, Inc., <www.ghdinc.net>

Scheidairy Farms – Freeport, Illinois

two-stage, mesophilic, mixed plug-flow loop, fixed cover



Scheidairy Farms is a dairy operation in Freeport, Illinois. They have a herd of 650 and plan to expand to 1,000 head. The farm produces about 21,500 gpd of manure and other treatable materials (i.e., bedding and parlor wash water), which will grow to an expected 33,000 gpd after expansion. They use skid steers to scrape collect manure, and plan to do solids separation after digestion using a Fan brand solids separator. They plan to use these digested solids for bedding. Their influent stream is expected to have a solids content in the range of eight to ten percent.

Farm Name:	Scheidairy Farms	**Location:**	Freeport, IL
Farm Type:	dairy	**Herd Size:**	650 head, expanding to 1,000
Collection Method:	scrape with skid steer	**Bedding Type:**	digested solids
Digester Type:	mixed plug-flow loop	**Design Temperature:**	100° F
Digester Notes:	two-stage, RAS, mesophilic, fixed cover		
Design Capacity:	1,000 head	**Date Operational:**	(predicted) late Sept. '04
Design HRT:	20 days	**Current HRT:**	na
Design solids %:	8-10%	**Current solids %:**	na
Biogas Use:	electricity, heat (200 kW)	**Utility Contract:**	not yet
Solids Separation:	yes, post digestion, Fan separator	**Solids Use:**	bedding
Farm Owns:	digester, energy generation	**Utility Owns:**	na
Digester Designer:	GHD, Inc.	**Utility:**	ComEd

Digester. Scheidairy Farms chose to install a mixed plug-flow loop digester designed by Steve Dvorak of GHD, Inc. This digester uses return of activated sludge to conserve biota, and uses a GHD patented gas recirculation system (see photo in the Herrema Dairy profile) for biogas-induced mixing. When at capacity (1,000 head) the digester will have a HRT of 20 days and a longer SRT. The target operating temperature for the digester is 100° F.

Biogas Use. The owners bought a Caterpillar engine-generator set to generate electricity and heat from the biogas. The biogas-rated generating capacity for the system is 200 kW. The owners plan to use recovered heat to heat the digester, make hot water, and provide in-floor heating. They do not yet have a contract with their servicing utility (ComEd) for electricity sales.

Revenues/Savings. Predicted revenues and savings from this system were not available.

Cost Estimates. Cost estimates for this system were not available.

Information Sources.

Steve Dvorak – GHD, Inc., <www.ghdinc.net>

Wild Rose Dairy – LaFarge, Wisconsin

combined phase, thermophilic, complete-mix, tank

Wild Rose Dairy in LaFarge, Wisconsin, is a 900 head (780 milking) dairy farm. Their herd produces an average of 22,000 gallons of manure per day. They use scrape collection and sawdust for bedding. They do not plan to separate solids or switch to separated solids for bedding in the near future. The owners plan to supplement their manure influent, which currently has a solids content of about 10 percent, with 2,000 to 3,000 gpd of high fat food-grade waste from a source or sources that have yet to be finalized. They have been following digester technology since the 1970s and feel the system they chose is the best option yet. They see the system as a way to add value to the manure, reduce odor, weed seeds and pathogens, and foster good neighbor relations. They feel a digester is consistent with their policy of operating in an environmentally sound manner.

Farm Name:	Wild Rose Dairy	**Location:**	LaFarge, WI
Farm Type:	dairy	**Herd Size:**	900 (780 milking)
Collection Method:	scrape	**Bedding Type:**	sawdust
Digester Type:	complete-mix tank, Microgy proprietary design	**Design Temperature:**	thermophilic (135° F)
Digester Notes:	mixed above ground tank, flow from top to bottom, high temperature		
Design Capacity:	800-1,200 head	**Date Operational:**	na
Design HRT:	20 days	**Current HRT:**	na
Design solids %	6-8%	**Current solids %:**	10% (will add liquid food waste)
Biogas Use:	electricity, heat (750 kW)	**Utility Contract:**	yes
Solids Separation:	no	**Solids Use:**	field applied
Farm Owns:	digester (non-recourse financing)	**Utility Owns:**	generation
Digester Designer:	Microgy Cogeneration Systems	**Utility:**	Dairyland Power Coop

Digester. Wild Rose Dairy chose to have a type of complete-mix digester (Microgy proprietary design) installed by Microgy Cogeneration Systems. The digester will be an above-ground tank, with a volume of 770,000 gallons, and will measure 40 feet in diameter and 40 feet in height (a similar installed system is pictured on the following page). The functional capacity is closer to 660,000 gallons because the digester also houses the mixing equipment and some gas storage. It is designed to operate in the thermophilic range (135° F) and have a HRT of 20 days. Actual HRTs will vary depending on herd size and practices (e.g., misting in summer makes higher volumes of influent and shorter HRT). In this system, like the one at Five Star, the manure flows from top to bottom and is mixed using an undisclosed mechanism. This system is designed to have a small "footprint" to simplify installation at existing dairies. These digesters are designed to accommodate additional food-grade waste substrates in the influent stream.

Biogas Use. Biogas from the digester will fuel a 775 kW (750 kW net) Waukesha engine-generator set designed specifically for biogas. The energy generation equipment will be owned and maintained by Dairyland Power Cooperative which will buy the biogas and sell the electricity generated as part of its "green power" program. Further details regarding the utility contract are not available. Process heat from the energy generation will be used to heat the digester. Other planned uses for the heat were not disclosed.

Revenues/Savings. Estimates of revenues and savings from the digester were not available. Microgy will maintain the digester over the life of the project. Revenues from biogas sales will go to Wild Rose but will be earmarked to buy down debt on the digester. Dairyland Power Cooperative will sell the generated electricity at an undisclosed "green energy" rate. Other benefits such as odor, weed seed and pathogen reduction, use of excess process heat, and replacement of commercial fertilizer will accrue to Wild Rose. Their soils are not P-saturated, so they do not want to remove the digested solids (which would also remove much of the P) because they would then have to buy commercial fertilizer to supplement their soil. They may eventually separate solids for bedding or sale as certified organic fertilizer, but do not plan to do so in the near future. If tipping fees are charged for additional food wastes added to the digester, Wild Rose would receive those as well.


Photo: Microgy Cogeneration Systems, Inc.

Cost Estimates. Cost figures for the systems were not available. Costs for digester installation will be borne by the farm with non-recourse financing. Income from biogas sales to Dairyland Power is earmarked to buy down the debt from the digester installation. Costs for energy generation equipment and maintenance will be borne by Dairyland Power. Wild Rose has the option of paying down the debt on the digester early, but the predicted period for debt payback is 10 years.

Information sources.

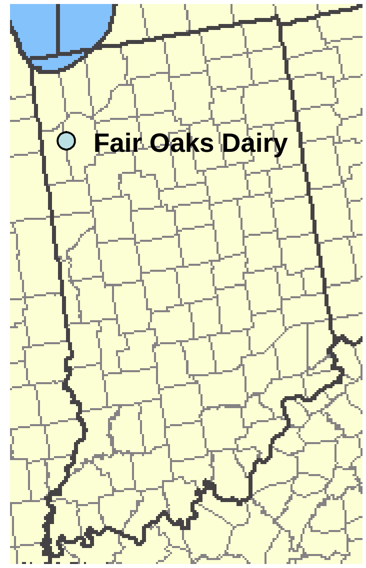
Robert Thelen, Wild Rose Dairy
Dan Eastman, Microgy Cogeneration Systems, Inc., <www.microgy.com>
Neil Kennebeck, Dairyland Power Cooperative, <www.dairynet.com>

Systems in Startup Phase

This section contains case studies of the one digester system that was in startup phase at the time of the interview. The startup phase of a digester is that time after construction of the digester is complete, and the time the system has reached a stabilized level of production.

Fair Oaks Dairy – Fair Oaks, Indiana

combined phase, mesophilic, high-rate vertical plug-flow, tank



Fair Oaks Dairy is a dairy operation in Fair Oaks, Indiana. The dairy profiled here (one of four dairies under the same ownership and of similar size at that location) has a herd size of 3,200 head with 2,800 milking. This herd produces approximately 120,000 gpd of manure. Manure is collected using Loewen vacuum collectors (pictured on the following page). They use sand bedding which requires sand removal systems in each digester (process patented by Dennis Burke). They also do digested solids separation with a Fan screw press type separator, and bacteria separation for recycling (using another patented process described in the "digester" section). Although the digester system can purportedly be operated at any solids concentration, the dairy's need to treat all waste, including parlor and holding area flush water, results in an influent solids concentration between three and seven percent. The dairy also has a cheese production facility on site and a "small amount" of whey is fed into digesters as well for a total average summer loading of about 250,000 gpd.

Farm Name:	Fair Oaks Dairy	**Location:**	Fair Oaks, IN
Farm Type:	dairy	**Herd Size:**	3,200 (2,800 milking)
Collection Method:	Loewen vacuum system	**Bedding Type:**	sand
Digester Type:	vertical plug-flow, high rate (x4)	**Design Temperature:**	95-98° F
Digester Notes:	4 vertical plug-flows, proprietary digestion and sand separation technologies, high percentage RAS		
Design Capacity:	na	**Date Operational:**	na
Design HRT:	6 days, SRT 18-24 days	**Current HRT:**	na
Design solids %	4-7 percent	**Current solids %:**	na
Biogas Use:	electricity, heat (700 kW)	**Utility Contract:**	yes
Solids Separation:	2 sand systems, a digested solids system (Fan) and a bacteria separation system (AGF)	**Solids Use:**	bacteria recycled into digester, digested solids are land applied
Farm Owns:	digesters, energy generation	**Utility Owns:**	na
Digester Designer:	Dennis Burke, EEC	**Utility:**	Jasper County REMC

Digester. Fair Oaks elected to install four digesters (pictured on the following page), designed by Dennis Burke of Environmental Energy Company (formerly Cyclus Enviroystems). It is described as a high-rate vertical plug-flow system. It operates in the mesophilic range of 95-98° F and retains and recycles a large amount of the biota. The design is patented by Dennis Burke, and uses the AGF process (which stands for "anoxic gas flotation") to separate out bacteria for recycling. By recycling the bacteria, a greater concentration of bacteria are available to degrade the manure while more of the manure substrate is converted to gas rather than bacterial biomass

Photo: Burke D, Environmental Energy Company

Photo: Stoermann M, Fair Oaks Dairy

(which is eventually wasted with the digester's effluent slurry). The HRT is about 6 days and the SRT is 18-24 days. The tanks are cylindrical and each is 40 feet in diameter and 50 feet tall.

Outputs and Uses. Biogas from these digesters will help fuel two 375 kW, 350 kW net, (biogas rated) Waukesha engine-generator sets. They plan to run the generators at full capacity supplementing the biogas with natural gas as needed so they can always run at full. They will use all electricity on this and their (three) other farms. The system is designed to remove and concentrate a majority of the nitrogen and phosphorus with the stacked solids. As a result, the nutrient content of the solids is significantly enhanced.

Maintenance Needs. The maintenance needs for this system are not yet known.

Project History. They started adding manure to the digester in mid-May 2004. The owners and designer were still working through the kinks in getting the system to run smoothly with farm operations when interviewed in late May. A condition on purchasing this system was that it could not negatively affect farm operations in any way. The owners report that the sand removal systems are working well. The engines are currently running well on natural gas and heating the digesters. They also report that the contractors they hired have worked well together.

System Costs. Information on system costs was not available.

Revenues and Other Benefits. They expect to use the process heat for the digesters only at this point. Separated solids will be sold as a nutrient-rich commercial fertilizer substitute. Expected buyers and revenues from this were not available.

Lessons and Comments. Lessons and comments were not available.

Information Sources.

Mark Stoermann – Fair Oaks Dairy, <www.fairoaksdairyadventure.com>

Dennis Burke – Environmental Energy Company, <www.makingenergy.com>

Operational Systems

Apex Pork – Rio, Illinois

combined phase, mesophilic, heated mixed covered lagoon, bank-buried floating cover

Apex Pork is a swine finishing operation in Rio, Illinois. They have a herd size of 8,300 in an all-in all-out operation which results in variable manure production (more when the herd is older and less when they are younger). They average roughly 11,000 gpd of manure production. They collect the manure with a pull-plug system and add some recharge pit water (which is recycled from their second stage lagoon) to their influent manure stream. The owners examined anaerobic digester manure storage options mainly to control odors from the lagoon.

Farm Name:	Apex Pork	**Location:**	Rio, IL
Farm Type:	swine finishing facility	**Herd Size:**	8,300 head
Collection Method:	pull plug	**Bedding Type:**	na
Digester Type:	heated mixed covered lagoon	**Design Temperature:**	mesophilic
Digester Notes:	Permalon® covered clay-lined lagoon, mechanical mixing		
Design Capacity:	na	**Date Operational:**	June 1998, Jan. 1999
Design HRT:	18-20 days	**Current HRT:**	18 days
Design solids %	3-6% (AgSTAR range)	**Current solids %:**	2-4%
Biogas Use:	heat (boiler)	**Utility Contract:**	na
Solids Separation:	na	**Solids Use:**	na
Farm Owns:	digester, boiler	**Utility Owns:**	na
Digester Designer:	RCM Digesters, Inc.	**Utility:**	na
Performance Data	no gas meter	**Measuring Period**	na

<u>Digester</u>. The owners chose a heated mixed covered lagoon (pictured at right) for their manure storage and treatment. The system, designed by Mark Moser of RCM Digesters, Inc., is a clay-lined covered lagoon with a Permalon® cover. The digester is mechanically mixed and is heated to maintain a mesophilic temperature (the target temperature is unknown).


Photo: Moser M, RCM Digesters, Inc.

<u>Outputs and Uses</u>. Biogas from the digester is used

to fuel a boiler (pictured at right). The heat from the boiler is used for heating the digester.

Photo: Moser M, RCM Digesters, Inc.

Maintenance Needs. The digester requires very little maintenance. They generally just check out the processes daily (about 10 minutes). They are planning their first clean-out of the system during the summer or fall of 2004 due to sludge build-up.

Project History. The first floating lagoon cover Apex installed, in the spring of 1998, was damaged during a storm and had to be replaced. They chose a more durable, bank-buried model (installed in fall-winter 1998) for the replacement and have been happy with it. The digester went through a second startup following the cover replacement which took 30 days of propane heat to allow switching to biogas. They will clean out sludge build-up in the lagoon for the first time this summer or fall. They also will be examining the heat rack for a suspected problem related to electrolysis.

System Costs. The total cost for the digester system was approximately $152,300, including $66,700 for the lagoon cover and gas collection equipment, and $85,600 for the boiler and gas handling equipment.

Revenues and Other Benefits. The primary benefit of this system is odor reduction. Installation of the digester has reduced or eliminated compliance investigations and odor complaints from neighbors.

Lessons and Comments. They commented that, although it may seem expensive for just odor control, they feel their investment was well worth it.

Information Sources.

Glenn Saline – Apex Pork

Mark Moser – RCM Digesters, Inc., <www.rcmdigesters.com>

Baldwin and Emerald Dairies – Baldwin and Emerald, Wisconsin

combined phase, psychrophilic, covered lagoon, bank-buried cover

Baldwin and Emerald dairies are located in western Wisconsin and are under the same ownership. The herd sizes are 1,225 and 1,600 head, respectively. Baldwin uses sand bedding and Emerald uses wood shavings. Neither farm employs solids separation to recover digested solids. However, Baldwin uses a sand removal system that is said to remove up to 98 percent of the sand from the manure stream prior to entry into the lagoon. The dairies produce 30,000 and 40,000 gallons per day (gpd) of influent, respectively, for their treatment systems. The solids content of their influent streams is about six percent for both farms.

Farm Name:	Baldwin Dairy	**Location:**	Baldwin, WI
Farm Type:	dairy	**Herd Size:**	1,225 (1,100 milking feeding lagoon)
Collection Method:	scrape raw to lagoon	**Bedding Type:**	sand
Digester Type:	covered lagoon	**Design Temperature:**	ambient
Digester Notes:	clay-lined lagoon with poly cover, combined phase, psychrophilic		
Design Capacity:	1,100 head	**Date Operational:**	1998
Design HRT:	6 months	**Current HRT:**	8 months
Design solids %	na	**Current solids %:**	~6%
Biogas Use:	flared	**Utility Contract:**	na
Solids Separation:	sand removal system only (98% removal), no solids separation	**Solids Use:**	land applied
Farm Owns:	digester	**Utility Owns:**	na
Digester Designer:	Tiry Engineering	**Utility:**	na
Performance Data	na	**Measuring Period**	na

Farm Name:	Emerald Dairy	**Location:**	Emerald, WI
Farm Type:	dairy	**Herd Size:**	1,600 (1,200 milking)
Collection Method:	scrape w/skid steer	**Bedding Type:**	wood shavings
Digester Type:	covered lagoon	**Design Temperature:**	ambient
Digester Notes:	poly-lined lagoon with poly cover, combined phase, psychrophilic		
Design Capacity:	1,600 head	**Date Operational:**	1999
Design HRT:	8 months	**Current HRT:**	8 months
Design solids %	na	**Current solids %:**	~6%
Biogas Use:	flared	**Utility Contract:**	na
Solids Separation:	no	**Solids Use:**	land applied
Farm Owns:	digester	**Utility Owns:**	na
Digester Designer:	Tiry Engineering	**Utility:**	na
Performance Data	na	**Measuring Period**	na

Digester. Baldwin Dairy has a clay-lined lagoon and Emerald has a poly-lined lagoon. Both were designed by Tiry Engineering with poly covers to control odor and keep out precipitation.

The Baldwin lagoon holds about 4.7 million gallons, and the Emerald holds about 12 million gallons. Both lagoons have bank-buried floating covers with biogas collection systems (the Emerald lagoon is pictured at right). The lagoons both have an HRT of about 8 months with current herd sizes.

Photo: Vrieze J, Baldwin and Emerald Dairies

Outputs and Uses. The systems produce biogas steadily, but the methane content varies with seasonal outdoor temperatures. Sampling indicates that summer biogas content is about 60 percent methane, which drops to about 40 percent in the winter. All biogas from both systems is flared (the flare for Emerald is pictured below).

Maintenance Needs. Very little maintenance is needed.

Photo: Vrieze J, Baldwin and Emerald Dairies

Project History. The covers for Baldwin and Emerald were installed in 1998 and 1999 respectively, and there have been no significant problems since.

System Costs. The cost of the lagoon cover and gas collection system for Baldwin was $70,000. For Emerald dairy, the cover and gas collection system cost $125,000.

Revenues and Other Benefits. Odors from the lagoons have been eliminated, and there are much lower odor levels overall for the neighborhood. The digestion of the manure has made handling easier (it's easier to pump and requires less agitation prior to pumping to fields). The owner estimates that the dairies also benefit significantly from the exclusion of precipitation provided by the lagoon covers. For the Emerald Dairy alone, he estimates that in an average year the cover reduces the amount of effluent they must land apply by over a million gallons (i.e., precipitation is excluded but evaporation is also virtually non-existent).

Lessons and Comments. The covered lagoon system is a good, low cost method of controlling odors. The owner wants to find ways to improve his methane production and use it constructively (rather than flare it). He is currently considering installation of heated digesters at both dairies. He is evaluating the feasibility of installing an Ecalene™ production facility, and combining the methane outputs from both digesters (the dairies are seven miles apart) to supply it.[5] He sees production of Ecalene from methane as a means to possibly make higher profits from sales than are generally possible through electricity generation and sales. The owner is also looking at options for installing tertiary treatment for the liquid portion of the digestate at Emerald to render it potable for cows.

He believes if he had to do it over again he would make the same choices – they were the best solutions at the time.

Information Sources.

John Vrieze – Baldwin and Emerald Dairies

[5] Ecalene™ is a fuel additive produced from methane using the Power Energy System™, licensed and sold by Power Energy Inc.

Double S Dairy – Markesan, Wisconsin

two-stage, mesophilic, mixed plug-flow loop, fixed cover

Double S Dairy is a dairy operation in Markesan, Wisconsin. They have a herd size of about 1,100 head, with 1,020 milking cows. The dairy made the switch from sand bedding to digested solids (with some use of sawdust as well during the transition) when they chose to install an anaerobic digester. They use a screw press type solids separator post digestion. The farm produces about 30,000 gpd of influent to be treated, and the farm uses a flush system for collection. They recycle the flush water before the digester to increase the solids portion in the influent and reduce the volume of influent to be treated.

Farm Name:	Double S Dairy	**Location:**	Markesan, WI
Farm Type:	dairy	**Herd Size:**	1,100 (1,020 milking)
Collection Method:	flush	**Bedding Type:**	digested solids
Digester Type:	mixed plug-flow loop	**Design Temperature:**	100° F
Digester Notes:	gas mixing, biota recycling, two-stage, fixed cover		
Design Capacity:	1,000 head	**Date Operational:**	January 2004*
Design HRT:	20 days	**Current HRT:**	estimate <20 days (SRT > 20 days)
Design solids %	8-9%	**Current solids %:**	na
Biogas Use:	electricity, heat (200kW)	**Utility Contract:**	yes
Solids Separation:	yes, post digestion	**Solids Use:**	bedding
Farm Owns:	digester, generation, screw press	**Utility Owns:**	generation**
Digester Designer:	GHD, Inc.	**Utility:**	Alliant Energy
Performance Data	na	**Measuring Period**	na

* The digester was operating with insufficient digester heat for over a year prior to this date.
** As of June 2004, the farm will also own its own generation equipment. They expect to install it in summer 2004.


Photo: Dvorak S, GHD Inc.

Digester. In 2001, Double S decided to install a mixed plug-flow loop digester (pictured at right with fixed cover visible in the center) designed by Steve Dvorak of GHD, Inc. The digester has a design capacity of 1,000 cows and a design HRT of 20 days. The current HRT is not available, but is estimated at less than 20 days based on inputs. Because the digester uses some biota recycling, the SRT is longer than the HRT and is likely greater than 20 days. The digester uses biogas re-circulated at the bottom of the digester to provide gas-induced mixing. The digester has two separate stages or phases within the loop and has a target temperature of 100° F.

Outputs and Uses. Biogas produced by the digester has been used to fire a 200 kW Hess engine-generator set (pictured at right). Following persistent operational problems, Double S is set to replace the system with a 200 kW Caterpillar engine-generator set that can also accommodate a turbo addition for an additional 60 kW capacity. Their goal is to generate close to 1.6 million kWh per year (running at capacity with 90 percent uptime). In addition to heating the digester, they are using, or plan to use, the heat from the energy generation for the parlor floor, offices and the floor in the shop.

Photo: Dvorak S, GHD Inc.

Maintenance Needs. The digester needs very little maintenance. They spend about 20 minutes per day inspecting and maintaining the digester.

Project History. The digester was built over the period October 2001 through February 2002. They had numerous problems during startup, most of which were apparently the result of conflicting recommendations regarding the optimal operating temperature for the Hess engine-generator set.[6] They determined that the system was not providing sufficient heat to the digester, at the lowest recommended engine operating temperature, which resulted in low biogas production and higher than expected bacteria levels in the solids. In addition, operation at the lower temperature resulted in bacteria growth in the gas feed lines which impeded gas flow, resulted in poorer performance of the engine, and required clean-outs. Alliant Energy (owner of the Hess system under the original contract) has offered Double S a release from their contract so they could buy new energy generation equipment and operate and maintain it themselves. Double S elected to buy a new Caterpillar 200 kW engine-generator set which is slated to be installed in summer 2004. In late 2003, they had switched to operating the Hess engine at a higher temperature (as recommended by the utility) which provided more heat to the digester. The digester then stabilized in January 2004 and it has been running "well" and producing "good biogas" since that time. They inadvertently ran the engine-generator set at over 200 kW for about 2 months without any problems, and without running out of biogas. They are pleased with their system overall. After making the switch from sand bedding to digested solids, they have had an increase in herd somatic cell counts from 120,000 (sand) to 180,000 (digested solids).

System Costs. The digester alone cost about $500,000 to make operational. Problems described in the History section resulted in some additional costs including: propane and composted bedding supplement purchases. They also had some problems with mastitis resulting in the loss

[6] The engine manufacturer, supplier and utility all had different recommendations regarding the preferred operating temperature for the engine.

of some cows, but whether this was from the bedding they produced or the supplements they imported is unknown. These costs are not quantified or included in the cost figure given. The cost of the original energy generation equipment (incurred by Alliant Energy) and the cost of the new engine-generator set (incurred by Double S) were not available.

Revenues and Other Benefits. Under the previous contract, the farm received payment from Alliant Energy based on the kWh of electricity generated. The payment rate and/or past amounts received were not available. The details of their new agreement with Alliant were not available. The farm estimates they save about $30,000 per year on bedding costs. Cost savings estimates for propane and herbicides were not available.

Lessons and Comments. The owners are happy with their digester.

Information Sources.

Dan Smits – Double S Dairy
Steve Dvorak – GHD, Inc., <www.ghdinc.net>
Duane Hanusa – Alliant Energy, <www.alliantenergy.com>

Gordondale Farms – Nelsonville, Wisconsin

two-stage, mesophilic, mixed plug-flow loop, fixed cover

Gordondale Farms is a dairy operation in Nelsonville, Wisconsin. They currently have 725 milking cows and plan to expand to between 850 and 900 within a month (i.e., in May 2004). At the time of interview, (April 2004) the farm was producing about 35,000 gpd of influent (including manure, bedding and wash water). They use scrape collection and use digested solids for bedding. They have a Fan brand screw press type solids separator and remove the solids after digestion. Their influent solids content is approximately seven percent. They are considering bringing in manure from another location to increase the solids content.

Farm Name:	Gordondale Farms	**Location:**	Nelsonville, WI
Farm Type:	dairy	**Herd Size:**	725 milking (expanding to 850-900)
Collection Method:	scrape	**Bedding Type:**	digested solids
Digester Type:	mixed plug-flow loop	**Design Temperature:**	101° F
Digester Notes:	gas mixing, biota recycling, two-stage, fixed cover		
Design Capacity:	800 head	**Date Operational:**	April 2002
Design HRT:	20 days	**Current HRT:**	17 days, SRT na
Design solids %	8-9%	**Current solids %:**	7 %
Biogas Use:	electricity, heat	**Utility Contract:**	yes
Solids Separation:	yes, post digestion, Fan separator	**Solids Use:**	bedding
Farm Owns:	digester	**Utility Owns:**	energy generation
Digester Designer:	GHD, Inc.	**Utility:**	Alliant Energy
Performance Data	876,051 kWh per year	**Measuring Period**	June 2003 – May 2004

<u>Digester</u>. Gordondale Farms installed a mixed plug-flow loop type digester (pictured at right in front of the engine-generator and solids storage building) designed by Steve Dvorak of GHD, Inc. The digester is a two-stage (separate compartments for acidogenic and methanogenic processes), with biogas induced mixing and RAS. The system used for RAS is pictured on the following page. The gas recirculation process used for mixing is patented by GHD (see the Herrema Dairy profile for a photo). The design HRT for the system is 20 days but they are currently running at about 17 days based on inputs. By design, the SRT is longer due to the RAS feature. They maintain the digester at 101° F.

Photo: Dvorak S, GHD Inc.

Outputs and Uses. The digester has reportedly produced biogas steadily but production was negatively affected by some recent upsets caused by input of footbath water, an anti-freeze leak, and a water pipe break. The quantities of biogas produced are unknown because the gas gauge was removed when it became corroded and interfered with engine performance. The biogas has been used to fuel a Caterpillar 3406 reciprocating engine-generator set with a biogas rating of 135 to 140 kW. Over the period of June 2003 through May 2004 the system has produced 876,051 kWh of electricity. Monthly totals ranged from a low of 17,240 kWh in July 2003 to a high of 95,767 kWh in January 2004 with the variation generally attributed to engine maintenance and the input problems described above. Digested solids are removed from the digestate with a Fan brand screw press type solids separator. Process heat is used to heat the digester, dairy parlor, offices, engine room, and warm water flush flume.

Photo: Gordon K, Gordondale Farms

Maintenance Needs. The digester itself requires little maintenance. Required routine maintenance and attention for the whole system amount to about 45 minutes per day.

Project History. The digester system was installed over the period of October 2000 through November 2001 as part of a dairy expansion. The owners installed the GHD-designed digester themselves. They started adding manure to the digester in November 2001, and the system stabilized in April 2002. The digester and energy generation systems were both operational at the time of the interviews. The energy generation system was down for two weeks following an anti-freeze leak due to a punctured line in a barn. This leak also depleted the microbe population affecting biogas production. They have also run it off-line for some periods and have taken it down for diagnostic tests. They also had a water pipe break in the spring of 2004 that affected gas quality and have seen biogas production affected by introduction of sanitizing footbath water into the digester. The digester has been operating 100 percent of the time. The owners tried three presses for solids separation before settling on the Fan brand separator. They are very pleased with how the Fan is working. Alliant Energy owns and maintains the energy generation equipment. Alliant Energy pays Gordondale Farms a set fee per kWh for energy generated from their biogas. Their herd somatic cell count is steadily around 260,000. They are expanding their herd to 850-900 milking cows and hope to expand the digester within the next two years.

System Costs. The digester system cost about $290,000 and the energy generation equipment cost about $230,000 (paid by Alliant Energy).

Revenues and Other Benefits. Over the 2003 calendar year Gordondale earned $23,000 through electricity sales to Alliant. They also save an estimated $28,800 per year on bedding costs (over using sand), $30,000 per year in commercial fertilizer replacement, $2,000 per year in avoided propane purchases, and $5,000 per year in avoided pest control services. They also benefit from reduced odor, reduced need for soil pH correction through lime applications, and the ability to run a warm water flush flume (using excess heat) and scrape collect manure daily all year. They also expect to realize savings from reduced weed seeds in the digestate, but cannot yet estimate what these will be.

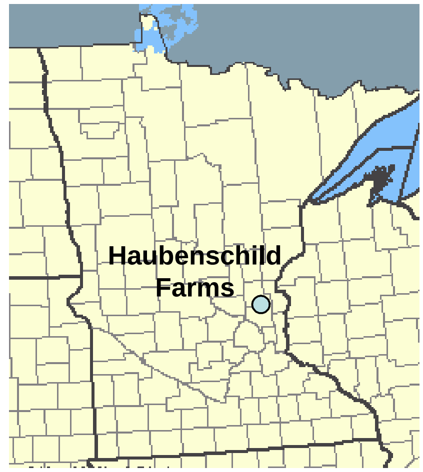
Lessons and Comments. The owners are very happy with how their system has worked out. They feel using digested solids for bedding is working well. If they had the chance to do it over again, they would own the energy generation equipment themselves so they could realize higher earnings from electricity sales.

Information Sources.

Kyle Gordon – Gordondale Farms
Steve Dvorak – GHD, Inc., <www.ghdinc.net>
Duane Hanusa – Alliant Energy, <www.alliantenergy.com>

Haubenschild Farms – Princeton, Minnesota

combined phase, mesophilic, plug-flow, flexible cover



Haubenschild Farms is a dairy operation located in Princeton, Minnesota. The dairy has a herd of approximately 1,000 head, with 840 lactating cows that contribute manure to the digester. The farm produces 22,000 gpd of manure and other substrates for treatment. They use scrape collection and shredded newspapers for bedding. The farm does not do solids separation.

Farm Name:	Haubenschild Farms	**Location:**	Princeton, MN
Farm Type:	dairy	**Herd Size:**	840 lactating
Collection Method:	scrape	**Bedding Type:**	shredded newspapers
Digester Type:	plug-flow	**Design Temperature:**	100° F
Digester Notes:	straight, combined phase, mesophilic, flexible cover		
Design Capacity:	1,000 head	**Date Operational:**	September 1999
Design HRT:	20 days	**Current HRT:**	16 days
Design solids %	10%	**Current solids %:**	9.5%
Biogas Use:	electricity, heat (135 kW)	**Utility Contract:**	yes
Solids Separation:	no	**Solids Use:**	digestate field applied
Farm Owns:	digester, energy generation	**Utility Owns:**	na
Digester Designer:	RCM Digesters, Inc.	**Utility:**	East Central Energy
Performance Data	86,000 cfd biogas	**Measuring Period**	3 years

<u>Digester</u>. Haubenschild Farms installed a heated plug-flow digester as part of their manure management system. The digester (pictured at right with the white inflated cover), designed by Mark Moser of RCM Digesters, Inc., is a straight plug-flow system. The digester is designed to operate in the mesophilic range with a target temperature of 100° F, and an HRT of 20 days. It is rectangular, and its dimensions are 150'L x 30'W x 14'D. The digester can hold 352,000 gallons of manure. Based on current load levels, the practical HRT is about 16 days.


Photo: Nelson C & Lamb J, The Minnesota Project

<u>Outputs and Uses</u>. The digester has averaged 86,000 cfd of biogas for the past three years. The owner estimates it produces about 70 cfm (100,000 cfd) 85-90 percent of the time, but this rate falls off when equipment replacements (pumps, piping, engine maintenance) are required resulting in a digester cool-down or change in the feed rate. Biogas is used to fuel a 150 kW Caterpillar 3406 engine-generator set (pictured on the following page), rated 135 kW for biogas,

which produces about 3,000 kWh of electricity per day (they also blend in about 10 cubic feet of propane to the fuel stream per day). The generator is an induction type which cannot operate independent of the grid. A little over half the electricity produced is used on the farm and the rest is sold per contractual agreement with East Central Energy (ECE).

Photo: Nelson C & Lamb J, The Minnesota Project

Maintenance Needs. They do regular maintenance on the Caterpillar engine including changing spark plugs once per year and changing the oil after every 1,000 hours of operation. It has required more frequent maintenance as the engine has gotten older, but they still have not needed to overhaul it after over 41,000 hours of operation. Their operation and maintenance costs were less than $.01/kWh at first, but they now estimate they are in the range of $.02-.025/kWh due to aging of the equipment.

Project History. The Haubenschild's built their digester in the spring of 1999 and started heating the manure in July 1999. The digester stabilized in September of that year. They estimate it has been operational over 98 percent of the time since then. They have had only minor problems related to normal wear and tear, and feel the system has produced really well. They are using about 50 percent of the electricity they produce and selling the rest (this ratio is more like 60 percent used and 40 percent sold in the summer months because of extra cooling fans used in those months).

System Costs. The digester system and energy generation cost a total of $355,000 to make operational. The farm put up $77,500 and got an additional $150,000 no-interest loan from Minnesota Department of Agriculture. They received a $50,000 grant from Minnesota Department of Commerce and a $37,500 grant from the Minnesota Office of Environmental Assistance. Finally they received $40,000 of in-kind services from AgSTAR. The owner notes that this installation was more expensive than would be typical for a similar size dairy because they elected to build some features beyond what was required. These include making the walls of the digester thicker (he noted that concrete alone was about 25 percent of the cost) and adding extra wiring and plumbing for contingencies and experiments.

Revenues and Other Benefits. The owner cites several benefits from using their digester system. They are using just over half of the 1.1 million kWh of electricity they produce annually on the farm, and selling the rest to ECE (at $0.073 per kWh) for a total net benefit of about $80,000 per year. They have been able to cease double pass herbicide applications on the fields to which they apply digested effluent because of the weed seed destruction, saving them about $30,000 this past year. They occasionally sell small amounts of digestate to neighboring farms as a soil amendment. They have been able to replace commercial fertilizer at a savings of between $40-

60,000 per year due to the application flexibility (because of reduced odor) and increased nutrient availability. Use of process heat for hot water and building heat has allowed them to reduce their propane expenses by about $4,000 per year. They have experienced fuel and time savings (although not calculated) from not having to stir the manure lagoon as frequently. Now when they do stir in the spring, an event that used to elicit complaints from the neighbors about odor, the neighbors do not even notice.

Lessons and Comments. The owners monitor their digester system closely and feed it two times per day. The Haubenschilds are extremely pleased with the digester which has provided a steady income for the farm during a period when milk prices have varied widely. The owner feels that installing a digester is not just a "can-do" but is more of a "should-do." He calls it the "ultimate recycling" because you turn the carbon cycle around in 21 days. They have been very happy with using shredded newspapers for bedding and feel it may be contributing to their higher than predicted biogas production.

They plan to participate in research during the summer and fall 2004 in cooperation with the University of Minnesota Agricultural Extension. They will be using their excess biogas (currently flared) to run a fuel cell and possibly a Stirling (external combustion) engine.

The Haubenschilds are not the only ones praising their system. Henry Fischer of ECE says they would very much like to have more farms like Haubenschild's as customers and renewable energy suppliers. ECE recognizes the benefits these systems provide to the cooperative. Biogas-based electricity generation is a welcome low cost renewable energy for their green energy program. In addition, ECE sees promotion of these systems as a means of boosting local economic development, helping them provide quality customer care, and providing positive (often front-page) publicity for the company. ECE has produced two videos to communicate the Haubenschild Farms' experiences to others and promote further adoption of anaerobic digesters at livestock operations.[7]

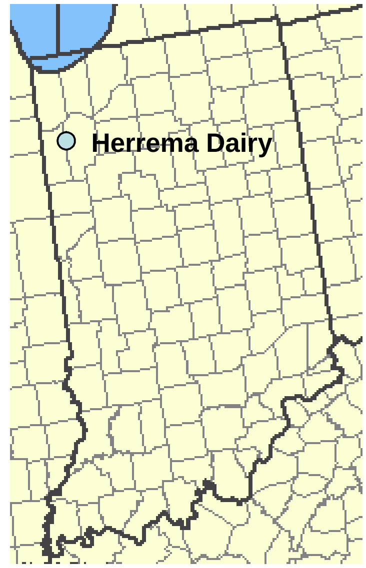
Information Sources.

> Dennis Haubenschild – Haubenschild Farms
> Carl Nelson and John Lamb – The Minnesota Project, "Final Report: Haubenschild Farms Anaerobic Digester – Updated!", August 2002, <www.mnproject.org>
> Mark Moser – RCM Digesters, Inc., <www.rcmdigesters.com>
> Henry Fischer – East Central Energy, <www.eastcentralenergy.com>

[7] Copies of the videos are free and can be requested from East Central Energy (contact Henry Fischer at Henry.Fischer@ecemn.com). There is a 30-minute Environmental Journal public television program outlining the agricultural, energy, and environmental benefits of anaerobic digesters, and a shorter 7-minute video that is geared toward electric utilities.

Herrema Dairy – Fair Oaks, Indiana

two-stage, mesophilic, mixed plug-flow loop, fixed cover



Herrema Dairy is a dairy operation in Fair Oaks, Indiana. They have a herd size of about 3,750 head with 3,400 milking. Their farm generates about 90,000 gallons of manure per day. This manure, combined with parlor water, results in 115,000 gallons of influent per day. The manure is scrape collected using skid steers and has an average solids content of approximately 7.5 percent. The dairy has three Fan brand solids separators to remove solids after digestion. They use digested solids for bedding.

Farm Name:	Herrema Dairy	**Location:**	Fair Oaks, IN
Farm Type:	dairy	**Herd Size:**	3,750 (3,400 milking)
Collection Method:	scrape with skid steer	**Bedding Type:**	digested solids
Digester Type:	mixed plug-flow loop (x2)	**Design Temperature:**	100° F
Digester Notes:	gas mixing, biota recycling, two-stage, fixed cover, shared heated wall		
Design Capacity:	3,750 head	**Date Operational:**	November 2002
Design HRT:	20 days	**Current HRT:**	17 days, SRT is higher
Design solids %	8-9%	**Current solids %:**	7.5%
Biogas Use:	electricity, heat (700 kW)	**Utility Contract:**	na
Solids Separation:	yes, post digestion, Fan separator	**Solids Use:**	bedding
Farm Owns:	digester, energy generation	**Utility Owns:**	na
Digester Designer:	GHD, Inc.	**Utility:**	Jasper County REMC
Performance Data:	na	**Measuring Period:**	na

Digester. Herrema Dairy chose to install two mixed plug-flow loop digesters designed by Steve Dvorak of GHD, Inc. The digesters are two-phase systems that use biota recycling and a gas mixing system (pictured at right) patented by Steve Dvorak. The digesters are built side-by-side and share a heated wall between them. They operate in the mesophilic range with a target temperature of 100° F. Each digester has the dimensions 73'W x 184'L x 14'D. The design hydraulic residence time is 20 days, but they are currently operating at about 17 days. Due to the biota recycling, the system has a SRT that is higher than the HRT.

Photo: Dvorak S, GHD Inc.

Outputs and Uses. The rate of biogas production for the AD system is unknown (there is no gas gauge installed) but is reported to be "steady." Biogas is used to fire two Hess engine-generator sets with biogas-rated capacities of 350 kW each. Separated solids are dried and used for bedding. Heat from the energy generation is used to heat the digester (the hot water tank used for digester heating is pictured at right). They may eventually use process heat to heat the barn and alleyway also.


Photo: Dvorak S, GHD Inc.

Maintenance Needs. The digester has worked well and required little maintenance. They have had frequent engine breakdowns and they have been unable to approach the generators' rated capacities for output. The management of their whole manure system (including the digester) requires one full-time person. They do not know what the maintenance demands of properly functioning engines would be.

Project History. The dairy and digester were built at the same time in 2002. They started feeding manure into the digester in July and August of 2002 and the system was stabilized by November 2002. Since then, the digester has been working 100 percent of the time. They have had trouble with the engines failing to perform to their rated capacity despite an abundance of biogas, and they have had frequent breakdowns. The engines are rated at 350 kW for biogas, but they have only been able to run them at 250 kW. At the time of the interview, only one engine was running and that at a rate of 250 kW. They suspect that the engine problems are related to conflicting recommendations regarding the optimal operating temperature of the engines. They are currently scheduled to receive replacement engines (supplied by the manufacturer) which will be run according to the manufacturer's specifications. They have had good experiences with using digested solids for bedding and are currently supplying solids to another new dairy as well. They have had fairly steady herd somatic cell counts in the 150,000 to 170,000 range.

System Costs. Cost information for the digester and energy generation systems was not available.

Revenues and Other Benefits. Information on revenues generated by the system or other benefits was not available.

Lessons and Comments. Owner lessons and comments were not available.

Information Sources.

Glen Musch – Herrema Dairy
Steve Dvorak – GHD, Inc., <www.ghdinc.net>

Maple Leaf Farms – Franksville, Wisconsin

combined phase, mesophilic, complete-mix tank, fixed cover

Maple Leaf Farms is a duck farm in Franksville, Wisconsin. The farm houses some 500,000 ducks and produces about 45,000 gpd in manure and other materials for treatment. They use scrape collection and pine shavings for bedding. The shavings are collected before the digester using an internally fed rotary drum screen. These are composted and then land applied. Prior to entering the digester, the input streams are pumped into a 2.5 million gallon holding tank to equalize inputs. The influent stream has an estimated solids content in the 1-2.5 percent range.

Farm Name:	Maple Leaf Farms	**Location:**	Franksville, WI
Farm Type:	duck	**Herd Size:**	500,000 ducks
Collection Method:	scraped to tank and piped	**Bedding Type:**	pine shavings
Digester Type:	complete-mix tank	**Design Temperature:**	mesophilic
Digester Notes:	combined phase, mesophilic, low speed mechanical mixers, biota recycling		
Design Capacity:	na	**Date Operational:**	1988
Design HRT:	7-10 days	**Current HRT:**	9 days
Design solids %	1-2.5%	**Current solids %:**	1-2.5%
Biogas Use:	electricity generation, heat	**Utility Contract:**	yes
Solids Separation:	yes, rotary drum, pre-digestion	**Solids Use:**	composted, land applied
Farm Owns:	digester, energy generation	**Utility Owns:**	na
Digester Designer:	Applied Technologies, Inc.	**Utility:**	We Energies
Performance Data	na (no gas meter)	**Measuring Period**	na

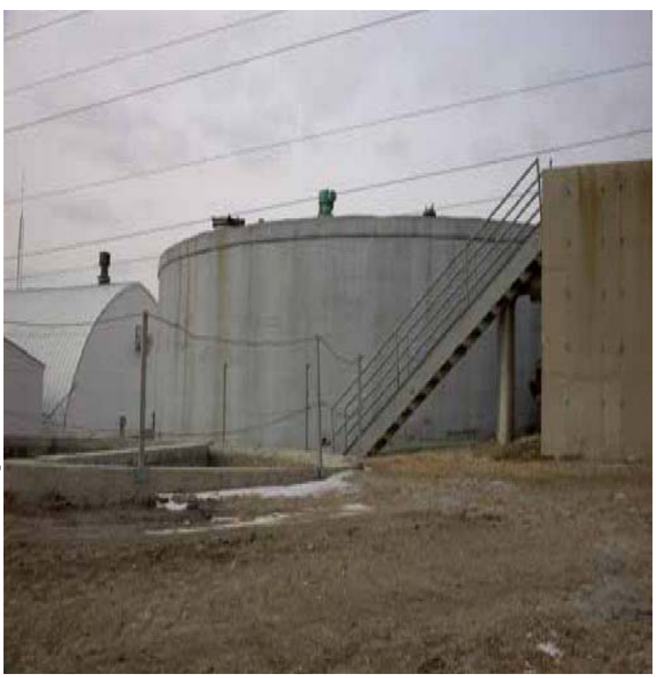


Photo: Rosdil R, Maple Leaf Farms

Digester. In 1988, Maple Leaf Farms decided to install a complete-mix tank digester (pictured at left) designed by Applied Technologies, Inc. The digester uses an anaerobic contact process with low-speed mechanical mixers (pictured on the following page). The digester is a central part of a multi-stage wastewater treatment facility on the farm. After the digester, there is a de-gas tower and a settling basin in which grit drops out. Solids (i.e., activated sludge) are then returned to the digester and liquids are sent to an aeration tank where ammonia is stripped out. Following the aeration tank the liquids are sent to a clarifier where more settling of solids occurs. From there solids are land applied and clarified liquid is sent to a storage lagoon and eventually spray irrigated. MLF has made some modifications to the original digester system including changing the feed method, heat exchangers and piping materials.


Photo: Rosdil R, Maple Leaf Farms

Outputs and Uses. Prior to 2002, biogas was flared and a natural gas fueled boiler was used to heat the digester. A cogeneration system was added in 2002. The Hess/Daewoo engine-generator has a capacity of 200 kW and has been operated as an induction generator (cannot operate independent of the grid) because they lack some of the necessary hardware to operate it as a synchronous generator. We Energies purchases all the electrical output and renewable energy attributes at a premium.

Maintenance Needs. The digester has only required one cleanout so far (they need to do this once every 5-8 years). They estimate the digester costs about $30,000 annually to maintain, and the energy generation equipment costs $0.011/kWh generated based on a maintenance agreement.

Project History. Maple Leaf Farms had the digester installed as part of an overall wastewater treatment system on their site in 1988. The digester had a bad startup the first time they tried. They cleaned it out and it was working fine within a month after refilling. They used a natural gas-fired boiler to heat the digester until they added a combined heat and power system in 2002. The engine-generator set worked fine from summer 2002 until late December 2003 when the engine failed. As of June 2004, they had yet to determine what the problem was with the engine. They switched back to using the old boiler to heat the digester and were flaring excess biogas. They were pursuing options to begin generating electricity again.

System Costs. The digester system cost about $350,000 (1988 dollars – translates to $534,000 in 2002 dollars) to install and the cogeneration system cost about $270,000 (2002 dollars). In 2002, Maple Leaf Farms received $65,000 from the Wisconsin Department of Administration toward the cost of the cogeneration system. The total cost for this system in inflation-adjusted dollars was $804,000.

Revenues and Other Benefits. Actual revenues and other quantifiable benefits are not available for this system. The system has allowed them to continue operating as a "good neighbor" despite the growth of the city around them.

Lessons and Comments. The owners feel it is a good process and are interested in getting their electricity generation working again.

Information Sources.

Lawrence Willegal – Maple Leaf Farms, <www.mapleleaffarms.com>
Robert Rosdil – Maple Leaf Farms

New Horizons Dairy – Elmwood, Illinois

combined phase, mesophilic, plug-flow, flexible cover

New Horizons (formerly Inwood) Dairy is a dairy operation in Elmwood, Illinois. Their herd of 1,100 milking cows (1,400 total) produces approximately 38,000 gallons of manure per day. The owners are gradually expanding their herd with a goal of reaching their facility capacity of 1,600 head. They scrape collect the manure with skid steers. Collected manure has an average solids content of about 15 percent. Each day they also add two pay-loader buckets of other substrates to their input stream including: crop wastes, haylage, and cooking grease to improve biogas output. They use 3 Fan brand solids separators (which the manager says "work great") to remove digested solids which are then composted. They have temporarily switched from using solids to using rice hulls for bedding, at their veterinarian's request, due to some instances of mastitis. They plan to eventually switch to a mixture of rice hulls and digested solids.

Farm Name:	New Horizons Dairy	**Location:**	Elmwood, IL
Farm Type:	dairy	**Herd Size:**	1,100 lactating, 1,400 total
Collection Method:	scrape w/skid steer	**Bedding Type:**	rice hulls (temporary)
Digester Type:	plug-flow (x2)	**Design Temperature:**	105° F
Digester Notes:	combined phase, mesophilic, flexible cover, shared heated wall		
Design Capacity:	2,000 head	**Date Operational:**	November 2002
Design HRT:	20 days	**Current HRT:**	>21 days
Design solids %	11-14%	**Current solids %:**	13-17%
Biogas Use:	electricity, heat (260 kW)	**Utility Contract:**	no
Solids Separation:	yes, post digestion, Fan separator	**Solids Use:**	was bedding, now field
Farm Owns:	digester, energy generation	**Utility Owns:**	na
Digester Designer:	RCM Digesters, Inc.	**Utility:**	AmerenCILCO
Performance Data	115,000 cfd (variable herd pop.)	**Measuring Period**	12 months (10/02-10/03)

Digester. The dairy has two straight plug-flow digesters (in the right half of the picture below) designed by Mark Moser of RCM Digesters, Inc. The digesters share an interior heated wall, and are mostly underground, with 1-1.5 feet of digester wall above grade. The previous owners

Photo: Mattocks R, Environomics Inc.

had the digesters and dairy built at the same time starting in October 2001. At the direction of those owners, the digesters were designed for a capacity of 2,000 head. However, the current owners see the dairy having a capacity of 1,600 head (at the time of the interview, they were increasing herd size). Due to the difference in population and design capacity, the current HRT for these digesters is over 21 days when the design HRT is 20. The target operating temperature is 105° F. Each digester can hold a volume of approximately 400,000 gallons, and together the two digesters measure 80'W x 110'L x 10'D. The digesters have flexible covers to accommodate biogas produced.

Outputs and Uses. Biogas from the digester is used to fuel two Caterpillar 3406 naturally-aspirated 160 kW (130 kW for biogas) induction engine-generator sets (pictured below). Due to the excess generating capacity, they have been running the two engines at below their rated capacities (on average about 74 kW and 100 kW) for an average output of 174 kW. Despite their efforts adding other substrates to their manure, their savings and sales of electricity have been

Photo: Mattocks R, Environomics Inc.

lower than predictions made based on a 2,000 head herd. They estimate that electricity production over the 2003 year was about 1.5 million kWh. The farm does not currently have a contract with their electric utility (AmerenCILCO). They did pay to have a bi-directional meter installed and are doing net-metering (i.e., they are using some electricity on the farm and selling some). They sell excess electricity produced to the utility at a rate of $0.024 per kWh.

Maintenance Needs. Information on daily maintenance was not available. The digester has been operational 100 percent of the time, and at least one engine has been working 99 percent of the time. Both engines together have been operational an estimated 71 percent of the time.

Project History. The farm and digester were built concurrently starting in October 2001. After some modifications, and an ownership change for the dairy, they began feeding the digester and heating the manure in October 2002. They started running the engines on biogas in November 2002. The system has been operational ever since. To compensate somewhat for the built-in excess capacity of the digester, the owners have been adding other substrates to increase the volume of inputs and improve biogas production. The digester operator says virtually "all wastes on the farm are either digested or composted." Substrates thus far have included: crop wastes, food wastes, haylage, and cooking grease. They use Fan brand separators to remove digested solids from the manure and are very pleased with how they have been working. These solids are then composted prior to being used as bedding. Recently they switched from using digested solids to rice hulls. Following some cases of mastitis, their veterinarian recommended they make the switch because he felt the solids they were using were too moist. They plan to use a mixture of solids and rice hulls which they say the cows like and it "keeps them really clean." The mixture also helps them maintain a favorable carbon to nitrogen ratio. Their system was installed with a mechanical scrape collection system (at a cost of $107,000) for the manure, but they scrapped it because it was killing cows. They bought skid steers for collection.

System Costs. The total cost to make this system operational was $1.526 million. This figure may be somewhat overstated because it may include equipment such as pumps, buildings and materials that would have been needed regardless of the manure handling facilities chosen. They received a $550,000 grant from the Illinois Department of Commerce and Economic Opportunity and the Renewable Energy Resources Program.

Revenues and Other Benefits. They estimate that over the first year of operation (October 2002 to October 2003) they generated 1.2 million kWh of electricity, offsetting about $36,000 in electricity purchases and earning $4,700 in electricity sales. They estimate that for the calendar year 2003 they generated about 1.5 million kWh but a breakdown of offsets and sales amounts was not available. Savings amounts from use of process heat and bedding, and reduced herbicide use due to weed seed destruction were not available. They plan to use process heat for a hydronics system to keep manure moving during cold weather which is expected to provide operational benefits. Estimates of their savings from replacement of commercial fertilizer were not available. They estimate that over one year starting in October 2002 they destroyed 521.5 tons of methane or the equivalent of 10,430 tons of carbon dioxide.

Lessons and Comments. They are happy they chose the system they did for simplicity and dependability. The only thing they would do differently would be to move the cogeneration shed closer to the digester.

Information Sources.

George Murphy – New Horizons Dairy
Pam Bromlow – New Horizons Dairy
Mark Moser – RCM Digesters, Inc., <www.rcmdigesters.com>
Richard Mattocks – Environomics, <www.waste2profits.com>

Stencil Farm – Denmark, Wisconsin

combined phase, mesophilic, plug-flow, flexible cover

Stencil Farm is a dairy operation in Denmark, Wisconsin. They have 900 milking cows and 1,000 head total. They use scrape collection with a skid-steer and collect approximately 20,000 gpd of manure and other materials requiring treatment. They use a Fan solids separator after digestion to reclaim digested solids which they use for bedding. Collected manure has a solids content of between nine and ten percent.

Farm Name:	Stencil Farm	**Location:**	Denmark, WI
Farm Type:	dairy	**Herd Size:**	1,000 (900 milking)
Collection Method:	scrape with skid steer	**Bedding Type:**	digested solids
Digester Type:	plug-flow	**Design Temperature:**	100° F
Digester Notes:	combined phase, mesophilic, flexible cover		
Design Capacity:	1,200 head	**Date Operational:**	June 2002, May 2004
Design HRT:	20 days	**Current HRT:**	22-23 days
Design solids %	9-12%	**Current solids %:**	9-10%
Biogas Use:	electricity, heat (140 kW)	**Utility Contract:**	yes
Solids Separation:	yes, post digestion, Fan separator	**Solids Use:**	bedding
Farm Owns:	digester, energy generation	**Utility Owns:**	na
Digester Designer:	RCM Digesters, Inc.	**Utility:**	Wisconsin Public Service
Performance Data	na	**Measuring Period**	na


Photo: Moser M, RCM Digesters Inc.

Digester. Stencil Farm installed a plug-flow digester (pictured at right) to reduce odor, produce bedding and create better quality fertilizer. The digester, designed by Mark Moser of RCM Digesters, Inc., is a combined phase system, with a target operating temperature of 100° F, and a flexible cover. The design HRT for this digester (at design herd capacity of 1,200 head) is 20 days, but they are currently running at about 22-23 days given the smaller herd size. The digester dimensions are 40'W x 110'L x 16'D, with a total digester volume of about 450,000 gallons.

Outputs and Uses. Biogas from the digester fuels a Caterpillar 3306 engine-generator set with a biogas rating of 140 kW. Biogas production levels have varied a lot lately and are not consistently monitored. Therefore, estimates of biogas production are not available. Prior to the start of engine problems, the system was reported to be averaging energy production at 123 kW and producing biogas steadily. Heat from the engine is used to heat the digester only.

Maintenance Needs. Other than noted below, the digester and energy generation system has required very little maintenance. The system readouts are next to the shop so they just check the gauges when they walk by which takes about ten minutes per day. They have followed the prescribed maintenance procedures for Caterpillar engines including oil changes every 1,000 hours and adjusting the lifters.

Project History. The system was constructed from June 2001 through January 2002 with Stencil Farm as the general contractor. They began feeding manure in January 2002 and the system had stabilized in June 2002 (the startup period was extended due to the release of footbath water into the digester which depleted the microbe population). Following a successful period of operation, they started experiencing engine breakdowns which in turn resulted in digester cool-downs and re-starts. In March 2004, they overhauled the engine at a cost of $25-30,000. As of May 2004, the system was again up to temperature and stabilized. They were continuing to have operational difficulties with the engine.

System Costs. The overall system cost approximately $500,000.

Revenues and Other Benefits. Revenues from electricity sales were not available. The farm has experienced benefits from odor reduction and use of digested solids for bedding, but dollar values for these benefits were not available. Upon switching from separated (undigested) manure solids to digested solids, they experienced a large drop in herd somatic cell count. They currently have a herd average somatic cell count in the 190,000 range.

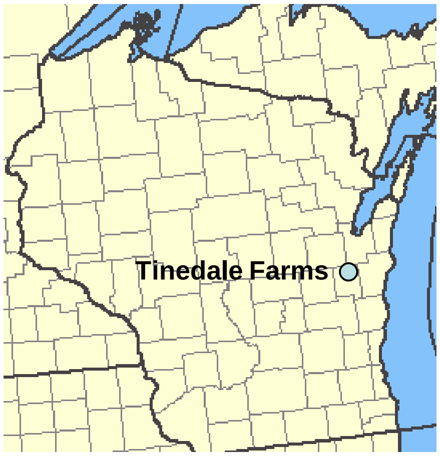
Lessons and Comments. The owner is quite satisfied with the digester, but feels the choices for engines to burn biogas are extremely limited. He is not happy with his energy generation system. If starting over, he suggests that in the absence of higher rates for electricity produced from biogas, he would consider buying a boiler to produce heat and avoid the engine problems.

Information Sources.

Gerry Stencil – Stencil Farm
Mark Moser – RCM Digesters, Inc., <www.rcmdigesters.com>
John Christiano – Wisconsin Public Service, <www.wisconsinpublicservice.com>

Tinedale Farm – Kaukauna, Wisconsin

combined phase, mesophilic, complete-mix loop, hard cover



Tinedale Farm is a dairy operation in Kaukauna, Wisconsin. They have about 1,800 milking cows and about 600 dry. The farm produces 50,000 gpd of manure and other materials for treatment. It is scraped to a pit, from which it gravity flows to the digester. They separate out their digested solids using an Ag Environmental Solutions (AES) designed separator (pictured below). The digested solids are used for bedding, and occasionally sold to neighboring farms.

Farm Name:	Tinedale Farm	**Location:**	Kaukauna, WI
Farm Type:	dairy	**Herd Size:**	2,400 (1,800 milking)
Collection Method:	scrape to pit then gravity flow	**Bedding Type:**	digested solids
Digester Type:	complete-mix (see notes)	**Design Temperature:**	100° F
Digester Notes:	designed as TPAD in plug-flow loop shape, converted to complete-mix due to problems with thermophilic phase, fixed cover		
Design Capacity:	na	**Date Operational:**	July 2003 (as meso only)
Design HRT:	20 days	**Current HRT:**	19-20 days
Design solids %	9-10%	**Current solids %:**	~8%
Biogas Use:	electricity, heat (375 kW)	**Utility Contract:**	yes
Solids Separation:	yes, post digestion, AES separator	**Solids Use:**	bedding, sales
Farm Owns:	digester, energy generation	**Utility Owns:**	na
Digester Designer:	Ag Environmental Solutions, LLC, and STS Consultants, LTD	**Utility:**	We Energies
Performance Data	200,000 cfd biogas	**Measuring Period**	6 months


Photo: Ag Environmental Solutions, LLC

Digester. Tinedale Farm installed a temperature phased anaerobic digester (TPAD) in 2000 and 2001. Their digester (pictured on the following page), designed by AES and STS Consultants, is the first application of a TPAD system to a dairy operation in the United States. The TPAD system, to which the Iowa State University Research Foundation, Inc. owns the patent, was adapted from a partially built plug-flow loop type digester, and so bears the same horseshoe shape as those systems. Following numerous technical difficulties with the thermophilic phase of the system (see the History section of this profile for more details on these), the owners have switched to operating the system as a complete-mix digester in the mesophilic (~100° F) range only. The digester volume is approximately 900,000 gallons, has three chambers, and measures 70'W x 135'L x 16'D. The digester cover is fixed and they do not use biota recycling. The manure is mixed using draft tube mixers.

Photo: Ag Environmental Solutions, LLC

Outputs and Uses. The digester has operated in steady state as a mesophilic system for the past six months. During that time it has averaged about 200,000 cfd of biogas production at about 65 percent methane content. Tinedale now uses both an iron sponge scrubber to remove H_2S and a coalescing filter to remove moisture prior to combustion. Biogas is used to fire a 375 kW Waukesha engine-generator set (pictured below) consistently near its rated capacity. They are recovering heat from the engine which is used to heat the digester. They have excess heat, but currently have no plans to use it in any other way.

Maintenance Needs. Moisture in combination with trace amounts of H_2S in the biogas has been a big problem for Tinedale's engines. The water and H_2S solution kept getting onto the cylinders and taking the oil off the liners causing excessive wear. They have had to fully tear down the engines twice for repair. Other routine maintenance needs for the digester and engine-generator set were not available.

Photo: Ag Environmental Solutions, LLC

Project History. AES and STS Consultants, designed and built a TPAD system at Tinedale Farm in 2001. In June 2001, they started running the digester at mesophilic temperatures. After the system stabilized, they increased the temperature in the first phase to thermophilic levels (~131°F), but found that the heat exchanger was too small to cool the manure back down to mesophilic temperatures at the end of the phase. This resulted in the first digester shutdown. During the second startup in February 2002, they seeded the digester with biosolids from the Appleton wastewater treatment plant. Subsequent restarts in 2002 and 2003 were plagued by technical problems including engine breakdowns, and failure of the thermophilic cultures to develop as predicted. Due to these issues, operation of the digester as a TPAD was abandoned in July 2003. They decided to continue operating the system as a mesophilic complete-mix digester. As part of a university study, they are currently adding magnetite to the influent stream to see if it inhibits the formation of H_2S by removing sulfur before it is converted to H_2S. To boost biogas production, they are investigating the possibility of adding sweet water from a local candy plant.

System Costs. Cost information was not available.

Revenues and Other Benefits. They estimate that they save $75,000 per year by using biosolids compared to cost of wood shavings. The owner really likes using the digested solids coming off the digester. When using these solids for bedding they have typically had somatic cell counts in the range of 250,000. Values for revenues from electricity sales were not available. We Energies purchases the entire electrical output and its renewable attributes at a premium. We Energies also pays an ancillary service fee to wheel the electricity to their service territory.

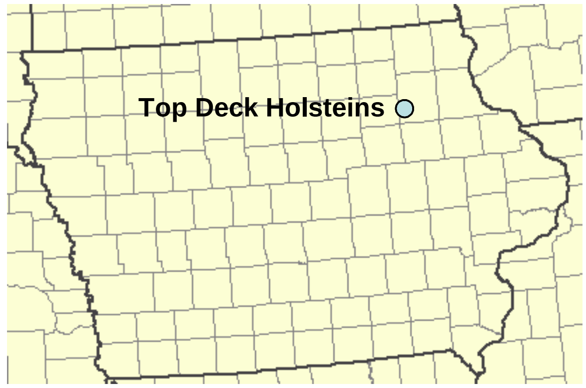
Lessons and Comments. Researchers studying the digester have concluded that use of a TPAD in this setting will require a better understanding of potential factors limiting its effectiveness (Katers J and Schultz J, 2003). Known barriers include ongoing equipment issues (primarily engine-related), and apparent toxicity of high volatile fatty acid concentrations and other farm additives to the thermophilic biota.

Information Sources.

Carl Theunis – Tinedale Farm, <http://www.ag-energy.com/>
John F. Katers – "Temperature Phased Anaerobic Digestion System Monitoring Project at Tinedale Farm: Final Report," August 31, 2003, <www.mrec.org/biogas/Tinedale_Farm_Monitoring_Study_Final_Report.pdf>

Top Deck Holsteins – Westgate, Iowa

combined phase, mesophilic, plug-flow, fixed cover



Top Deck Holsteins, Inc. is a 650-700 head dairy operation in Westgate, Iowa. The farm produces about 17,000 gpd of manure and other treatable materials. These are collected by automatic scrapers and a flush system in one (maternity) alley. The manure has an overall solids content of about 11 percent. They are using oat hulls and mattresses for bedding. They plan to eventually switch to digested solids for bedding, but have not yet purchased the separator. They will also use under-floor forced air for drying of the solids.

Farm Name:	Top Deck Holsteins, Inc.	**Location:**	Westgate, IA
Farm Type:	dairy	**Herd Size:**	650-700 (600 milking)
Collection Method:	automatic scrapers 2 barns, flush 1 barn	**Bedding Type:**	oat hulls
Digester Type:	plug-flow	**Design Temperature:**	98° F
Digester Notes:	combined phase, mesophilic, fixed cover, pre-heat tank		
Design Capacity:	na	**Date Operational:**	summer 2002
Design HRT:	14 days (1/2 day in preheat tank)	**Current HRT:**	14 days
Design solids %	na	**Current solids %:**	~11%
Biogas Use:	electricity, heat	**Utility Contract:**	yes
Solids Separation:	planned	**Solids Use:**	planned for bedding
Farm Owns:	digester	**Utility Owns:**	generation
Digester Designer:	Dan Meyer, Ray Crammond	**Utility:**	Alliant Energy
Performance Data	na (variable)	**Measuring Period**	na


Photo: Meyer D, ISU Fayette County Extension

Digester. Top Deck installed a plug-flow digester (pictured at right with insulation and angled access pipes visible) as part of an overall dairy expansion. The digester was designed by Dan Meyer of Iowa State University Fayette County Extension, and Ray Crammond of AGRIN, LLC, includes a pre-heat tank to bring the collected manure up to 98° F. The plug-flow digester is straight, with a fixed cover, and has a shorter HRT due to the presence of the pre-heat tank. The design HRT for the digester itself is 14 days, and it can hold up to 240,000 gallons of manure.

Outputs and Uses. Alliant Energy supplied the energy generation equipment for Top Deck, and has a gas purchase agreement with them. Alliant buys the biogas and runs it through a 100 kW Waukesha induction engine-generator set and a 30 kW Capstone Microturbine. Biogas measurements have been taken sporadically and suggest some variability in production. The measured methane content has been in the range of 60-70 percent. Some of the variability in volume of biogas was attributed to frequent breakdowns of the used engine-generator set and the repercussions that has had on the system. The microturbine, alternatively, has been operational and functioning well. Recovered heat from the microturbine is sufficient to heat the digester only in warmer seasons, so they needed to rent a boiler and buy LP gas to heat it in winter when the engine was not working. Once the engine problems are solved, they plan to buy a solids separator and switch to digested solids for bedding.

Maintenance Needs. Normal maintenance for the engine includes oil changes every 1,000 hours of operation. The digester requires little maintenance.

Project History. The digester was built as part of a farm expansion that began in October 2000, and was completed in March 2002. They had some trouble early on with foaming in the digester and some manure solids coming up the gas pipe. They also found out that the control panel was malfunctioning. The digester was reportedly going "good" but the engine-generator set has broken down repeatedly. The biogas has been going to the microturbine and the rest to the flare. The owners feel a new engine-generator set would make the system more stable and enable them to get the predicted benefits out of the digester and energy sales agreement.

Photo: Rutkowski A, Alliant Energy

System Costs. The digester and energy generation system cost $501,500 (Meyer D no date). According to the final report, the Iowa Department of Natural Resources and Natural Resources Conservation Service contributed $157,900, Alliant paid $250,000 for the energy generation equipment and to connect the system to the grid, and Top Deck paid $93,600 for the digester.

Revenues and Other Benefits. The farm owners have not seen many of the predicted benefits due in part to the engine malfunctions. Much of the produced biogas has been flared. Information on revenues received for electricity sales was not available. Information on other revenues and benefits was not available.

Lessons and Comments. The owners still think the concept of using AD on dairies is a good one. In retrospect, they would buy a boiler as a backup means of heating the digester in the event the engine is not working. Alliant Energy and more recently, Top Deck Holsteins, has had to rent a boiler and buy LP gas in the wintertime to maintain digester temperature which has proven quite costly. The owners would like to see more government financial support to reduce the risk for farmers adopting AD systems.

Information Sources.

Derek Decker – Top Deck Holsteins
Dan Meyer, Top Deck Final Report,[8] no date.
Duane Hanusa – Alliant Energy, <www.alliantenergy.com>

[8] This report is available for download at the following URL <http://www.state.ia.us/dnr/energy/MAIN/PROGRAMS/METHANE/documents/TopDeckFinalReportFormat.pdf>

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