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An Economic Comparison of Two Anaerobic Digestion Systems on Dairy Farms

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Abstract. *Two dairy farms in New York State have recently installed anaerobic digesters as a method to control odors and create value added by-products from their manure. The mass flow, nutrient flow and economics of these two systems will be compared. One farm chose a plug flow digester with liquid solid separation. The separated liquid effluent is stored in an upright metal manure storage structure and applied to the land by a custom operator. The solids are marketed off site. The other farm chose a mixed digester incorporating food waste. They also separate the solids, but use them for bedding. The separated digested liquid effluent is stored in an earthen storage facility and irrigated on the cropland. Both these systems save money when compared to traditional manure handling. However the amount of money saved per cow is quite different.*

Keywords. Anaerobic Digestion, Dairy Manure, Plug Flow Digester, Complete Mixed Digester, Food Waste, Methane

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Introduction

Anaerobic digestion has been used and continues to be proposed as one method to treat manure to reduce odors and recover by-products. These systems have met with varying success on farms. Many farms are considering the use of anaerobic digestion as it is perceived as one way to reduce odor that over time may give a positive return to the farm. Each farm is different and anaerobic digestion systems are different both in cost and in function. In this paper two dairy farms are compared and contrasted. Both farms wanted odor control. For one farm it was needed in order to overcome community resistance to the farm. The other farm while benefiting from the odor control used it as an opportunity to add another profit center to their operation. Although both farms used grant money to partially offset the costs of the digester, the economic comparisons in this paper show the costs and benefits can vary a great deal.

Farm Descriptions

Farm D

Farm D is a new 850 cow dairy operation located in Homer, NY. They broke ground on December 4, 2000 and the first cow went through the milking parlor on August 7, 2001. The anaerobic digester was part of the original designs for manure management and odor control. Odor reduction for the local community was the primary reason for this manure management choice. The plan is to use the biogas to generate electricity using 4-28 kW Capstone microturbines, which are already in place. The electricity will be used on site, and any excess will be sold back to the grid. The microturbines will also recover heat that can be used to maintain the temperature of the digester as well as warm the floors in the barns. When the microturbines aren't running most of the biogas from the digester can be flared off while some of it runs to the boiler. The digested effluent will be separated into solids and liquids. The screw press separator and housing are next to the digester and Farm D is currently investigating potential markets for the solids. The stored digested liquid is stored in an upright metal tank and then applied to 1400 acres of owned and rented cropland.

System Description

A plug flow digester was installed at Farm D. It is an in ground concrete manure storage structure with about 20 days retention time. The digester is equipped with an airtight expandable rubberized dome to trap biogas consisting of methane and carbon dioxide, and other trace gases such as hydrogen sulfide from the digesting manure. The manure is kept at approximately 100^{o}F in the digester for optimal biogas production.

Process Description

Primary manure flow is through a gravity step-dam system under the barns. Parlor and milk house wastewater is collected in a 21,000 gallon holding tank. This water is used to flush the milking center holding area. Solids from this holding tank are pumped regularly to the top of the flow gutter from the bottom of the tank. This design allows for complete monitoring and control of water entering the flow gutter. One of the main reasons for this requirement is to maintain manure with 12% solids to feed the digester to optimize plug flow.

Each barn is scraped to the flow gutter in the center of the barn using mechanical alley scrapers. In the first barn (i.e., hospital barn), the elevation of the floor of the flow gutter is 1157

feet. In the second barn, the elevation is 1156, and 1155 in the third barn. Using a series of one-foot step-dams, the manure flows easily to the final collection pit. Agitation is available here to homogenize the manure.

Approximately 20,000 gallons of manure and milking center wastewater are fed into the digester each day. Most of the digestion occurs in approximately 20 days. Methanogenic bacteria in the manure, when kept at an optimal 100^{o}F (mesophillic range), cause the manure to decompose. This produces biogas consisting of methane (about 65%), carbon dioxide (about 34-35%), a small amount of sulfide compounds (0.1-0.36%), and other trace gases.

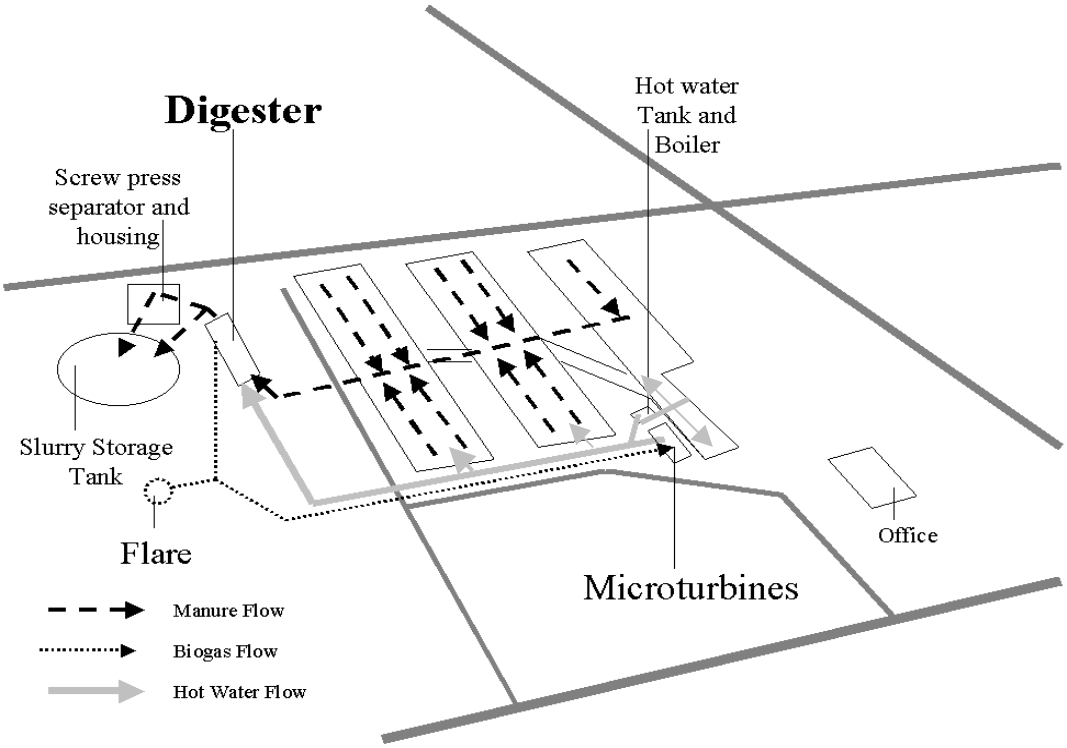

Figure 1: Layout of farm D and digester.

Farm M

Farm M is located in Chautauqua County, New York. This farm planned for 675 milking cows is the single largest dairy operation in the Clymer Valley, employs 16 people, and has considerable impact on the local economy. To address a variety of issues including odor, nutrient planning, and increasing revenue, Farm M installed an anaerobic digester with support from New York State Energy Research and Development Authority (NYSERDA) in late December 2001.

Farm M, before turning to anaerobic digestion, faced several problems. Manure generated at Farm M was stored in an earthen storage basin and spray-irrigated on the ground in March, April and November. The barns are just a mile upwind of the Village of Clymer. During times of spray irrigation, the public school had to keep its windows closed and neighboring businesses received comments about the odor. The odor from dairy manure handling and spreading on the farm had seriously affected the local community. Also, the Town of Clymer discovered its public water supply exceeded the maximum contaminant level of 10 mg/l for nitrate-nitrogen in 1994,

indicating the presence of manure nutrients in the groundwater. It is well known that anaerobic digestion is an effective technology to reduce odor from animal waste. Thus, to save its standing in the community, Farm M initiated this project primarily to reduce odor from manure management. Another driving force was to reduce the potential for nutrients from manure to leach into the groundwater by allowing odorless spreading during the growing season. Finally, the economic benefits of the installation of methane digester will reduce electrical and natural gas purchases at approximately $41,000 per year according to the estimate in EPA AgSTAR program's feasibility study.

Digester System

The digester system on Farm M Dairy Farm is shown in Figure 2. Manure from the alleys is scraped daily to a gravity flow hopper. It then flows to the raw manure tank. A valve can divert the manure from the hopper directly to the storage if needed. Another piping system gravity flows liquid food waste products down to the food waste tank.

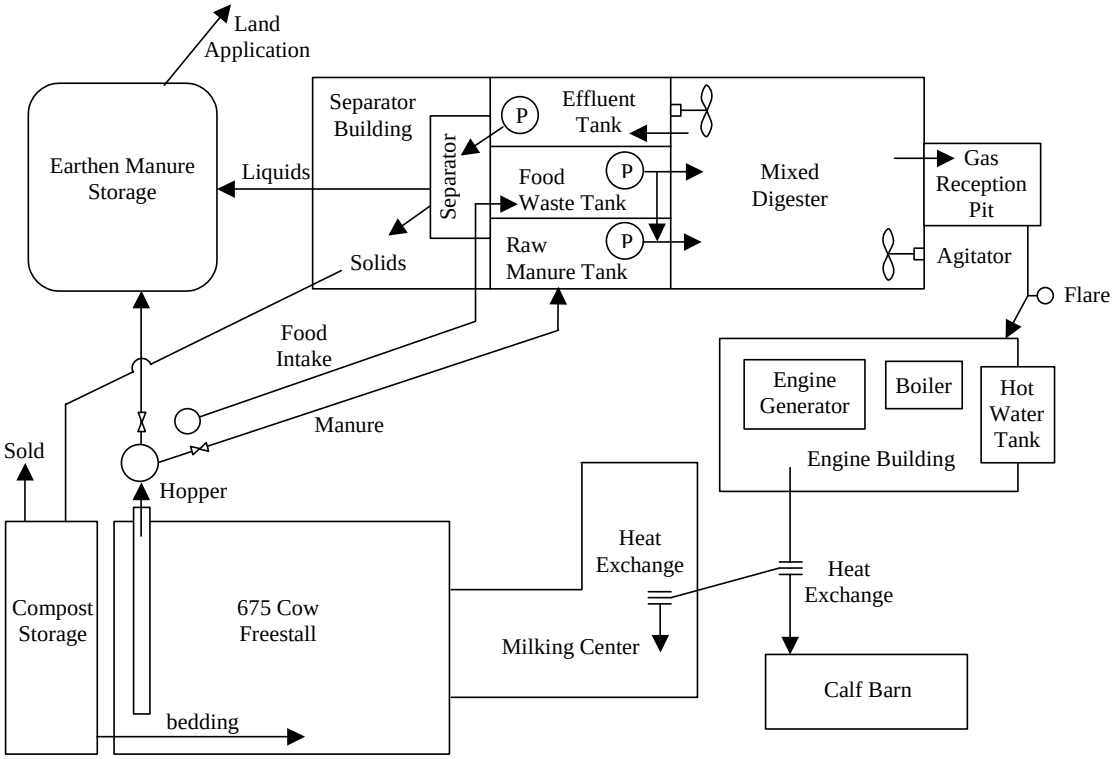

Figure 2: Layout of Farm M and digester

The food waste being processed includes wash water from an ice cream plant, used oil and breadcrumbs from a fish stick processor, and spoilt grape juice. Food processors typically have difficulty disposing of these wastes. They all have a high BOD that make the municipal sewage treatment plants reluctant to take their sporadic loadings. They are too liquid to be accepted in a landfill, designing and constructing individual treatment pants on-site is too expensive, and direct land application creates odors in the summer and is not permitted in the winter. By combining them with a continuously operating anaerobic digestion system a win-win-win

alternative was found. The dairy got tipping fees and the energy production. The food processors found a way to dispose of their waste, and environmentally recycling the energy and nutrients met the goals of the regulating authority.

The digester installed on this farm is a complete mix digester, which is a rectangular concrete tank buried in the ground (78' long x 68' wide x 16' deep). The digester was built on a slope to utilize gravity to aid the flow of manure from the barn collection system to the end production. However pumps are used to load the digester two times a day from both the raw manure tank and the food waste tank. A flexible, impermeable cover on the digester traps the gas.

Manure is scraped daily and gravity flows to a collection pit. Two 20-Hp manure pumps fixed at two opposite corners of the digester running 2 hours per day turn and mix the manure. The retention time is about 20 days.

The gas produced has ranged from 50% methane to as much as 71% methane as varying amounts of food waste to manure are introduced to the digester. The engine generator set can legally produce 130 kW of electricity. Waste heat is recovered to heat the digester to 100^{o}F and to provide hot water to the calf raising facility and milking center.

After digestion a Vincent screw press separator fitted with a hog screen is used to separate liquids and solids. Fewer solids are produced on farm M and the solids are smaller. The solids are composted for about 12 days, being turned 4 times as they move through the composting storage. They are then used as bedding for the freestalls or sold off-site.

The farm uses a preexisting manure storage basin to store the liquids. The liquids are field applied by tanker truck, tank spreader and big gun irrigation to the fields. With the odor much reduced, the farm can apply the nutrients on hay ground after each cutting and on fields close to the village without complaints. By applying the digested effluent during the growing season the potential for nitrogen leaching is greatly reduced.

Economics

Comparing the costs of each system as shown in Table 1 provides an opportunity to show the impact of alternative design and construction impacts of the two projects. Although the digester costs are similar, they represent two different structures and two different ways of contracting. Farm M was its own general contractor and built a more complex structure, with higher sidewalls and a poured in-place center beam. Farm D contracted the whole job out. Farm M's system is more complex; however there are fewer animals so the overall size of the digester is smaller, reducing some of the construction costs. Farm D is using microturbines to generate its electricity, this method has an increased capital cost versus the engine generator set.

Although the actual benefits may vary over time and some of the benefits listed are projected, farm M has done an excellent job of finding other uses for its methane, electricity and heat produced beyond using the waste heat to maintain the manure temperature at 100^{o}F. The food waste disposal, although adding initial costs for the permits, the agitator and the food waste tank, makes an income for the farm of $200,000 per year. The food product drying operation uses rice hulls and whey to make a product that would be suitable for dog food, or possibly a TMR ration addition.

Table 1: Economics of the two farm digester systems. Actual Costs and projected benefits.

		Farm D	Farm M
	Items	Cost/Benefit	Cost/Benefit
Capital Costs	Digester	$350,000	$330,000
	Electrical and Heating System		
	Microturbines	$185,000	
	Boiler and Piping	$50,000	
	Engine Generator		$96,317
	Switching equip and building		$32,614
	SubTotal	$235,000	$128,931
	Solids and Liquids Separation		
	Separator	$46,613	$46,613
	Separator Building	$42,387	$15,076
	SubTotal	$89,000	$61,689
	Liquid Storage	$315,000	$45,000
	Others	$43,800	$56,900
	Total Capital Cost	**$1,032,800**	**$622,520**
	Total Annual Capital Cost	**$71,895**	**$61,232**
Annual Operating Costs	Maintenance, Repairs, Insurance	$29,619	$20,662
	Spreading	$58,000	$93,947
	Management	$6,370	$1,301
	Total Annual Costs	**$93,989**	**$115,910**
Annual Benefits Including	Electric Savings and Sales	$42,400	$50,085
	Heat Savings (on farm)	$6,000	$6,000
	Odor Control	$15,000	$5,100
	Solids (bedding or offsite sales)	$12,000	$21,600
	Nutrients (fertilizer use on farm)	$45,000	35,700
	Food Waste Tipping Fee		$200,000
	Whey Food Drying Operation		$100,000
	Total Annual Benefits	**$120,400**	**$418,485**
Annual Cost Per Cow ($/cow/year) (note: negative cost = income)		**$53.51**	**- $357**

Another large difference between the two farm systems is the long-term storage. Farm D needed an above ground metal storage because of the high water table and porous soils. Farm M has suitable soils and topography so an earthen storage could be used to save initial capital costs. The initial capital costs for the digester are about the same for the two farms.

While Farm D shows a $53 annual cost per cow for their manure handling system, this should be compared with the $71 annual cost per cow for the storage and spreading cost alone. The farm then would have significant odor problems as well. Farm M has done very well in utilizing synergies in their community to add revenue to their operation in what was a costly operation.

Conclusion

As environmental regulations controlling direct land application of livestock waste increase, more and more farmers are faced with discovering innovative ways of handling the manure from their farm. Farmers must find a cost efficient means to remove the objectionable characteristics of their manure so that it may be recycled in an environmentally friendly manner. This should be done by producing a profit from the by-products of the treatment on successful dairy operations. Both of these farms have reduced their manure handling costs by using anaerobic digestion

Farm D has higher capital costs and lower benefits but still saves money and achieves odor control over storage and spreading. Farm M has found ways to better integrate their manure handling into other enterprises on and off the farm, in effect, turning their system into a profit center while also controlling odors.

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