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Anaerobic Digestion for Energy and Pollution Control

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Abstract. Anaerobic digestion is again being taken seriously because of increasing concerns about the environmental hazards of manure. The push to produce more renewable energy locally to reduce dependence on fossil fuels has also had an effect. A well running plug-flow digester on the Haubenschild dairy in Princeton, Minnesota has provided two continuous years of electrical energy production and operational data. Air pollution control and energy production coupled with the nutrient utilization are the reasons the digester project was installed at Haubenschild Farms. The 900 cows produce enough methane to generate about 2000 kWh per day of electricity, most of which is used on the farm. The remainder is sold as "Green Energy" and marketed to consumers who wish to use electricity generated from renewable sources. The digester is producing at least 30 percent more biogas beyond the design numbers. The dairy also saves $400 per month in heating costs by using waste heat from the generator. The up-time on the generator has been about 95%. This project has shown that a payback of 5 years or less on investment is possible.

Keywords. Anaerobic Digestion, Methane, Odor, Pollution Control, Energy, Biogas

Introduction

Anaerobic digestion as a manure treatment system is again being taken seriously because of increasing concerns about the environmental hazards of manure. Odor and nutrient concerns of neighbors impact the ability of existing animal producers to expand or modernize their operations to remain competitive. The push to produce more renewable energy locally to reduce dependence on fossil fuels has also had an effect. A well running plug-flow digester on Haubenschild Dairy Farm Inc. in Princeton, Minnesota has provided two an a half continuous years of electrical energy production and operational data.

This farm is currently operating a plug flow anaerobic digester coupled with an engine generator for production of electricity with heat as a byproduct. The anaerobic digester was built in 1999 in conjunction with a dairy herd expansion from 200 cows to the current 900 cows. Cows are housed in two naturally ventilated freestall barns. The freestalls have mattresses and the cows are bedded with recycled newsprint. Manure is scraped from the barn three times per day at milking to a 12' x 12' x 240' cross alley collection pit. This manure then flows to a 14' x 14' x 14' reception pit. Approximately 11,000 gallons are pumped from the reception pit twice per day to the plug flow digester. This manure has a solids content of approximately 10%. The digester is an insulated concrete tank (30' x 14' x 130') with a high density polyethylene (HDPE) cover. Manure from the digester flows over a weir and into a 3.2 million gallon HDPE lined manure storage. Manure is pumped from the manure storage throughout the year and surface applied to fields of alfalfa and corn using a 7500 gallon manure tank wagon. A unique part of this successful system is the driving force of the owner, Dennis Haubenschild who has pursued a twenty year dream of installing a digester on his farm. A champion of the system, he has spent innumerable hours lobbying local officials, friends, family and state officials to support the project.

Biogas production

Biogas production from the digester is greater than anticipated. The measured amount flowing through the engine generator (figure 1) is approximately 70,000 cubic feet of biogas per day (approximately 87 ft^3/cow per day). This is 30% above the biogas design figures of 65 ft^3/cow per day. The excess biogas is burned in a flare that operates an estimated 60% of the time. The owner estimates that he is flaring 10-15 ft^3 per minute (20-30% excess) and plans to install a meter in the future to measure the flared gas. Therefore all the figures in this paper are conservative. Biogas production throughout the 2.5 years of operation has been very stable. The biogas is approximately 60% methane and 40% carbon dioxide.

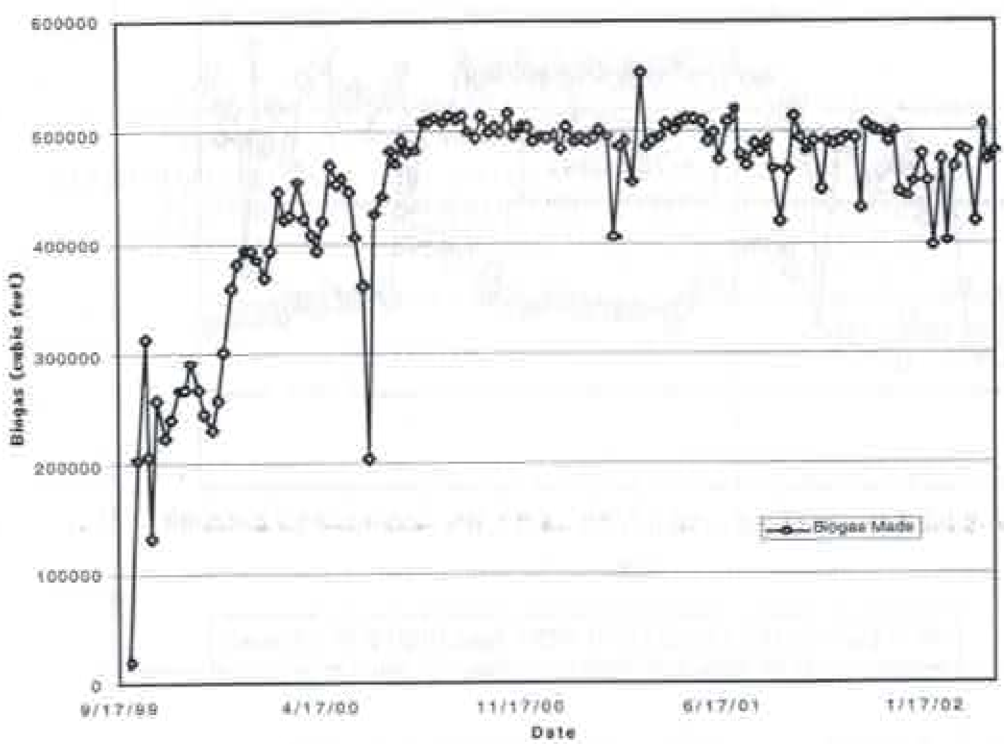

Figure 1. Biogas produced per week that is consumed by the engine generator

Energy production

Methane from the digester is used to power a CAT 3406 engine which drives a 150 kW generator. Heat from the engine is used to heat the anaerobic digester (maintained at 100 degrees F throughout the year). Approximately 2900 kW of energy are generated each day while the dairy operation uses approximately 1500 kW per day. This excess electrical energy is sold back to the local energy cooperative at 7.25 cents per kWh. Figure 2 shows the weekly electrical generation and consumption since operation began. Excess heat is also used to heat the freestall barn floors and the milking parlor.

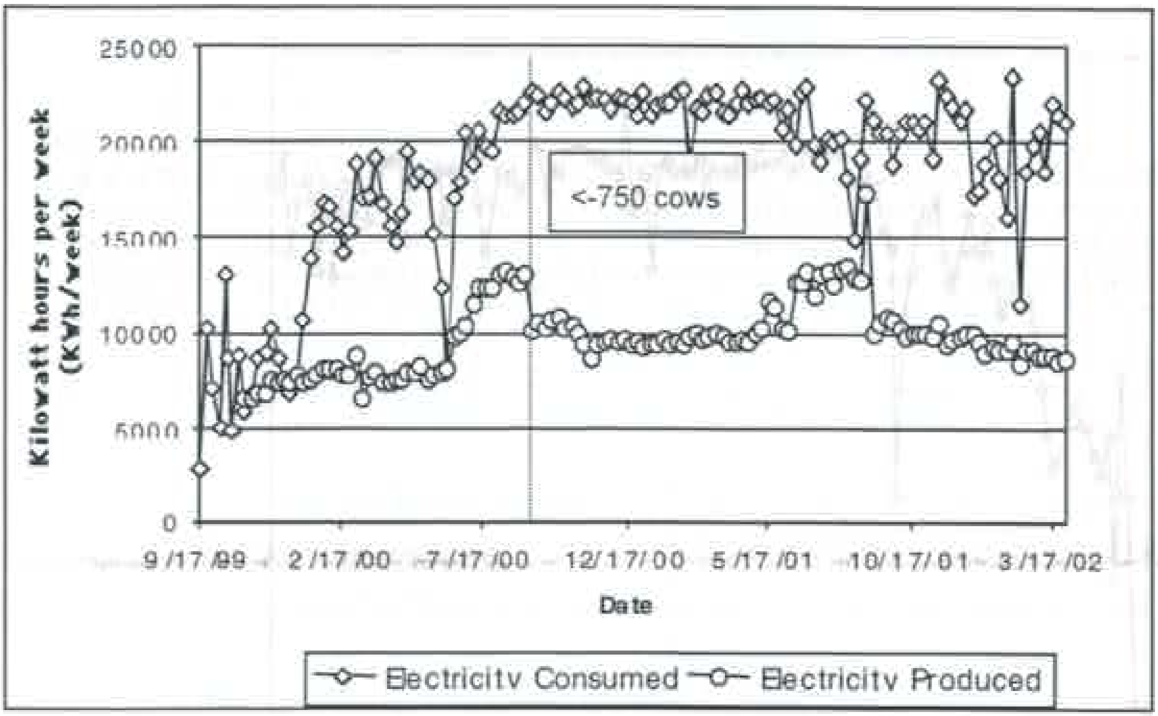

Figure 2. Weekly consumption and generation of electricity

Economic Analysis

Initial investment in the anaerobic digester system was $355,000. Payback on the system at 10% interest and the current energy production/utilization is estimated at 5-7 years. This payback does not include heat energy used in the free stall barn and parlor and the other benefits of odor reduction, weed seed and pathogen reduction, and possible crop response benefits. All of these "other" benefits are currently being researched through a National Resource Conservation Service (NRCS) funded research project conducted by the University of Minnesota.

A comparison of the payback on a ten year mortgage may be of interest. Using the $355,000 cost of the system as a 10 year mortgage, the monthly payment on interest and pricipal would be $4691 on an 10% rate and $4307 at 8% interest. These are easily met by the electricity generated.

Feasibility of Anaerobic Digesters on Minnesota Farms

With the increased need for odor control and the recent attention to potential economic benefits of anaerobic digestion, there is a need to assess the economic feasibility of anaerobic digestion systems. Unfortunately, this economic evaluation is extremely site specific and dependent on a variety of factors. Often by looking solely at the economic benefit of electrical production and sale the economic evaluation is unfavorable for many types and sizes of operation. Other benefits that have the potential to improve this economic picture include the need for odor control, pathogen reduction measures and weed seed reduction. However, it is difficult to assess the economics of these secondary benefits.

The first factor to consider when evaluating the feasibility of an anaerobic digester is the primary goal of the digestion system. If the primary goal is economic odor control then the cost of the digester should be compared to the cost of other technologies to achieve the same odor control. Also, the amount of odor reduction achieved by the different odor control technologies must also be considered. For instance, anaerobic digestion is estimated to reduce odor from the manure storage and during land application by 60-90%. However, anaerobic digestion will not reduce odors coming from the barns or other manure sources. In contrast, a biofilter will remove odors from the barns but not from the manure storage. Therefore, any feasibility study of anaerobic digest must begin with an assessment of the odor sources on the farm and the variety of options available.

In evaluating the economics of anaerobic digestion, several system options must be considered. The most basic anaerobic digestion system is a covered manure storage and methane flare. This system is the most economical because the only cost involved is the cover and flare. However, with this system there are no economic returns. To achieve some return on this covered lagoon investment, some farms have chosen to add a heat recovery system. Instead of flaring the methane captured by the cover, the methane is burned in a boiler and the hot water used for heating buildings. This is a relatively inexpensive option that provides some economic return.

The next level of investment with potential return is to install a complete mix or plug flow digester. This digester increases the amount of methane produced and recovered that can be used in the boiler system. Considerations for this option must include the heat use on the farm. Many facilities (dairy and swine finishing operations) have limited need for additional heat on the farm so the additional benefit of this upgrade must be carefully considered.

The next upgrade in an anaerobic digestion system is to include a engine/generator set to produce electricity. This is a significant investment but also has the potential to generate some economic return with the sale of excess electricity or by offsetting current electrical charges. High energy use (electrical) facilities such as dairies or nursery barns will benefit the most from an upgrade to electricity production.

All of these anaerobic digestion systems result in manure with reduced odor but only those with heated digesters will benefit from the reduced viable weed seed count and reduced pathogens. If these are critical issues, there may be some additional benefit to constructing a digester besides increased methane production and increased heat or electrical output. Current research at the University of Minnesota is assessing these other benefits.

With all the variables to consider when assessing the feasibility of an anaerobic digester it is safest to ask for assistance from someone with experience in the design and construction of these systems. These variables consider current energy consumption and potential energy production and the rate ($/kWh) for the additional electricity produced. Other considerations are the interest rate on the investment and the financial assistance available. A self assessment checklist to determine the feasibility of an anaerobic digester developed for the Minnesota Agricultural Utilization Research Institute can be found at http://www.auri.org/research/digester/diglead.htm. Other information on anaerobic digestion can be found on the University ot Minnesota Manure web page at www.bae.umn.edu/extens/manure under the topic heading "Treatment".

The USEPA AgSTAR program (http://www.epa.gov/agstar/) developed software (FarmWare 2.0 to assess the feasibility of anaerobic digesters. Two studies (Garrison and Richard 2001, and Hind 2002) have used this software to estimate economic feasibility of anaerobic digestion on several types and sizes of farms. Results from Garrison and Richard (2001) are found in Table 1. These results suggest that breakeven costs for anaerobic digesters require fairly large animal numbers (large volumes of manure). However, this analysis did not include the other economic benefits of those items discussed earlier (e.g. odor and pathogen reduction).

Table 1. Economic breakeven* points for anaerobic digestion systems using Farmware (Garrison and Richard, 2001).

Facility	Head Size Breakeven Point for Scenarios (see table 2) #1	#2	#3	#4	#5	#6
Swine Farrow to finish	>20,00 0	>20,000	>20,000	>20,00 0	>20,000	>20,00 0
Swine Finish	>20,00 0	>20,000	4792	13949	>20,000	1856
Dairy Tie-Stall PF	>5000	>5000	222	>5000	>5000	1090
Dairy Tie-Stall CM	>5000	>5000	148	>5000	>5000	314
Dairy Free-Stall, PF	>5000	>5000	234	>5000	>5000	1230
Dairy Free-Stall CM	>5000	>5000	148	>5000	>5000	330

*Breakeven is defined as having a Net Present Value of 0.
PF = Plug Flow
CM = Complete Mix

Table 2. Assumptions for Scenarios in Table 1

Scenario #	Electrical Rate $/kWh	Propane heat % heat supplied ($/gal)	Loan Rate %	Producer Down payment %
1	0.06	0	10	20
2	0.08	0	10	20
3	0.12	0	10	20
4	0.06	90 (1.00)	10	20
5	0.06	0	0	5
6	0.06	90 (1.00)	0	5

The study by Hinds (2002) also reviewed the economic feasibility of anaerobic digestion systems using FarmWare (Table 2). The results of this analysis are somewhat more favorable. In this analysis, breakeven costs occurred in dairy facilities with as few as 400 cows and swine finishing facilities with as few as 10,000 pig places. The differences between these two studies (Garrison and Richard, 2001 and Hind, 2002) is unclear however the likely differences are minor.

Another noteworthy comparison is the difference between the predicted economics using FarmWare and the actual economics of Haubenschild Dairy Inc. (Table 3). In this case, Farmware under predicted both the capital cost and the methane production from the system. The resulting economics however were fairly similar with both the predicted and actual payback on the investment of approximately 6 years. Unfortunately, this scenario is not likely for most producers because of the high rate of return on the sale of electricity (7.25 cents per kWh). Current rates for electrical buyback in Minnesota are estimated to be 3.4 cents per kWh plus an additional 1.5 cents incentive payment from the state. Using this rate of return on the sale of electricity (5.7 cents per kWh) the loan payback on the Haubenschild system would be 7.5 years instead of the 5.5 years (using 20% downpayment on investment and 10% annual rate of interest on the loan). Estimates from FarmWare with 7.25 cents per kWh payment for electricity result in an estimated payback period of 6.5 years.

Table 3 Comparison of predicted and actual economics of Haubenschild anaerobic digester.

Plug Flow Digester	Farmware	Actual	Actual with 3.4 cents/kWh
Total cost:	**$289,116**	**$355,000**	**$355,000**
- Mix tank:	$21,515	$32,400	$32,400
- Digester:	$110,132	$125,100	$125,100
- Engineering:	$25,000	$40,000	$40,000
- Generator:	$132,469	$157,500	$157,500
Annual O&M ($/yr.):	$13,230	17167 (est)	17167 (est)
Annual Benefits ($/yr.):	**$63,947**	**$86,973**	**$72,099**
- Electricity ($0.0725/kWh):	$63,947	$82,973	$58,605
- Propane:	-	$4,000	$4,000
- State Incentive ($0.015/kWh)			$9,494
Energy Produced:			
Electricity (kWh/yr.):	882,022	1,144,450	1,144,450
Installation information:			
Number of Cows	1000	800	800
Generator (kW):	112	150	150
Biogas (ft3/day):	65,000	71,000	71000
Manure (gal/day):	18000	22000	22000
Assumptions:			
Total cost ($/cow)	$289	$444	$444
Generator cost ($/kW)	$1,183	$1,050	$1,050
Electricity (kWh/cow/yr.)	882	1431	1431
Electricity (kWh/cow/day)	2	4	4
Generator size (kW/cow)	0.11	0.35	0.35
Biogas (ft3/cow/day)	65	89	89
Manure (gal/cow/day)	18	27	27

Safety Emphasis

The digester has been designed to meet safety considerations for manure pollution control. The concrete structures exceed the NRCS and Minnesota standards. The storage pond is lined with polyvinyl chloride and is fenced to keep animals away. Safety devices are in place to limit the pressure on the digester cover. Placards warn of dangers throughout the electrical system and guards are placed to keep people and animals out of dangerous locations.

Conclusion

The strong support of a champion is beneficial to a project having the magnitude of the Haubenschild Digester. Garnering additional support and seeing the project through takes time and concerted effort. The economic reality of being paid retail rates for the excess energy as well as avoiding the cost of buying energy for the dairy operation is enormous. The excellent management of the dairy barn with biodegradable bedding is an added plus. A sand bedded operation would create some very difficult problems for a digester. The high percentage of generation time has also been very beneficial to the operation. Others contemplating anaerobic digestion as a manure management system, will need attention to detail and persistence in getting the job done right so the project will succeed.

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