

Strategic Hurdles to Widespread Adoption of On-Farm Anaerobic Digesters

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Abstract.

The anaerobic digestion of dairy manure, and its ability to produce energy, has been known for many years but the technology has not gained widespread adoption. Recently there has been renewed interest in the technology. Vermont received funding from DOE to set up pilot facilities and investigate why the technology has not received widespread use. We identified a number of strategic hurdles that are preventing farmers from adopting the technology. Understanding what the problems are is crucial if we are to increase the use of this technology.

A white paper search was done to identify the current status of digesters including looking at the unacceptably high failure rate on farm systems. A resource assessment identified the volume of digestible organic wastes and manures were available in Vermont. One farm in Vermont (Foster Brothers) has had a digester since 1982 and we have done a number of changes to that system that address some of the problems identified in some of the failures that have occurred. A number of farm-specific feasibility studies were carried out and several farms have had systems designed for them. We have three farm systems under construction for summer 2004 that address some of the hurdles we identified. We also addressed the problem legislatively, passing one of the most progressive net metering laws in the country. Vermont farmers can net meter system up to 150 kW in size.

Keywords. Anaerobic digestion, on-farm generation, manure management.

Introduction

The Vermont Agency of Agriculture, Food and Markets is committed to identify, and help develop, technologies that will integrate all of the nutrient management activities on the farm, addressing the environmental issues, while making manure into an income generator for the farm. Our goal is to make the manure handling activities revenue neutral or better yet, positive to the overall farm operation. We see anaerobic digestion as a key component to be considered in alternative manure management systems.

In 1999, with the help of Senator James Jeffords who secured the funding, the Vermont Public Service Department, and the Vermont Agency of Agriculture, Food and Markets embarked on a joint venture to look at why anaerobic digesters were not in widespread use. The initial thought was to build a few demonstration sites, but it quickly was shifted to a more strategic approach. What were the obstacles and questions that needed to be answered before more systems would be used? Why did the systems built in the late 1970's and early 1980's fail at such a high rate? The mission was; to identify, and help overcome, the strategic hurdles to widespread adoption of agricultural methane recovery and use technologies.

Initial Work:

Our first step was to do a literature review to determine the past and current, development and use of farm digesters. We discovered the reasons for many of the failures but equally important, we were able to show the potential benefits of the technology. We also funded a "Resource Assessment." Jeff Fehrs of Williston, VT, investigated the potential organic wastes in Vermont that could be used in farm digesters. The findings were not surprising in that dairy manure was by far the largest source. Whey, food wastes and other animal manures were more of a niche market that would be useful on some farms but not worth widespread development. If all of the cow manure in the state were digested it would produce around 28 megawatts of power. These documents are available on-line at www.vermontagriculture.com. Follow the links to "Alternative Manure Management."

Feasibility Studies:

An article on the project was published in AGRIVIEW (Vermont Agency of Agriculture's bi-weekly newspaper) asking for farmers that would volunteer to let us do a feasibility study at their farm. There were 16 respondents. Two of these were diversified livestock farms that were too small to be practical. The remainders were given more information about digesters. Four more dropped out, having concluded that digesters were not practical for their farms. One farmer was considering a new facility and agreed to call us back if they decided to build. (Barn and digester are now under construction.)

Two farms were small farms that we wanted to investigate the potential for making hot water from the manure.

- One milked 35 cows, had been in the Peace Corps and wanted a hot water heating system.
- The other was milking 75 cows and had a Bed and Breakfast. They wanted hot water heating for the barn and house.

Dr. Stan Weeks, the agricultural engineer retained by the program, did a preliminary engineering analysis, but on both farms, the manure was too dry and it was not cost effective to change to a liquid manure system.

Seven of the farms had an "AgStar" economic analysis done by Dan Scruton and Jeff Forward. The results were:

- Four had a reasonable cash flow (less than or equal to a 7 year payback)
 - 1 of these is under construction. (1000+ cows)
 - 1 beds with sand and after preliminary engineering analysis a system was not recommended (600 cows)
 - 1 was in the planning stage considering a barn complex and wants to install a digester if they decide to build (1000+ cows)
 - 1 is planning expansion and only cash flows after expansion (will be 600 cows)
- 3 had unacceptable rate of return (9 to 13.6 year paybacks)

Feasibility Conclusions:

- On retrofit scenarios with electrical generator systems, traditional digesters will not be self-supporting from energy value with less than 500 cows, or if the power bill is much under 10 cents per kWh. Further analysis on systems would suggest that many farms in the 500 to 700 cow range have marginal to poor economic returns using current tradition technologies such as Plug-flow digesters.
- Odor control and other benefits will need to sway the dairies that do not have positive cash flow from energy production to use the technology.
- The payback from building a digester is marginal when compared to other uses for farm capital.
- Hot water systems may fit but only on small farms with liquid manure systems or diversified operations such as a farmstead cheese maker that would have both manure and whey to digest.

Existing Demonstration Site:

Foster Brothers Farm in Middlebury, VT has had an active digester since 1982. When we started our program the Foster Brothers farm digester was down for renovation and needed a new cover. The digester already had dual channels and experience operators with a strong desire to advance the technology, so they had the potential of being an excellent demonstration site. We set out to answer the questions raised by our literature search to try and develop a simpler, lower cost digester system than is currently available. The system was rebuilt into two side-by-side digesters allowing us to do trials.

We have answered many of the initial questions.

- We found that steam injection was a good way to heat manure. It both warmed and mixed the manure at a reasonable cost (about 1 cent US per kWh of power produced)

- We found that insulation on the top of a soft-top digester was un-needed as the natural foam layer kept the manure at a stable temperature.
- We discovered that the heating pipes in most digester that lead to plugging and crusting are not needed.
- We also learned that it is difficult to get a good seal on concrete digester tanks, especially when re-sealing older concrete tanks.

Hurdles Identified Were:

- **MARGINAL ECONOMICS** – the cost/payback comparisons on most commercially available systems is poor to negative. If the system does not cash flow without grants or cost-shares it will probably not produce enough revenue to be sustainable on a long-term basis.
- Traditional designs are only suitable for very large farms.
- Traditional designs often require a substantial change in farm management to fit the farm to the system. To be successful, we need to develop systems that will work on a wide variety of management strategies with minimal changes of farm practices.
- Problematic designs causing high maintenance.
 - Most traditional, and most current, designs have heat pipes traversing the manure in the digester. This makes heat exchange from the engine simple but adds to the maintenance problems as the pipes may build up with an insulating layer or impede the manure flow. Municipal digester standards specify heat exchangers are to be outside of the digester for these reasons.
 - Whole manure digesters are prone to crusting and plugging but they also give the highest amount of energy. Designs for whole manure need to have a way of dealing with these issues.
 - It is difficult to consistently make concrete gas-tight.
- Gas quality – Manure based biogas is lower in methane than natural gas and only has 50% to 60% of its energy value. It also has H₂S, a corrosive gas that if allowed to condense will form acids that corrode the metal parts of an engine.
- Sale to power grid is complicated and the wholesale price is low. From a straight economic standpoint a system will not cash flow with just wholesaling of electrical power unless a premium is paid because it is a renewable source. Depending on the system design, a system may be able to make a profit selling power in excess of farm needs.
- There is little or no existing service industry with experience installing and servicing farm digester systems. There are more now than there were a few years ago, but more is needed.
- One of the biggest hurdles is time on the part of the farmer. It will take time every day to oversee the system. The time estimated for a typical digester is ½ hour per day and ½ day per month.
- There have been problems with the systems installed since the 1990's as well. Some of these problems were explainable but enough of the systems are not producing the energy they were designed to produce that I consider digester technology as still in the research phase.

Current Activities and Solutions:

Net Metering:

To address the problem of complicated sales to the grid, we implemented net metering. Net metering is the ability to produce power and send the power out onto the grid and run your electric meter backward if you are producing more power than you need and then use that power at times you are using more power than you are producing. The net at the end of the month is the bill for that meter. In Vermont we have been able to get rules in place that allow up to 1% of a utility's power to be in net metering systems. On farms you can produce power on one meter and use it back on any meter associated with farm operation (barns and houses including employee housing). The meters all need to be with the same utility. This dramatically improves the payback for a farm system. More detail on net metering can be found in presentation number 044136.

Cow Power:

Central Vermont Public Service, Vermont's largest utility is setting up a program whereby they will buy power from farm methane systems and sell it as renewable power to consumers. The premium (estimated at about \$0.04 per kWh) would be paid by the consumer and given to the farm customer. This encourages farms that can produce significantly more power than they can utilize in a net metering scenario an option to build a system that can produce maximum power and sell it all to a single vendor.

St. Albans Bay Manure Coop:

There are the equivalent of 10,000 cows in the St. Albans Bay region of Vermont. Most of these cows are within about 4 miles of a correctional facility. The farmers in the area are very interested in putting together a manure cooperative that would do a combined heat and power system with the facility. This would both address the spreading issues like odor, and nutrient loading issues. The proposal has been through its initial feasibility and will go out for more ideas from specific companies this year. One large challenge is, the hauling cost of manure exceeds its energy value of the electricity it can produce. By-products from the manure or a value-added energy component will need to be identified to have a system that can cash flow. An initial feasibility done by Spencer Bennett is available on the Vermont Agency of Agriculture, Food and Markets website, www.vermontagriculture.com.

Systems Slated for Construction in 2004:

Vermont has three digester systems under construction.

1. Whole manure digester for 300 cows. The barn is an 8-row freestall with 4 automatic milking units (robots). The alleys are automatically scraped to a gravity-flow cross channel that ends a two-day capacity reception pit. A grinder pump will be used to feed the manure through a heat exchanger system. This will both add to the energy efficiency of the systems and minimizes the chance of top-crust formation. The digester will be fed automatically about every 10 minutes utilizing a combination of timers and floats. The steady feeding should maximize digester efficiency and provide a steady output of gas.

The heat exchanger is two-stage, with the first stage captures heat from the exiting, digested, manure and exchanges it into the cold incoming manure. The second stage

exchanges heat from water heated by the engine jacket with the incoming manure. The manure is then steam injected to assure it goes into the digester at around 38°C (100° F) The digester is a glass-bonded-to-steel silo with no mechanical agitation. It has a conical bottom making sludge removal simple and easing cleanout. The genset is custom built for biogas utilizing a standard industrial engine. The goal of the system was to build a system that would need minimal adjustment by the farmer and uses as many off-the-shelf items as practical.

2. The second farm has several freestall barns pooling the manure from the milk herd and young stock to a central reception pit. It is a whole manure horizontal, mixed plug-flow, digester. The digester is a long concrete tank that has a side-by-side design with the manure flowing in a "U" pattern so that the entrance and exit are at the same end of the unit. The agitation is done with gas taken from the headspace of the digester and blown into the bottom of the digester causing an agitation pattern that is perpendicular to the manure flow. The manure will be separated as it is removed from the digester. The separated solids will be dried further for use as bedding, land applied, or sold as compost. This makes a system that will produce both energy and bedding. The University of Vermont will be doing a split-herd controlled study to determine the suitability of digested manure solids as bedding.

3. The third system is on a 300 cow freestall operation. It is a significant variation from traditional systems that, if successful, will change the way manure is handled. The system will be modular so that the digester and other key components it can be factory built, hauled to the site and set in place. It will allow for component design eliminating the need for site-specific individually designed systems that are predominantly site built. The manure will be separated, with the liquid going to a system that will reduce it to dischargeable water with the all of the nutrients going to a sludge. The digester will be a two-day retention time (20 days is typical). It will be packed with attached growth material that will greatly increase the biological activity in the manure. The liquid will then go through a series of tanks that will drop out the nutrients. The goal is to segregate the phosphorus from the nitrogen and the other nutrients. This will allow for precise nutrient balance on land applications and provide for a fertilizer to sell if the farm does not need all of its nutrients. This system will eliminate odors from spreading liquid manure, the pathogens associated in the liquid manure, the water portion of the manure and the rainwater that accumulates in traditional pits. This concept could save road damage in the spring by eliminating much of the water hauled to fields in large manure tankers.

Conclusions:

There is an exciting future for anaerobic digester, but it is not yet time for farmers to rush into a system with the old technologies. The new systems have the potential of reducing the cost of construction, better management of manure nutrients and easier operation. The goal of the Agency of Agriculture, Food and Markets is to move manure from the expense column to the profit column. This will only happen if we move forward investigating innovative alternatives to traditional designs and uses. It is imperative that we make manure easier to handle, nutrient use more precise, and develop income streams from the manure.