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EXAMINATION OF ANAEROBIC DIGESTER PERFORMANCE PROTOCOL USE

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Examination of Anaerobic Digester Performance Protocol Use

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REPORT SUMMARY

The Association of State Energy Research and Technology Transfer Institutions (ASERTTI), U.S EPA AgSTAR Program, and the U.S. Department of Agriculture Rural Development jointly supported the development of a protocol (Martin 2007) for evaluating and monitoring performance of the growing number of on-farm anaerobic digesters. Since publication, ASERTTI, with a grant from the Blue Moon Fund, launched a study titled “Pilot Performance and Cost Database for Anaerobic Digestion Systems for Livestock Manures” to better understand how the protocol was being used, and find ways to increase the volume and quality of performance data available to the public. ASERTTI contracted with one of its members, the Energy Center of Wisconsin, to lead this study. The Energy Center of Wisconsin worked with a number of other ASERTTI member organizations in gathering and analyzing data for this report.

The project has produced an MS Access database populated with data on installed farm anaerobic digester systems, pre-made reports summarizing performance data for Web posting, and this report describing experiences and identifying problems that researchers have encountered in using the protocol.

Based on information gathered during the course of this project, the primary obstacle to using the protocol is the overall cost. The cost for at least 12 months of sampling and laboratory analysis, as well as for writing the performance report, has deterred researchers from attempting protocol use. The cost issue will be addressed to a limited extent by the release of an international protocol that has tiers of protocol use rather than the current all-or-nothing approach. However, funding for protocol use will continue to be a significant issue.

In other cases, once the decision to use the protocol was made, barriers appeared that made continued adherence to the protocol very difficult if not impossible. These included farm issues, weather related issues, and operational issues with equipment, which in several cases caused researchers to be unable to meet the requirements of the protocol.

It should be noted that the scope of work for this project required adjustment due to a scarcity of data and apparent barriers to protocol use. The focus shifted to examination of attempted uses of the protocol, gathering and conditioning data from these attempts, and exploring options for providing useful information to the public. The principal investigator (PI) opted to produce a database with information from the public reports on protocol uses, and create a system by which reports could be generated and made available on the ASERTTI Web site. This solution is a compromise that uses the limited protocol data, allows inclusion of appropriate caveats, and provides the information most likely to be of interest to users. A fully searchable on-line database does not make sense at this point given the limited amount of protocol adherent records that are publicly available, and the safeguards and explanations needed to interpret the data.

The database and formats for generated reports will need to be updated as new records become available and when an international protocol is finalized. Continued provision of performance data will require an ongoing effort to process, evaluate, and create records to add to the database.

INTRODUCTION

Recent growth in use of anaerobic digester systems at livestock operations has created the need for comparable information on system performance so consumers can make informed choices. To this end, the Association of State Energy Research and Technology Transfer Institutions (ASERTTI), U.S EPA AgSTAR Program (AgSTAR), and the U.S. Department of Agriculture Rural Development supported development of a protocol for characterizing, monitoring, and evaluating performance of farm-based anaerobic digesters (Martin 2007).

The project is Phase Two of the ASERTTI Digester Program. The goal of this effort is to help overcome the challenges of collecting new data and analyzing existing ASERTTI/AgSTAR protocol driven data, promote greater levels of testing, and create recommendations for digester operation improvement. An additional goal is to provide public access to the protocol information. This document represents the final report for the ASERTTI project Pilot Performance and Cost Database for Anaerobic Digestion Systems for Livestock Manures.

This final report describes some modifications that were necessary from the original scope of work as a greater understanding of the current situation with digester testing and protocol became known. It became apparent that due to the dearth of protocol-adherent data available, examination of the early attempts at using the protocol should be the primary focus, with an exploration of means by which barriers could be removed or reduced to expand its use and increase its utility. The Principal Investigator (PI) and ASERTTI intend to explore options for continuing this effort.

Attempts to use the protocol have been sparse, and the successful gathering and reporting of protocol adherent data even rarer. This is due to a number of factors that have deterred researchers from using the protocol, and others that prevented successful completion of monitoring efforts once the decision to use the protocol was made. Some of these issues and complications are further discussed in the Findings section of this report.

FINDINGS

One large issue is that the cost of using the protocol, including a year of monitoring and laboratory testing, is prohibitive for many. A representative of Western United Resource Development, an organization tasked with evaluating the outcomes of farm digester projects funded through the California Energy Commission's Dairy Power Production Program, cited cost as the primary reason they were unable to use the full protocol in evaluating systems.¹ They would very much like to use the protocol if funding were available. Other researchers using the protocol noted that it was beyond the ability of almost all farms to conduct or pay for such a study.

The sheer expense and time commitment (12 months of monitoring) associated with protocol use prevented the PI from conducting protocol-adherent case studies under this project. Instead, the focus shifted to gathering data on digester studies that had attempted to use all or parts of the protocol. In addition, the PI plans to gather economic data from Wisconsin digester systems (under a different project) using that portion of the protocol that can be included in the ASERTTI database. However, this data is unlikely to become available until after this project ends.

Funding for protocol use will need to be from third parties which, with one notable exception, have not made protocol adherent study of digester installations a priority. The one notable exception is New York State Energy Research and Development Authority (NYSERDA), which has funded studies of several farm systems in New York State, most of which are still in the data gathering and analysis stage.

Although cost was the largest factor in the decision whether or not to use the protocol to measure a digester's performance, once the decision to use all or part of the protocol was made, and adequate funding was available, there were still barriers to successfully completing the study. To gain a better understanding of practical difficulties people had in attempting to use the protocol, we spoke with those who have produced case studies using the protocol, as well as other digester experts familiar with the protocol. This was accomplished through a series of phone conversations and a conference call, as well as a review of published documents on those studies. The group included representatives from California, Illinois, New York, Washington, and Wisconsin.²

As of this report writing only eight publicly documented attempts at using the protocol were available. Table 1 summarizes these attempted uses of the protocol and results.

¹ Kathi Schiffler, Western United Resource Development, Inc. (WURD), personal communication, March 2009. WURD published a program evaluation report of ten California digester systems in 2006. This study did sampling and analysis of performance data at ten systems installed in the State of California. These studies, however, only took one day representative samples at each farm.

² This group included: John Cuttica, University of Illinois Chicago; Curt Gooch, Cornell University; John Katers, University of Wisconsin Green Bay; Larry Krom, Wisconsin Focus on Energy, John H. Martin, Hall Associates; and Dave Sjoding (Craig Frear?), Washington State University.

Table 1 – Protocol Use and Results

Farm Name	Difficulties Encountered	Results of Protocol Use
AA Dairy	Digester is substantially oversized resulting in higher (~150%) than designed hydraulic retention time (HRT)	High HRT may make digestion efficiency results look more favorable than if operating at design HRT. This will need to be stated with results.
Castelanelli Brothers	Monthly herd size numbers were imprecise, as were amounts flushed to the digester. Also digester releases some unmeasured amount of biogas to the atmosphere. Use of wastewater for flushing makes in/out digestion efficiency measurements more complex.	Not protocol compliant due to missing herd size and influent volume data (study also assumed about 75% of manure is fed to digester). Per cow and digestion efficiency measurements are problematic. Loss of unknown amount of biogas further complicates conversion measures.
Colorado Pork	Overall volume of biogas produced not measured (only gas to the engine was measured). Improving water control measures during measurement period caused declining volume of influent over time – system was not in “steady-state.” The system had significant settling in the digester, which was intermittently mixed. Numerous engine and electrical failures occurred during study period.	Not protocol compliant due to lack of steady state conditions and missing biogas data. No utility intertie so farm only produced electricity it could use. Solids reductions are overestimated due to solids settling in reactor. Settling over time reduces HRT and digestion efficiency. These resulted in many gaps in data and reliance on estimates versus measurements.
Deere Ridge Dairy (a.k.a. Gordondale Farms)	Herd size increased 15% midway through the study. Only 6 months of biogas measurements available due to meter removal by farm. Measurement of biogas vol. per COD destroyed was anomalous.	Determined HRT change after herd increase to not be significant (water conservation increased – must have resulted in influent solids increases although not documented)
Green Valley Dairy	Only one biogas composition measurement taken. Measurement period was 10 months and 3 sampling dates were missed due to engine repair and other maintenance. Several missing temperature measurements. Influent volume is estimated by employee, not measured. Only gas to the engine is measured, so vented amounts are unknown.	Not protocol compliant due to only 10 months monitoring, missed sampling dates, influent volume uncertainties, total biogas not measured.
New Hope View Dairy (formerly DDI)	New configuration, equipment and monitoring data expected. Monitors could not measure all biogas produced.	Not protocol compliant due to missing biogas data. New data expected in 2009.

Farm Name	Difficulties Encountered	Results of Protocol Use
Ridgeline Farm (formerly Matlink)	Multiple off-farm food wastes also added, measurements are for combined feedstocks (although separate characterizations for off-farm wastes were included in the study).	High biogas production due to co-digestion of high-energy off-farm food wastes. Performance measures will appear unusual due to influent constituents. New data expected in 2009.
Suring Community Dairy	Measurement period was 10 months. Influent volume is an estimate. Biogas lost through pressure relief valves is unknown but estimated at 2%. Engine generator set fueled by both biogas and diesel, run only during peak periods. Some samples were missed due to frozen effluent sample ports. Influent flow rates were unavailable, some estimates were made.	Not protocol compliant due to 10 month monitoring period, uncertain measure of influent volume, only part of biogas measured, TVS and COD measures not synchronous with biogas measures, electricity generation measures complicated by co-firing of engine with biogas and diesel. Influent numbers and per cow estimates are tenuous.

Sources: AA Dairy – Martin and Roos 2007, Gooch and Pronto 2008, Gooch et al. 2007
 Castelanelli Brothers – Martin June 2008
 Colorado Pork – Martin 2003
 Deere Ridge Dairy – Martin and Roos 2007, Kramer 2008
 Green Valley Dairy – Baldwin and Katers 2009, Kramer 2008
 New Hope View Farm – Gooch et al. 2007
 Ridgeline Farm – Pronto and Gooch 2008, Gooch et al. 2007
 Suring Community Dairy – Baldwin and Katers 2009, Kramer 2008

Several difficulties were apparent from these interviews and from the published reports. In some cases the farms were operating in a substantially different manner than the design assumptions made by the digester designers, making interpretation of performance measures problematic. For example, one digester was oversized (due to the decision not to go through with a planned herd expansion), and another operated well below the design temperature for the system. These issues do not preclude a monitoring study from adhering to the protocol, but make analysis of the systems’ performance more complex requiring constant reiteration of the caveats and explanation of their significance.

Monitor-related problems are another factor that can derail attempted protocol uses. In some cases, adequate biogas monitoring equipment (for the purposes of a protocol study) is not installed with the digester. This may result in only biogas going to the utilization equipment being measured while biogas that is flared, goes to an alternate use such as a boiler, or is vented as pressure relief is not measured. For these reasons several farms had no measure of overall biogas production. Another monitoring problem arises when equipment is installed but malfunctions or is removed by the owner. Each of these problems can result in the failure of a monitoring study to be adherent to the protocol.

Weather and on-farm issues also resulted in missed measurements. Some samplings were thwarted due to frozen sampling ports during colder winter weather. Other times there were conflicts between scheduled measurement visits and on farm activities such as maintenance of farm systems or replacement of digester related equipment. These higher priority farm and digester operation issues meant that researchers could

not draw the samples they needed and farm workers were unavailable to assist them in alternative sampling options.

In some cases key data such as influent volumes were missing or estimated instead of measured. The protocol does not specify a methodology for measuring flows, but does call for full descriptions of the method and rationale used for measuring manure flows in the system. Because this information serves as a basis for per-cow loadings and biogas production measurements, studies that only quoted estimates by farm employees without an explanation as to how those were produced were deemed to be not adhering to the protocol.

These difficulties also bring up questions as to what will constitute protocol adherence for monitoring projects such as:

- How many scheduled measurements can be missed in a 12 month measurement period before the data does not count as protocol compliant?
- What if a key measure is an estimate rather than a direct measure?

As a result, only three of the eight monitoring projects that sought to gather protocol based data could be considered in rough adherence to the protocol. Knowledge of those experiences, and recognition of potential problems like those discussed above, can help future protocol users anticipate and avoid difficulties, and produce protocol adherent studies.

DATABASE LIVE QUERYING VERSUS PRE-MADE REPORTS

This project scope of work originally included creation of an online searchable database of protocol adherent data on farms and digesters. The PI created and populated a Microsoft Access database using all known published attempts at using all or significant parts of the protocol. Appendix A has an annotated listing of the database fields. The database contains basic farm information on 22 farms. Seventeen of these records were adapted from records produced as part of a Wisconsin's Focus on Energy project to create the Wisconsin Biogas Casebook – July 2008 Edition (Kramer 2008). Three of the Wisconsin farms also include at least partial protocol data through projects funded by Wisconsin's Focus on Energy (Baldwin and Katers 2009) and EPA AgSTAR (Martin and Roos 2004, and Martin 2005). Eight of the 22 farm/digester profiles contain at least partial protocol data beyond basic farm information. These eight farms (see Table 1) were used to generate sample reports for possible listing on the ASERTTI Web site as examples of protocol use. Of these eight farms using at least part of the protocol, only three were interpreted by the PI to be fully protocol compliant.

Given the small number of successful protocol uses at the time of this report writing, the limited number of data listings that would be useful to viewers, and the strings of caveats needed to interpret data listings, live on-line querying of the database was not developed. It is the PI's opinion that performance data is best presented in the form of a case study in which farm operations, livestock characteristics, and other relevant variables affecting digester performance and measurements can be adequately communicated. The case study format, however, does not allow easy comparisons between systems. To facilitate such comparisons while providing important caveats, a series of pre-made reports designed to provide the information of most interest to users was chosen as a workable compromise.

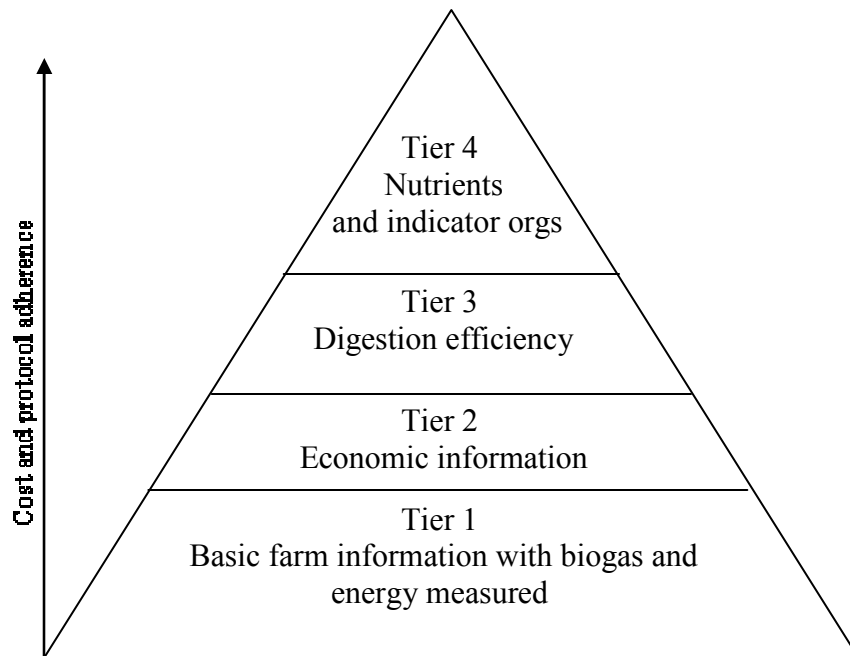
The group of digester experts was also consulted regarding appropriate data to display to Web site users, and options for representing digester performance and other information. The PI prepared some draft reports generated using the farm digester database and sent them to the reviewers. The reports included:

1. Farm Basic Information List
2. Individual Farm Reports
3. Influent Characterization Percentages
4. Waste Stabilization
5. Biogas Production and Composition
6. Economic Info
7. Data Qualifications

These reports, incorporating comments received whenever possible, are included in Appendix B, and files were submitted to ASERTTI for Web posting. The PI made the final decision on the reports, formats and contents. Representation of these data sets in a meaningful way, including relevant caveats and qualifications will be an ongoing challenge. Setting up querying functions for a Web-based database may become a sensible service to add to the ASERTTI Web site when and if additional records of protocol adherent system studies become available and can be interpreted, converted into matching formats, and entered into the database.

INTERNATIONAL PROTOCOL

A notable development is the work by AgSTAR and digester interests throughout the world to produce an internationally agreed-upon protocol. As of July 2009, the new international digester evaluation protocol had not yet been released. John H. Martin of Hall Associates, the primary author of both the current protocol version and the international version, indicated that the international version was expected to be only slightly different than the ASERTTI/AgSTAR version. One key difference will be the option for users to use pre-defined portions of the protocol giving them lower cost options to provide consistent and comparable performance and farm data. Figure 1 shows how one such tiered protocol might work.

Figure 1 – Example Tiered Protocol Data Groups

The base of the pyramid represents Tier 1, the lowest cost level of protocol use which would include only basic farm and system information and measurements of biogas and energy generated. Each higher level would include the information of those below it, would include a greater amount of protocol data, and would be more costly to complete. A key cutoff point is between Tiers 3 and 4; adherence up to Tier 3 could be enough to adequately portray digester performance without the more costly testing required for changes in nutrients and indicator organisms which are more in the realm of environmental variables.

The database and reports produced in this project should be reviewed and modified when an international protocol is released.

CONCLUSIONS AND NEXT STEPS

The ASERTTI/AgSTAR protocol serves an important function in providing a standard means of characterizing farm-based anaerobic digester systems and their performance. These early applications of the protocol described in this report have provided valuable information on barriers to its use. The new international protocol will take an important step in encouraging more widespread use of standardized characterizations by offering tiered options of varying cost rather than “all-or-nothing” adherence. It appears, however, that funding for full protocol use will continue to be an issue and that any efforts to develop more farm system data using the protocol will need to be funded by some entity other than the farm, the digester designer, or the involved utility. None of these groups alone will likely be motivated enough to bear the expense. The future availability of comparable performance data rests in the hands of other funders. There may be opportunities for funding data gathering on digester systems such as building a funding mechanism into grant programs like Renewable Energy for America Program (REAP), including study funding in budgets of regional Clean Energy Centers, or through state grant program requirements.

Some data from studies of at least five other systems using the protocol are expected to become available within the next two years due to NYSERDA funding of digester studies, and an already completed study of a Washington State farm. Table 2 lists these farms.

Table 2 – Expected Near-term Protocol Studies

Farm Name	State	Status
Emerling Farms	NY	Monitoring complete in 4/09
Noblehurst Farms	NY	Interim report data available (Cornell U, NYSERDA project), monitoring complete in 10/09
Patterson Farms	NY	Monitoring complete in 3/09
Sunny Knoll Farms	NY	Monitoring complete in 6/09
VanderHaak Dairy	Washington	Paper awaiting completion of peer review

This project has delivered a Microsoft Access database designed to house measurement data needed for protocol adherent studies, and the information needed to form the framework of case studies for on-farm anaerobic digester systems. The database also includes forms for entering data, and pre-made report formats to display data with relevant caveats, limitations and explanations. Substantial data conversions were necessary to make data from the monitoring projects reasonably uniform. In addition, the case studies required thorough examination to understand the problems encountered and other caveats to the gathered data. It is not possible to design a system to automatically glean data from new publications as they arise, convert measurements, and document study details to expand and update the database. Data from current studies that are underway, and any possible future studies that are launched will need to be processed by a person familiar with digester technologies and farm operations in order to extract data for inclusion in the farm system database.

An option ASERTTI may want to consider to encourage more system monitoring and study could be to support development of informational documents on using the protocol with pointers and lessons learned so obstacles encountered could be avoided, costs could be minimized, and efforts, once started, could meet with more-frequent success.

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APPENDIX A – ANNOTATED LISTING OF DATA FIELDS

Fieldname	Data Type	Description
ID Number	Auto Number	
Incl excl WI	Boolean	yes or no is it included in the (WI) casebook
Incl excl prot	Boolean	yes or no it has some protocol data
AgSTAR ID	Text (50)	ID from AgSTAR database, those starting with FOE assigned for WI biogas casebook
Owner or Contact Name	Text (50)	person to speak with regarding the digester
Contact email	Text (50)	
Contact phone numbers	Text (50)	phone and cell numbers for contact
Farm name	Text (50)	
Address	Text (50)	
Locality	Text (50)	
County	Text (50)	
State	Text (50)	
Zip	Text (50)	
Type of operation	Text (50)	dairy, swine, layer, beef feedlot, other
Type of manure system being replaced	Text (100)	storage tank, pond, pit, anaerobic lagoon, stack
OD Freq of collection	Text (50)	Operational details how frequently waste is collected
Dairy breed	Text (50)	Holstein, Guernsey, etc.
OD Avg total animals feeding digester	Text (50)	average total animals feeding the digester
Swine operation subtype	Text (50)	farrow to wean, farrow plus nursery, farrow to finish, etc.
Swine avg sows-preg gilts-litters per sow-year	Text (50)	average number of sows and pregnant gilts and number of litters per year
Swine avg fdr pigs-grow finish cycles	Text (50)	average number of feeder pigs and number of gro/finish cycles per year
Layer avg hens	Text (50)	average number of laying hens
Other numbers and types of animals	Text (50)	if other, how many and what kind of animals are there
Digester status	Text (50)	operational, retired, startup, construction, troubleshooting, planned
Year installed	Text (50)	year installation is complete
Year operational	Text (50)	year steady state operation achieved
Business model description	Text (250)	
Type of collection system	Text (100)	scrape, flush, pull plug, etc.

Fieldname	Data Type	Description
Type of digester	Text (50)	mixed, plug flow, attached film, covered lagoon, two-stage plug flow, other
System designer	Text (50)	make this field relational to designer info table
DA no of animals	Text (50)	assumed herd size for design purposes
DA swine type or types avg weight	Text (100)	assumed swine type or types and avg live weight
DA bedding type est quantity	Text (50)	assumed bedding type and estimated quantity used
DA manure vol per day	Text (50)	assumed manure volume in cubic ft/day
DA wastewater volume	Text (50)	assumed wastewater volume (e.g., none, milking center wastewater, washdowns...)
DA other waste vol	Text (150)	assumed vol of other wastes in cubic ft/day (incl non-farm wastes), and characteristics
DA total vol influent	Text (50)	assumed total vol of influent per day
DA influent solids content	Single	assumed solids content (%) of influent
DA volatile solids percent	Single	assumed volatile solids concentration in influent
DA pretreatment	Text (150)	assumed pretreatments for influent (none, grav settling, screening, screw press...)
DA post-treatment of effluent	Text (250)	assumed treatment of digester effluent (none, solids separation by screening, ...) incl use or disposal
DA effluent storage	Text (100)	assumed method of effluent storage (none, earthen pond...)
Digester description	Text (200)	general descr. of system, incl types of materials, positioning on/in land, etc.
Cover type	Text (50)	rigid, flexible, concrete, steel, etc
Digester dimensions	Text (100)	height, length, width, diameter
Digester insulation	Text (100)	types, locations and thicknesses of insulation
Digester op and gas volume	Text (100)	operating volume and ancillary gas storage volume if present
Digester HRT	Text (50)	design hydraulic retention time
Digester temperature	Text (50)	design operating temperature
new RAS or other bacteria retention	Text (100)	describe means of retaining or reintroducing bacteria into the digester
Comp with NRCS CPSs	Text (100)	compliance with standards 365 (ambient) or 366 (controlled temp) y/n
OD bedding type and est quantity	Text (50)	op details type of bedding and quantity used
OD waste vols and chars	Text (250)	op details of volumes and characteristics of wastes fed into digester
OD influent solids content	Single	op details of avg solids percentage in influent
OD influent VS content	Single	op details of avg VS percentage in influent

Fieldname	Data Type	Description
OD freq of waste addition	Text (100)	op details of frequency of waste additions
OD pretreatment	Text (150)	op details regarding pretreatment of influent
OD dig temperature	Text (50)	op details of average daily digester temperature and monthly range
OD HRT	Text (50)	op details of HRT in days
OD antibiotics	Text (50)	op details on use of monensin or other antibiotics
OD effluent treatments	Text (200)	none, solids separation, use and disposal, P removal
OD vol of dig solids produced and fate	Text (200)	what volume of solids is produced per day or week and where do they go
new enviro credits details	Text (200)	describe env credits and ownership, aggregator etc
Biogas utilization	Text (100)	how is biogas used (none, elec gen, on-site boiler or furnace, sold to 3rd party)
Type of prime mover	Text (150)	engine generator set, microturbine, furnace/boiler, none
Elec gen manuf-model-cap	Text (100)	if elec gen manufacturer and model of prime mover design capacity (kW)
Component integration	Text (100)	describe how components were integrated (by factory or owner)
Orig of equipment controller	Text (50)	manuf integrated, 3rd party off-the-shelf, 3rd party custom
System installer	Text (50)	who installed the energy gen system
Stand-alone capacity	Text (50)	y/n
Pretreatment of biogas	Text (100)	describe any biogas treatments prior to use (none, condensate trap, cryer, H2S removal, etc.) mfgs and models
Exhaust gas emissions control	Text (100)	describe any emissions controls installed for exhaust gases
Utility	Text (50)	if interconnected with electric util, provide name
Utility contract type	Text (150)	describe utility contract if applicable (sell all/buy all, surplus sale, net metering)
Electric power at site	Text (50)	one phase, three phase
Heat source if recovered and Btu	Text (150)	cooling system or exhaust gas or both and recovery capacity (Btu/hr)
Waste heat use	Text (150)	digester heating, water heating, space heating, etc.
Boiler or furnace info	Text (150)	if used on site for fuel, boiler or furnace mfg, model, and rated capacity (Btu/hr)
Biogas sale	Text (200)	if biogas sold to 3rd party, descrip of methods of processing, transport and end use
System cost as built	Text (100)	cost of total system "as built"
Cost basis	Text (100)	turnkey by developer, owner acted as general contractor, constructed with farm labor, etc.
Itemized component costs	Text (250)	digester, biogas utilization system, etc.

Fieldname	Data Type	Description
Biogas production	Text (50)	cuft per day of biogas production and how measured and what period
Methane portion of biogas	Single	percent of biogas that is methane
CO2 portion of biogas	Single	percent of biogas that is CO2
H2SO4 portion of biogas	Single	percent of biogas that is hydrogen sulfide
Electricity generated	Text (50)	kWh of elec generated and how measured and what period
Primary heat generated	Text (50)	if heat is primary output, amount of heat and how measured and what period
Waste heat generated	Text (50)	if CHP amount of heat recovered and how measured and what period
History or summary of operations	Memo	owner descrip of constructing, contracting, startup, operation, innovations, ideas...
Comments	Memo	Likes, dislikes, what would do differently?
Protocol adherent	Text (50)	do the following measurements adhere to the protocol yes, no, partial
Data dates or periods	Text (150)	what are the time periods for data on operations or measurements?
Data sources	Memo	documents, people or other data sources
mt combined fdstks or farm only	Text (50)	(mt=measurement) either "combined" feedstocks or "farm" only for influent measurements
mt Volume in M3 per cow day	Single	cubic meters of manure produced per cow per day
mt TS in kg per cow day	Single	total solids in kilograms per cow per day
mt TVS in kg per cow day	Single	total volatile solids in kilograms per cow per day
mt FS in kg per cow day	Single	fixed solids in kilograms per cow per day
mt COD in kg per cow day	Single	chemical oxygen demand in kg per cow per day
mt TKN in kg per cow day	Single	total Kjeldahl nitrogen in kilograms per cow per day
mt TP in kg per cow day	Single	total phosphorus in kilograms per cow per day
mt percent TS in influent	Single	concentration of TS in influent (percentage)
mt percent TVS in influent	Single	concentration of TVS in influent (percentage)
mt percent FS in influent	Single	concentration of FS in influent (percentage)
mt percent COD in influent	Single	concentration of COD in influent (percentage)
mt percent TKN in influent	Single	concentration of TKN in influent (percentage)
mt percent TP in influent	Single	concentration of TP in infuent (percentage)
Fdstk 1 type and source	Text (50)	what is added and where did it come from
Fdstk 1 dates or freq of addition	Text (50)	dates or frequency of addition for this feedstock

Fieldname	Data Type	Description
Fdstk 1 volume added daily avg	Single	average daily volume added in gallons
Fdstk 1 TS mg per kg	Single	average daily mg total solids/kg of feedstock
Fdstk 1 TVS mg per kg	Single	average daily mg total volatile solids/kg feedstock
Fdstk 1 COD mg per kg	Single	average daily mg chemical oxygen demand/kg feedstock
Fdstk 1 TVA mg per kg	Single	average daily mg total volatile acids/kg feedstock
Fdstk 1 pH	Single	average daily ph of feedstock added
Fdstk 2 type and source	Text (50)	what is added and where did it come from
Fdstk 2 dates or freq of addition	Text (50)	dates or frequency of addition for this feedstock
Fdstk 2 volume added daily avg	Single	average daily volume added in gallons
Fdstk 2 TS mg per kg	Single	average daily mg total solids/kg of feedstock
Fdstk 2 TVS mg per kg	Single	average daily mg total volatile solids/kg feedstock
Fdstk 2 COD mg per kg	Single	average daily mg chemical oxygen demand/kg feedstock
Fdstk 2 TVA mg per kg	Single	average daily mg total volatile acids/kg feedstock
Fdstk 2 pH	Single	average daily ph of feedstock added
mt reduction in TS	Single	percent of total solids reduced
mt reduction in TVS	Single	percent of total volatile solids reduced
mt reduction in FS	Single	percent of fixed solids reduced
mt reduction in COD	Single	percent of chemical oxygen demand reduced
mt reduction in soluble COD	Single	percent of soluble COD reduced
mt reduction in TVA	Single	percent of total volatile acids reduced
mt reduction in TKN	Single	percent of total Kjeldahl nitrogen reduced
mt reduction in TP	Single	percent of total phosphorus reduced
mt reduction in fecal coliform	Single	Log 10 measure of reduction in fecal coliform bacteria
mt reduction in fecal streptococcus	Single	Log 10 measure of reduction in fecal streptococcus bacteria
mt reduction in avium paratuberculosis	Single	Log 10 measure of reduction in avium paratuberculosis
% red f coli	Single	percentage reduction in fecal coliform bacteria
% red f strep	Single	percentage reduction in fecal streptococcus
% red MAP	Single	percentage reduction in avium paratuberculosis (MAP)
mt biogas avg percent methane	Single	average percent methane in the biogas
mt biogas avg percent CO2	Single	average percent carbon dioxide in the biogas
mt biogas avg percent H2S	Single	average percent hydrogen sulfide in biogas

Fieldname	Data Type	Description
mt biogas produced in M3 per cow day	Single	cubic meters of biogas produced per cow per day
mt methane produced in M3 per cow day	Single	cubic meters of methane produced per cow per day
mt biogas in M3 per kg TVS added	Single	cubic meters of biogas produced per kg of total volatile solids added
mt biogas in M3 per kg TVS destroyed	Single	cubic meters of biogas produced per kg of total volatile solids destroyed
mt methane in M3 per kg TVS added	Single	cubic meters of methane produced per kg of total volatile solids added
mt methane in M3 per kg TVS destroyed	Single	cubic meters of methane produced per kg of total volatile solids destroyed
mt methane in M3 per kg COD destroyed	Single	cubic meters of methane produced per kg of chemical oxygen demand destroyed
measurements details	Memo	time periods measurements were taken and other relevant details
Qualifications	Memo	caveats comments and additional thoughts and qualifications
Cost of digester	Long	overall cost of the digester system alone
Descrip of dig subparts and costs	Text (150)	breakdown of digester parts and costs (structure, engineering, pumps)
Cost of biogas utilization	Long	overall cost of prime mover(s) using biogas
Descrip of BU subparts and costs	Text (150)	breakdown of biogas utilization components costs
Cost of solids separation	Long	overall cost of solids separation operation
Descrip of SS subparts and costs	Text (150)	breakdown of solids separation components and costs
Cost of liquid storage	Long	overall cost of liquid storage (lagoon)
Descrip of LS subparts and cost	Text (150)	breakdown of liquid storage cost items
Annual projected capital costs	Long	use annual cash flow approach, lending rate applied to turnkey cost over 20 (or 10) year useful life
Annual O&M	Long	assume 3% of turnkey cost
Other annual costs	Long	misc costs
Annual revenue	Long	from digester and energy generation and sales including heating fuel avoided

APPENDIX B – FARM SYSTEM REPORTS GENERATED FROM THE DATABASE

Farm basic information list

Farm name	State	Type	Protocol adherent	OD Avg total animals feeding digester	Type of digester	Year installed
AA Dairy	NY	dairy	yes	600	plug-flow	1998
Castelanelli Brothers Dairy	CA	dairy	partial	2850	covered lagoon	2004
Colorado Pork, LLC	CO	swine	partial	6200 (sows and gilts)	complete mix, intermittent	1999
Deere Ridge Dairy aka Gordondale Farms	WI	dairy	yes	850 (milking)	mixed plug-flow	2001
Green Valley Dairy	WI	dairy	partial	2500	complete mix	2006
New Hope View Farm aka DDI	NY	dairy	partial	962	plug-flow	2001
Ridgeline Farm (formerly Matlink)	NY	dairy	yes	525	complete mix	2000
Suring Community Dairy	WI	dairy	partial	950	complete mix	2005

Individual Farm Reports

Farm and Digester Information

Farm name	Locality	County	State
AA Dairy	Candor	Tioga	NY

Type of operation	OD Dairy avg milking herd size	Other numbers and types of animals	Year operational
dairy			1998

DA no of animals
1034

Type of collection system
scrape then pumped

Type of digester	System designer	Digester HRT	Digester temperature
plug-flow	RCM Digesters, Inc.	24	95 deg F

Biogas utilization
electricity and heat

Type of prime mover
engine generator set, diesel engine modified for biogas by addition of spark ignition

Elec gen manuf-model-cap
Caterpillar 3306 130 kW capacity

Protocol and Feedstocks

Protocol adherent	Combined fdstks or farm only	Percent TS in influent	Percent TVS in influent
yes	farm	11.15%	9.44%

Percent FS in influent	Percent COD in influent	Percent TKN in influent	Percent TP in influent
1.71%	8.90%	0.48%	0.08%

Digestion Properties

Reduction in TS	Reduction in TVS	Reduction in FS	Reduction in COD
25.10%	29.70%	-0.29%	41.90%

Reduction in TVA	Reduction in TKN	Reduction in TP
-------------------------	-------------------------	------------------------

86.10%	0.00%	0.00%
% red f coli:	% red f strep:	% red MAP:
99.90%	99.20%	

Biogas Production

Biogas avg percent methane	Biogas avg percent CO2	Biogas avg percent H2S
59.10%	39.20%	0.19%

Data Details and Qualifications

Measurements details

Measurements taken for Martin and Roos study described in the paper "Comparison of the Performance of a Conventional and a Modified Plug Flow Digester for Scraped Dairy Manure," 2007, measurements were taken from May 2001 through early June 2002

Qualifications

The digester was substantially oversized (planned herd expansion had not yet occurred) resulting in a HRT of 34 days. Expect new data in 2009.

Economics

Cost of digester

189,000

Descrip of dig subparts and costs

manure pump 9,000, engineering design 20,000, concrete digester and components 160,000

Cost of biogas utilization

61,000

Farm and Digester Information

Farm name	Locality	County	State
Castelanelli Brothers Dairy	Lodi	San Joaquin	CA
Type of operation	OD Dairy avg milking herd size	Other numbers and types of animals	Year operational
dairy			2004
DA no of animals			
na			
Type of collection system			
flush, stored effluent for flushing, gravity sand settling basin, lift station pump, wire screen			
Type of digester	System designer	Digester HRT	Digester temperature
covered lagoon	RCM Digesters, Inc.	40	some excess heat added,

Biogas utilization

electricity and heat, excess flared

Type of prime mover

internal combustion engine and generator set, diesel engine modified with spark ignition for biogas use

Elec gen manuf-model-cap

Caterpillar 3406TA 180 kW

Protocol and Feedstocks

Protocol adherent	Combined fdstks or farm only	Percent TS in influent	Percent TVS in influent
partial	farm	1.18%	0.62%
Percent FS in influent	Percent COD in influent	Percent TKN in influent	Percent TP in influent
0.55%	1.08%	0.12%	0.01%

Digestion Properties

Reduction in TS	Reduction in TVS	Reduction in FS	Reduction in COD
67.10%	62.40%	77.60%	59.70%
Reduction in TVA	Reduction in TKN	Reduction in TP	
100.00%	53.30%	24.80%	

% red f coli:	% red f strep:	% red MAP:
91.49%	72.46%	

Biogas Production

Biogas avg percent methane	Biogas avg percent CO2	Biogas avg percent H2S
70.00%	30.00%	0.00%

Data Details and Qualifications

Measurements details

Measurements taken from Martin J, "An Evaluation of a Covered Anaerobic Lagoon for Flushed Dairy Cattle Manure Stabilization and Biogas Production," June 17, 2008 (revised), produced for AgSTAR, US EPA.

Qualifications

Not protocol compliant due to missing herd size and influent volume data. There were problems with monthly herd size numbers and amounts of manure flushed to the digester, so per cow measures of performance are sketchy. Study assumed 75% is fed to digester. Reduction estimates for digestion efficiency were estimated by subtracting mean flushwater constituents. Digester releases some methane to atmo during hottest months to avoid damage, that volume is unmeasured.

Economics

Cost of digester

0

Descrip of dig subparts and costs

total \$882,136, itemized costs not available (incl BU)

Cost of biogas utilization

0

Farm and Digester Information

Farm name	Locality	County	State
Colorado Pork, LLC	Lamar	Prowers	CO

Type of operation	OD Dairy avg milking herd size	Other numbers and types of animals	Year operational
swine			1999

DA no of animals

na

Type of collection system

pull plug pits under slatted floors

Type of digester	System designer	Digester HRT	Digester temperature
complete mix, intermittent	RCM Digesters, Inc.	40 (est)	95 deg F

Biogas utilization

electricity and heat

Type of prime mover

engine generator set

Elec gen manuf-model-cap

80 kW engine generator set

Protocol and Feedstocks

Protocol adherent	Combined fdstks or farm only	Percent TS in influent	Percent TVS in influent
partial	farm	4.72%	3.86%

Percent FS in influent	Percent COD in influent	Percent TKN in influent	Percent TP in influent
1.65%	6.14%	0.45%	0.10%

Digestion Properties

Reduction in TS	Reduction in TVS	Reduction in FS	Reduction in COD
55.15%	63.98%	38.57%	67.56%

Reduction in TVA	Reduction in TKN	Reduction in TP
91.51%	5.06%	47.51%

% red f coli: **% red f strep:** **% red MAP:**
99.98%

Biogas Production

Biogas avg percent methane	Biogas avg percent CO2	Biogas avg percent H2S
67.90%	32.10%	0.00%

Data Details and Qualifications

Measurements details

Measurements data taken from Martin J, "An Assessment of the Performance of the Colorado Pork, LLC. Anaerobic Digestion and Biogas Utilization System," March 18, 2003. Prepared for AgSTAR, US EPA. Measurement period from April 2000 to April 2001.

Qualifications

Not protocol compliant due to lack of steady state, missing biogas data. Electricity data is low because no intertie to utility during measurement period, only produced what farm could use. Total biogas volume measure not available because only gas to engine measured. Frequent engine and electrical failures during measurement period (out of service 32 days in 12 months) - elec gen, . Solids reductions overestimated due to "significant"solids settling and accumulation in the reactor. Not really a complete mix system - only mixed for 30-45 min/day. Hydraulic loading rate declined significantly over period of study due to improving water conservation measures. Therefore, this assessment should be considered to be under "quasi-steady-state"

conditions.

Economics

Cost of digester

248,000

Descrip of dig subparts and costs

soil tst 13900, dig and equip 191200, engrng 38900, startup 4000,

Cost of biogas utilization

120,000

Farm and Digester Information

Farm name	Locality	County	State
Deere Ridge Dairy aka Gordondale Farms	Nelsonville	Portage	WI

Type of operation	OD Dairy avg milking herd size	Other numbers and types of animals	Year operational
dairy		na	2002

DA no of animals

750

Type of collection system

scrape

Type of digester	System designer	Digester HRT	Digester temperature
mixed plug-flow	GHD, Inc.	22 days	mesophilic, 100deg

Biogas utilization

electricity and heat

Type of prime mover

engine generator set

Elec gen manuf-model-cap

Caterpillar 140kW per GHD, 150 per LK

Protocol and Feedstocks

Protocol adherent	Combined fdstks or farm only	Percent TS in influent	Percent TVS in influent
yes	farm	8.81%	6.72%

Percent FS in influent	Percent COD in influent	Percent TKN in influent	Percent TP in influent
2.09%	6.99%	0.35%	0.08%

Digestion Properties

Reduction in TS	Reduction in TVS	Reduction in FS	Reduction in COD
35.40%	39.60%	31.10%	38.50%

Reduction in TVA	Reduction in TKN	Reduction in TP
87.80%	0.00%	0.00%

% red f coli:	% red f strep:	% red MAP:
99.50%	94.99%	

Biogas Production

Biogas avg percent methane	Biogas avg percent CO2	Biogas avg percent H2S
55.90%	43.80%	0.31%

Data Details and Qualifications

Measurements details

Measurements taken for Martin and Roos study described in the paper "Comparison of the Performance of a Conventional and a Modified Plug Flow Digester for Scraped Dairy Manure," 2007, meas period Jan - Dec 2004, also econ info from Martin 2005.

Qualifications

Herd size increased from 750 to 860 during the 7th month of the study. High measured reduction in FS is theorized to be soil from unpaved alleyways in barn settling in the digester.

Economics

Cost of digester

650,000

Descrip of dig subparts and costs

costs of dig comps not avail, 650k is turnkey cost, farm labor during constr reduced cost to farm to 550k, O&M estimated at 3% of dig and BU costs

Cost of biogas utilization

198,000

Farm and Digester Information

Farm name	Locality	County	State
Green Valley Dairy	Green Valley	Shawano	WI
Type of operation	OD Dairy avg milking herd size	Other numbers and types of animals	Year operational
dairy			2007
DA no of animals			
2500			
Type of collection system			
scrape with skid steer			
Type of digester	System designer	Digester HRT	Digester temperature
complete mix	Biogas Nord, Biogas Direct	22 days	mesophilic, 102 deg F
Biogas utilization			
electricity and heat			
Type of prime mover			
engine generator set			
Elec gen manuf-model-cap			
Caterpillar 600kW model 3512, ordered a second engine			

Protocol and Feedstocks

Protocol adherent	Combined fdstks or farm only	Percent TS in influent	Percent TVS in influent
partial	farm	7.26%	6.20%
Percent FS in influent	Percent COD in influent	Percent TKN in influent	Percent TP in influent
1.06%	5.27%	0.28%	0.04%

Digestion Properties

Reduction in TS	Reduction in TVS	Reduction in FS	Reduction in COD
32.16%	36.96%	3.94%	38.73%
Reduction in TVA	Reduction in TKN	Reduction in TP	
85.16%	7.41%	18.21%	

% red f coli:	% red f strep:	% red MAP:
98.51%	92.98%	

Biogas Production

Biogas avg percent methane

Biogas avg percent CO2

Biogas avg percent H2S

Data Details and Qualifications

Measurements details

Measurement data is drawn from Baldwin A and Katers J, "Performance Analysis of Anaerobic Digestion Systems at Two Dairy Farms in Northeastern Wisconsin," funded by Focus on Energy, 2009.

Qualifications

Not protocol compliant due to <12 mo. monitoring, missed sampling dates, influent volume uncertainties, total biogas not measured, several missing temp measurements. Only one meas of biogas composition taken - therefore not valid for drawing conclusions. Measurement period was 10 months (and 3 scheduled sampling dates were not workable due to site problems). Total volume of influent is estimated at roughly 80000 gpd. This affects several other measures of "total" components in influent and is therefore not included in protocol measurements. Several digester temperature measurements are missing due to equipment failure. Only gas to the engine is measured and flared or vented amounts are unknown.

Economics

Cost of digester

Descrip of dig subparts and costs

Cost of biogas utilization

Farm and Digester Information

Farm name	Locality	County	State
New Hope View Farm aka DDI	Homer	Cortland	NY

Type of operation	OD Dairy avg milking herd size	Other numbers and types of animals	Year operational
dairy			

DA no of animals

na

Type of collection system

scrape

Type of digester	System designer	Digester HRT	Digester temperature
plug-flow	RCM Digesters, Inc.	20	100 deg F

Biogas utilization

heat, electricity

Type of prime mover

biogas boiler, low Btu microturbine (not used during measurement period)

Elec gen manuf-model-cap

70kW Ingersoll Rand microturbine

Protocol and Feedstocks

Protocol adherent	Combined fdstks or farm only	Percent TS in influent	Percent TVS in influent
partial	farm	9.81%	8.21%

Percent FS in influent	Percent COD in influent	Percent TKN in influent	Percent TP in influent
1.60%	10.35%	0.37%	0.06%

Digestion Properties

Reduction in TS	Reduction in TVS	Reduction in FS	Reduction in COD
26.20%	29.30%	10.29%	14.70%

Reduction in TVA	Reduction in TKN	Reduction in TP
55.00%	-1.00%	0.90%

% red f coli:	% red f strep:	% red MAP:
99.70%		99.10%

Biogas Production

Biogas avg percent methane	Biogas avg percent CO2	Biogas avg percent H2S
64.00%	36.00%	0.00%

Data Details and Qualifications

Measurements details

Measurements taken from Gooch C, Inglis S and Wright P, "Biogas Distributed Generation Systems Evaluation and Technology Transfer: NYSERDA Project No. 6597 - Interim Report for May 2001 to May 2006," Cornell University, April 15, 2007.

Qualifications

Not protocol compliant due to missing biogas data. CO2 measurements taken, CH4 estimated assumes H2S near 0, influent concentrations from Cornell studies, kg/cow/day calculated based on 10mg/liter = 1% concentration. Not all biogas is metered, amount metered (used in boiler) is estimated to be less than half of that produced. For this reason, biogas volumes are not included. Data given is partially compliant with protocol. Expect new data in 2009.

Economics

Cost of digester

442,200

Descrip of dig subparts and costs

itemized costs for digester not available

Cost of biogas utilization

138,200

Farm and Digester Information

Farm name	Locality	County	State
Ridgeline Farm (formerly Matlink)	Clymer	Chautauqua	NY

Type of operation	OD Dairy avg milking herd size	Other numbers and types of animals	Year operational
dairy			2001

DA no of animals

na

Type of collection system

scrape to gravity flow to reception pit, pumped into digester

Type of digester	System designer	Digester HRT	Digester temperature
complete mix	RCM Digesters, Inc.	20	100 deg F

Biogas utilization

boiler, food dryer, electricity

Type of prime mover

engine generator set

Elec gen manuf-model-cap

Waukesha engine with 145kW generator (130kW biogas rating?)

Protocol and Feedstocks

Protocol adherent	Combined fdstks or farm only	Percent TS in influent	Percent TVS in influent
partial	combined	15.50%	14.30%

Percent FS in influent	Percent COD in influent	Percent TKN in influent	Percent TP in influent
	20.00%	0.34%	0.57%

Digestion Properties

Reduction in TS	Reduction in TVS	Reduction in FS	Reduction in COD
63.90%	69.60%	-0.05%	68.60%

Reduction in TVA	Reduction in TKN	Reduction in TP
87.10%	-2.80%	-3.60%

% red f coli:	% red f strep:	% red MAP:
98.40%		94.80%

Biogas Production

Biogas avg percent methane	Biogas avg percent CO2	Biogas avg percent H2S
68.50%	31.50%	0.00%

Data Details and Qualifications

Measurements details

Measurements taken from Gooch C, Inglis S and Wright P, "Biogas Distributed Generation Systems Evaluation and Technology Transfer: NYSERDA Project No. 6597 - Interim Report for May 2001 to May 2006," Cornell University, April 15, 2007.

Qualifications

Influent concentrations from Cornell studies, kg/cow/day calculated based on 10,000mg/liter = 1% concentration. High biogas production due to high energy off farm wastes being added. Other measures will appear unusual due to addition of off farm wastes. Expect new data in 2009-10.

Economics

Cost of digester

337,000

Descrip of dig subparts and costs

digester construction and materials = 260000, mix pumps = 77000

Cost of biogas utilization

128,931

Farm and Digester Information

Farm name	Locality	County	State
Suring Community Dairy	Suring	Oconto	WI
Type of operation	OD Dairy avg milking herd size	Other numbers and types of animals	Year operational
dairy			2006
DA no of animals			
1000			
Type of collection system			
scrape			
Type of digester	System designer	Digester HRT	Digester temperature
complete mix	American Biogas Co., Inc.	28 days	mesophilic, 100 deg F
Biogas utilization			
electricity and gas			
Type of prime mover			
engine generator set, 250kW per LK			
Elec gen manuf-model-cap			
Dreyer & Bosse 250 kW (230 net), engine is dual fuel using 20% diesel			

Protocol and Feedstocks

Protocol adherent	Combined fdstks or farm only	Percent TS in influent	Percent TVS in influent
partial	farm	7.79%	6.44%
Percent FS in influent	Percent COD in influent	Percent TKN in influent	Percent TP in influent
1.35%	5.39%	0.35%	0.04%

Digestion Properties

Reduction in TS	Reduction in TVS	Reduction in FS	Reduction in COD
30.81%	35.33%	9.21%	26.71%
Reduction in TVA	Reduction in TKN	Reduction in TP	
72.35%	-2.98%	13.65%	

% red f coli:	% red f strep:	% red MAP:
98.07%	92.38%	

Biogas Production

Biogas avg percent methane

Biogas avg percent CO2

Biogas avg percent H2S

55.70%

Data Details and Qualifications

Measurements details

Measurement data is drawn from Baldwin A and Katers J, "Performance Analysis of Anaerobic Digestion Systems at Two Dairy Farms in Northeastern Wisconsin," funded by Focus on Energy, 2009.

Qualifications

Not protocol compliant due to <12 mo. monitoring, uncertain influent volumes, biogas TVS and COD measures not synchronized, electric production includes use of diesel fuel, not all biogas measured. Total volume of influent based on estimates of farm employee, not based on measurement. Because this affects several other measures including "total" components in influent, these measures are excluded from evaluation analyses. Owners estimate about 2% of biogas produced is lost through pressure relief valves and not measured. Engine gen set was fueled with both biogas and diesel, and run only during peak demand hours. Biogas production per day is estimated based on consumption when engine was running. Biogas, TVS and COD measures do not necessarily occur in the same time periods due to engine down times. Average digester temperature was below design specifications throughout.

Economics

Cost of digester

Descrip of dig subparts and costs

Cost of biogas utilization

Influent characterization percentages

Farm name	mt Volume influent in M3 per cow day	mt combined fdstks or farm only	mt percent TS in influent	mt percent TVS in influent	mt percent FS in influent	mt percent COD in influent	mt percent TKN in influent	mt percent TP in influent
AA Dairy	0.059	farm	11.15%	9.44%	1.71%	8.90%	0.48%	0.08%
Castelanelli Brothers Dairy	0.8566985	farm	1.18%	0.62%	0.55%	1.08%	0.12%	0.01%
Colorado Pork, LLC	0	farm	4.72%	3.86%	1.65%	6.14%	0.45%	0.10%
Deere Ridge Dairy aka Gordondale Farms	0.086	farm	8.81%	6.72%	2.09%	6.99%	0.35%	0.08%
Green Valley Dairy		farm	7.26%	6.20%	1.06%	5.27%	0.28%	0.04%
New Hope View Farm aka DDI	0.086477	farm	9.81%	8.21%	1.60%	10.35%	0.37%	0.06%
Ridgeline Farm (formerly Matlink)	.07908965	combined	15.50%	14.30%		20.00%	0.34%	0.57%
Suring Community Dairy	0.084	farm	7.79%	6.44%	1.35%	5.39%	0.35%	0.04%

Notes:

1. "MT" in the column header signifies a measured data field.
2. Numbers given are averages over the period of time measurements were taken.
3. Farms including off farm food wastes will have significantly higher levels of several components.

Waste stabilization

Farm name	mt combined fdstks or farm only	mt reduction in TS	mt reduction in TVS	mt reduction in FS	mt reduction in COD	mt reduction in soluble COD	mt reduction in TVA	mt reduction in TKN	mt reduction in TP	% red f coli:	% red f strep:	% red MAP:
AA Dairy	farm	25.10%	29.70%	-0.29%	41.90%	30.00%	86.10%	0.00%	0.00%	99.90%		99.20%
Castelanelli Brothers Dairy	farm	67.10%	62.40%	77.60%	59.70%		100.00%	53.30%	24.80%	91.49%	72.46%	
Colorado Pork, LLC	farm	55.15%	63.98%	38.57%	67.56%	0.00%	91.51%	5.06%	47.51%	99.98%		
Deere Ridge Dairy aka Gordondale Farms	farm	35.40%	39.60%	31.10%	38.50%	58.80%	87.80%	0.00%	0.00%	99.50%	94.99%	
Green Valley Dairy	farm	32.16%	36.96%	3.94%	38.73%	49.05%	85.16%	7.41%	18.21%	98.51%	92.98%	
New Hope View Farm aka DD1	farm	26.20%	29.30%	10.29%	14.70%	22.30%	55.00%	-1.00%	0.90%	99.70%		99.10%
Ridgeline Farm (fmrlly Matlink)	combined	63.90%	69.60%	-0.05%	68.60%	66.10%	87.10%	-2.80%	-3.60%	98.40%		94.80%
Suring Community Dairy	farm	30.81%	35.33%	9.21%	26.71%	37.98%	72.35%	-2.98%	13.65%	98.07%	92.38%	

Notes:

1. "MT" in the column header signifies a measured data field.
2. Reductions in FS (fixed solids) likely signify settling of solids in the digester which may exaggerate digestion efficiency.
3. Herd sizes substantially above or below system design capacity will create shorter or longer hydraulic retention times resulting in lower or higher percentages of digestable substances converted than an equivalent system operating at design capacity.
4. Systems receiving substantial readily digestable feedstocks such as food processing wastes will likely show larger percentage reductions of digestable materials and higher biogas outputs than systems digesting manure alone.
5. Reductions in indicator organisms are either specific percentages from reports, or calculated if no specific percentage is given.

Biogas prod and composition

Farm name	Biogas utilization	mt combined fdstks or farm only	mt biogas avg percent methane	mt biogas avg percent CO2	mt biogas avg percent H2S	mt biogas produced in M3 per cow day	mt methane produced in M3 per cow day	mt biogas in M3 per kg TVS added	mt biogas in M3 per kg TVS destroyed	mt methane in M3 per kg TVS added	mt methane in M3 per kg TVS destroyed	mt methane in M3 per kg COD destroyed
AA Dairy	electricity and heat	farm	59.10%	39.20%	0.19%	2.21	1.3	0.39	1.3	0.23	0.77	0.34
Castelanelli Brothers Dairy	electricity and heat, excess flared	farm	70.00%	30.00%	0.00%							
Colorado Pork, LLC	electricity and heat	farm	67.90%	32.10%	0.00%							
Deere Ridge Dairy aka Gordondale Farms	electricity and heat	farm	55.90%	43.80%	0.31%	3.08	1.72	0.56	1.36	0.3	0.76	0.74
Green Valley Dairy	electricity and heat	farm				2.82		0.38	1.02			
New Hope View Farm aka DDI	heat, electricity	farm	64.00%	36.00%	0.00%	0.65	0.42					
Ridgeline Farm (formerly Matlink)	boiler, food dryer, electricity	combined	68.50%	31.50%	0.00%	7	4.79					
Suring Community Dairy	electricity and gas	farm	55.70%			2.11	1.17	0.39	1.1	0.22	0.61	0.97

Notes:

1. "MT" in the column header signifies a measured data field.
2. Empty cells and 0 indicate no data available.
3. Systems receiving substantial readily digestible feedstocks such as food processing wastes will likely show larger percentage reductions of digestible materials and higher biogas outputs than systems digesting manure alone.

Economic info

Farm name	Cost of digester	Descrip of dig subparts and costs	Cost of biogas utilization	Descrip of BU subparts and costs	Cost of solids separation	Descrip of SS subparts and costs	Cost of liquid storage	Descrip of LS subparts and cost	Annual projected capital costs	Annual O&M	Other annual costs	Annual revenue
AA Dairy	189000	manure pump 9,000, engineering design, 20,000, concrete digester, and components 160,000,	61000	engine genset 15,000, (used), rebuild 11,000, plumb/elec/mech sys, 9,000, cable to util hookup 8,000, elec eng consultant 18,000	53000	effl pump 3,000, separation equip 25,000, building, 25,000	60000	lagoon 18,000, plastic liner 42,000				
Castelanelli Brothers Dairy		total \$882,136, itemized costs not available (incl BU)								22842		
Colorado Pork, LLC	248000	soil tst 13900, dig and equip 191200, engrng 38900, startup 4000,	120000	eng gen set 67000, elec and intertie 17600, bldg piping etc 35400						5459		
Deere Ridge Dairy aka Gordondale Farms	650000	costs of dig comps not avail, 650k is turnkey cost, farm labor during constr reduced cost to farm to 550k, O&M estimated at 3% of dig and BU costs	198000	160000 - engine gen set, 38000 install, labor and materials (owned by utility)						25440		
Green Valley Dairy												
New Hope View Farm aka DDI	442200	itemized costs for digester not available	138200	biogas boiler, 2 30kW low Btu Capstone Microturbines, cost split unknown	89000	separator 46613, building 42387	315000		52978		26339	60400
Ridgeline Farm (formerly Matlink)	337000	digester construction and materials = 260000, mix pumps = 77000	128931	engine genset = 96317, switching equip = 10000, engine bldg = 22614	61689	separator = 46613, separator bldg = 15076	45000	other costs listed = 56900	61232			
Suring Community Dairy												

Note: Cost data may not be uniformly gathered and defined. Empty fields mean the data is not available.

Data qualifications

Farm name	Measurements details	Qualifications
AA Dairy	Measurements taken for Martin and Roos study described in the paper "Comparison of the Performance of a Conventional and a Modified Plug Flow Digester for Scraped Dairy Manure," 2007, measurements were taken from May 2001 through early June 2002	The digester was substantially oversized (planned herd expansion had not yet occurred) resulting in a HRT of 34 days. Expect new data in 2009.
Castelanelli Brothers Dairy	Measurements taken from Martin J, "An Evaluation of a Covered Anaerobic Lagoon for Flushed Dairy Cattle Manure Stabilization and Biogas Production," June 17, 2008 (revised), produced for AgSTAR, US EPA.	Not protocol compliant due to missing herd size and influent volume data. There were problems with monthly herd size numbers and amounts of manure flushed to the digester, so per cow measures of performance are sketchy. Study assumed 75% is fed to digester. Reduction estimates for digestion efficiency were estimated by subtracting mean flushwater constituents. Digester releases some methane to atmo during hottest months to avoid damage, that volume is unmeasured.
Colorado Pork, LLC	Measurements data taken from Martin J, "An Assessment of the Performance of the Colorado Pork, LLC. Anaerobic Digestion and Biogas Utilization System," March 18, 2003. Prepared for AgSTAR, US EPA. Measurement period from April 2000 to April 2001.	Not protocol compliant due to lack of steady state, missing biogas data. Electricity data is low because no intertie to utility during measurement period, only produced what farm could use. Total biogas volume measure not available because only gas to engine measured. Frequent engine and electrical failures during measurement period (out of service 32 days in 12 months) - elec gen, . Solids reductions overestimated due to "significant"solids settling and accumulation in the reactor. Not really a complete mix system - only mixed for 30-45 min/day. Hydraulic loading rate declined significantly over period of study due to improving water conservation measures. Therefore, this assessment should be considered to be under "quasi-steady-state" conditions.
Deere Ridge Dairy aka Gordondale Farms	Measurements taken for Martin and Roos study described in the paper "Comparison of the Performance of a Conventional and a Modified Plug Flow Digester for Scraped Dairy Manure," 2007, meas period Jan - Dec 2004, also econ info from Martin 2005.	Herd size increased from 750 to 860 during the 7th month of the study. High measured reduction in FS is theorized to be soil from unpaved alleyways in barn settling in the digester.

Farm name	Measurements details	Qualifications
Green Valley Dairy	Measurement data is drawn from Baldwin A and Katers J, "Performance Analysis of Anaerobic Digestion Systems at Two Dairy Farms in Northeastern Wisconsin," funded by Focus on Energy, 2009.	Not protocol compliant due to <12 mo. monitoring, missed sampling dates, influent volume uncertainties, total biogas not measured, several missing temp measurements. Only one meas of biogas composition taken - therefore not valid for drawing conclusions. Measurement period was 10 months (and 3 scheduled sampling dates were not workable due to site problems). Total volume of influent is estimated at roughly 80000 gpd. This affects several other measures of "total" components in influent and is therefore not included in protocol measurements. Several digester temperature measurements are missing due to equipment failure. Only gas to the engine is measured and flared or vented amounts are unknown.
New Hope View Farm aka DDI	Measurements taken from Gooch C, Inglis S and Wright P, "Biogas Distributed Generation Systems Evaluation and Technology Transfer: NYSERDA Project No. 6597 - Interim Report for May 2001 to May 2006," Cornell University, April 15, 2007.	Not protocol compliant due to missing biogas data. CO2 measurements taken, CH4 estimated assumes H2S near 0, influent concentrations from Cornell studies, kg/cow/day calculated based on 10mg/liter = 1% concentration. Not all biogas is metered, amount metered (used in boiler) is estimated to be less than half of that produced. For this reason, biogas volumes are not included. Data given is partially compliant with protocol. Expect new data in 2009.
Ridgeline Farm (formerly Matlink)	Measurements taken from Gooch C, Inglis S and Wright P, "Biogas Distributed Generation Systems Evaluation and Technology Transfer: NYSERDA Project No. 6597 - Interim Report for May 2001 to May 2006," Cornell University, April 15, 2007.	Influent concentrations from Cornell studies, kg/cow/day calculated based on 10,000mg/liter = 1% concentration. High biogas production due to high energy off farm wastes being added. Other measures will appear unusual due to addition of off farm wastes. Expect new data in 2009-10.

Farm name	Measurements details	Qualifications
Suring Community Dairy	Measurement data is drawn from Baldwin A and Katers J, "Performance Analysis of Anaerobic Digestion Systems at Two Dairy Farms in Northeastern Wisconsin," funded by Focus on Energy, 2009.	Not protocol compliant due to <12 mo. monitoring, uncertain influent volumes, biogas TVS and COD measures not synchronized, electric production includes use of diesel fuel, not all biogas measured. Total volume of influent based on estimates of farm employee, not based on measurement. Because this affects several other measures including "total" components in influent, these measures are excluded from evaluation analyses. Owners estimate about 2% of biogas produced is lost through pressure relief valves and not measured. Engine gen set was fueled with both biogas and diesel, and run only during peak demand hours. Biogas production per day is estimated based on consumption when engine was running. Biogas, TVS and COD measures do not necessarily occur in the same time periods due to engine down times. Average digester temperature was below design specifications throughout.