

Anaerobic Digester Implementation on Small Dairy Farms in Michigan and Wisconsin: A Literature Review

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Abstract

Small dairy farmers (farms with less than 200 cows) in Michigan and Wisconsin are interested in anaerobic digestion. The purpose of this literature review is to identify factors that encourage and discourage small digester implementation in Michigan and Wisconsin. Of all the factors that inhibit rapid adoption of anaerobic digestion on farms, the cost of a digester system is the most prohibitive. Designing less expensive digester systems and adopting policies that are favorable to small digester implementation are two factors that would overcome this barrier and spur building more digesters on small dairy farms. There is a great need for more applied and basic research, as well as targeted farmer educational programs. Specific research and education suggestions are offered that could increase the number of digesters on small dairy farms in Michigan and Wisconsin.

I. Introduction

Rural communities in Michigan and Wisconsin depend on dairy farms for tax revenues. A University of Minnesota study suggests that for every 1,000 dairy cows, the annual contribution to the community was approximately \$2.7 million, employment of 12 people, and use of 1,224 acres of corn and 621 acres of hay. The purchased services for 1,000 animals added \$65,550 in veterinary and breeding, \$167,232 in interest, \$63,835 in supplies, \$58,650 in utilities, \$57,600 in taxes and insurance, and \$342,985 in yearly wages (Conlin, 2003). Dairies create a ripple effect on both the agricultural economy and the economic well-being of rural America. When a dairy farmer spends money locally, it creates a multiplier effect of more than two and a half times the original dollar spent (Innovation Center for U.S. Dairy, 2011). Keeping dairy farms financially solvent is paramount to maintaining the economic viability of rural communities (Flanders et al., 2006; The Center for Dairy Excellence, n.d).

One way to keep small dairies, which make up over 87% of American dairies today, in business is to help them reduce energy, heat, and fuel expenses (NASS, 2013). Small dairy farmers are interested in anaerobic digestion, but they lack knowledge on the economics of installing, operating and maintaining digesters. There is no central repository for this information. Although there is a plethora of economic data for large scale anaerobic digester systems, the available data for small scale digester systems is fragmented and must be found, retrieved, interpreted and put in a form farmers can use to make informed digester purchasing decisions. This literature review seeks to identify and compile this fragmented information.

For the purposes of this literature review, a small dairy farm is defined as a farm with less than 200 cows, which matches the USDA herd size reporting delineation and is close to the average number of head in licensed dairy herds in the U.S (which is 187). Also, for the purposes of this literature review, a small digester is one that sized to function properly on a small dairy farm.

II. Small digester implementation in Michigan and Wisconsin, the United States, and the World

As of September 2012, Michigan has six on-farm digesters, all of which are located on Confined Feeding Animal Operations (CAFOs). Wisconsin has 29 on-farm digesters (USEPA, 2012b). All but one of the Wisconsin digesters is located on a CAFO. The number and types of digesters on small dairy farms is not well known in the United States. The US EPA AgSTAR program maintains a database of all digesters in the United States. The overwhelming majority of digesters in the database are located on large farms. Only three dairies listed in the database had 200 cows or less, and one of them was a university research facility (USEPA, 2012b).

Anaerobic digesters are widely used outside of the United States to produce biogas for cooking and lighting. As of 2009, there were almost 50 million small-scale digester operations around the world. There are an estimated 37 million small-scale digesters operating in China alone (Lansing and Moss, 2009). In Mexico there are as many as 200 digesters operating on small dairy and hog farms (Gould, 2013). Germany has defined small-scale digesters as digesters which produce <200kWh per day. To generate 200 kWh per day requires a digester sized to receive the manure from at least 168 dairy cows. Germany is working to increase the amount of digesters of this size in order to create a greater market for bioenergy. In 2009 most of the 400 digesters built in Germany were operating at <250kWh per day (Weiland, 2009). In Austria 93% of digesters process under 5,000 tons per day and produce electricity at under 100 kW (Gell, n.d.).

III. Analysis

A. Factors that encourage small digester adoption in Michigan and Wisconsin.

State policies

State policy spurred the increase in the number of on-farm digesters in Wisconsin. The Renewable Energy Sales Tax Exemption offers sales tax exemption to all sales made by clean energy systems. For example, this exemption allows all digesters in Wisconsin to sell their electricity produced from methane to the municipal electric grid without taxing the sale. The Renewable Energy Grant Program offers grants for a variety of renewable energy systems, including digesters. The minimum and maximum digester awards are \$5,000 and \$500,000 respectively. This award at its maximum is enough to cover half of the capital (including generator) of a plug flow digester servicing a farm size of 500 head (AgSTAR, 2010). Wisconsin mandates utilities to generate 10% of their retail electricity sales from renewable energy resources by 2015; however, requirements vary by utility (DSIRE, 2013).

State policy aimed at increasing the number of on-farm digesters is more of an afterthought in Michigan. In Michigan, the Biomass Gasification and Methane Digester Property Tax Exemption offers farmers who are certified digester operators and have registered digesters on their property 100% exemption from real and personal property taxes. Also, the state offers Biomass Energy Program Grants for the adoption of anaerobic digesters. These grants average around \$25,000. Michigan's Renewable Portfolio Standard (RPS) mandates utilities to generate 10% of their retail electricity sales from renewable energy resources by 2015 (DSIRE, 2013).

Odor control

Many dairy farms in Michigan and Wisconsin are located near metropolitan areas, which result in conflicts with neighbors over odors. Anaerobic digesters reduce manure odors. In natural manure degradation there is an unbalance between acid fermentation and methane production, allowing volatile organic compounds to form that cause odor. In anaerobic digestion, the two phases of acid fermentation and methane production are kept in balance and odorants are degraded (Wilkie, 2005). Anaerobic digestion destroys about 60 to 75% of the volatile solids found in untreated manure (Heber, n.d). A study conducted by Odgers and Struss (2009) found that treating material with a low temperature digestion reduced odor in storage lagoons by 15% when compared to an untreated storage lagoon. It was also found that covering the storage lagoon with an impermeable cover, such as that used in a passive digestion system, reduced odors released over time by almost 100%. Land applying digestate in place of regular manure also is an odor-reducing practice because digestate is free of odor-causing volatile organic compounds (Lazarus, 2008). During the first six hours after spreading, when the rate of odor emission is highest, digestion reduced odor emission by 79% (Wilkie, 2000).

Plant available nutrients

Anaerobic digestion is effective at both preserving the nitrogen content of the manure and retaining it in forms useful to plants (Dahlberg et al., 1988). Compared to digester influent composition, the effluent composition has 2% to 5% less volume and the same amount of N, P, and K, (Jacobson, et al., 2005). In a study conducted by Dahlberg it was found that the average difference in organic nitrogen between stored manure was no greater than 0.1%. It was also found that anaerobic digestion may possibly increase the amount of ammonia readily available for plant use. Overall it was concluded that “anaerobic digestion did not degrade the quality of the dairy manure,” meaning that there seemed to be no difference between the nutrient values of dairy manure and digestate (Dahlberg et al., 1988).

Income from tipping fees and the production of heat, fuel and electricity

A study conducted by Lansing and Klavon (n.d) found that small digesters produced over \$5,000 of revenue annually from biogas production. Income generation can come from many sources. Companies with organic waste material may pay farmers with digesters to take their waste to avoid paying tipping and gate fees. In Michigan and Wisconsin a tipping fee is charged by the state for persons to deposit their waste into a landfill. In addition to a tipping fee, landfills may charge a gate fee. In Michigan the state tipping fee is \$0.36/ton while the gate fee average is \$78/ton (WDNR, 2013). In Wisconsin the state tipping fee is \$13/ton while the gate fee average is \$56/ton (WDNR, 2013). The higher the tipping fee the more likely companies will be to pay farmers to take their waste.

Carbon credits are a potential source of income. Methane combusted through a flare or genset can be sold as carbon credits. Carbon credits are purchased off of credit markets. Credit prices are volatile throughout the world and can be sold from as much as \$5.00 USD/metric ton to \$0.14 USD/metric ton. They average around \$1.00-2.00 USD/metric ton (ICE, 2013). Lansing and Klavon (n.d.) found that small digesters averaged around \$1,000/year revenue out of \$16,000/year revenue in carbon credit sales.

Electricity can be used as a source of revenue for small digesters, but often the straight use of methane as heat is more efficient. Currently, electricity prices average around \$0.11 USD/kWh (USEIA, 2013). By selling electricity, digesters bring in more revenue, but for a small-scale system, this current revenue is not enough to overcome the higher initial capital costs of the generator. Lansing and Klavon (n.d) state however that if electricity prices were to increase, farmers could afford a higher initial capital cost.

Digester Flexibility

Another benefit is that digesters are not limited to treating a single type of waste. Digesters are often more efficient when a combination of organic feedstocks are added (Safferman, 2013). As feedstocks such as food waste are added, biogas output increases, which leads to more possible revenue for a digester system. Michigan State University recently built a digester that accepts food waste from on-campus cafeterias and mixes it with manure from the Michigan State University Dairy Farm. Optimizing feedstock recipes optimizes methane generation (Kirk, 2013).

B. Factors that discourage small digester adoption in Michigan and Wisconsin.

Dairy industry consolidation trends

According to the National Agricultural Statistics Service, there are 58,000 dairy herds in the United States. Just over 87 percent of those herds have less than 200 cows. Another 6.5 percent have herd sizes between 200 and 499 head (NASS, 2013). The average herd size of licensed dairy operations in the US was 187 head. In Michigan it was 176 head and Wisconsin 111 head (Anonymous, 2013). The number of dairy herds in the US has dropped from approximately 190,000 in 1990 to 100,000 in 2000 to its current level of 58,000 (NASS, 2011). This is a trend that will continue as the dairy industry consolidates into larger farms, leading to fewer opportunities for small-scale digestion in the future.

State policies

In Michigan and Wisconsin, the mandate to have 10% of a utility's retail electricity sales from renewable energy resources has been met. Utilities are not motivated to buy any more than they have to, consequently, putting electricity on the grid is not an option for new projects.

Digesters are not required to obtain an air permit in Michigan if the biogas produced is piped off site. Also, if the gas from the digester is going to a flare or boiler, a permit is not required if the actual emission rate of sulfur dioxide (SO₂) does not exceed 1 pound per hour. Farmers need to obtain a Permit to Install from the Michigan Department of Environmental Quality (MDEQ), Air Quality Division, prior to installing the flare or boiler if SO₂ rates exceed 1 pound per hour. A water quality permit, a soil erosion permit, and a solid waste permit may be required if the digester is receiving feedstocks other than manure. The most common case is if the digester is being used to treat pre or post-consumer food waste. Also, farmers may be required to obtain a permit for land application of digestate if other substances are going into the digester besides manure (MDEQ, 2013).

In Wisconsin permits are required in Wisconsin no matter how much is SO₂ emitted due to odor regulations. No malodorous gases may be released from a system without a permit (WDNR, 1999). Different digesters are allowed to emit different amounts of SO₂ based on their size and feed-stock composition (WDNR, 2008). Other than this, most digesters are not required to have a permit unless a generator is connected to the system and combustion is occurring (Dunn, 2013).

Farmer views on small scale digestion

Wilkerson (2012) reported that small farmers believe that anaerobic digestion is not suitable for their type of farms. One respondent indicated that he had “no ability to do it” on his 600 acre farm. Another respondent said that he assumed anaerobic digestion technology was not available for small farms. Overall, 45% of farmers surveyed were disinclined and 21% were inclined to adopt anaerobic digester technology. Of the farmers willing to adopt digester technology, a majority of them owned small farms of less than 50 acres.

Even though digester technology has been around for centuries, it is not understood by the general farming population. Misconceptions and lack of knowledge impact the adoption of anaerobic digestion technology. Wilkerson, in the study mentioned earlier, points out that there are many misconceptions about digesters within the farming community. For example, farmers wrongly believed that digesters require only manure. One respondent mentioned how digester technology is environmentally damaging, as “it burns carbon when methane is burned as fuel,” and is water intensive. Another respondent states that digesters would not be a “real improvement” for farms that already utilize “good farming practices”. Wilkerson reports that 12% of respondents indicated they did not know the barriers to anaerobic digestion. Similarly, 9% of respondents indicated they did not know of any positive reasons to implement an anaerobic digester. Overall, it was conveyed that the technology was currently available, but

that people did not know about it. Wilkerson concludes by saying the “information highway only works when information is there...the information link is missing”.

Cost of digesters

The adoption rate of small scale digesters is low (Wilkerson, 2010). One factor is economies of scale - as farms get smaller, the capital cost per head increases. For example, the capital cost per cow is approximately \$500 on a 3,000 cow dairy farm with a plug flow digester, while the capital cost on a 500 head dairy farm is approximately \$1,400 per head. This trend is the same throughout all digester types (AgSTAR, 2010). Safferman (2013) states that the investment cost to implement an on-farm digester ranges from \$350-1,000 per head. This volatility in price range makes it very difficult for small farmers to implement digesters. Small commercial digester systems are available but are still too expensive without being subsidized by grant dollars. AgSTAR excludes farms with under 500 head from their survey on the future of digester energy potential because they assume that digesters this size are not profitable (AgSTAR, 2012).

Natural gas market

While the natural gas market can aid digester implementation, it can also discourage it. This is because natural gas prices are not fixed. When natural gas prices are high, the value of biogas increases. When natural gases are low, digester technology becomes less attractive. Currently, methane prices are the lowest they have been since 2000 at around \$2.60 per thousand cubic feet, which means that digesters produce less income than they would have in 2008 when natural gas prices were around \$7.50 per thousand cubic feet (EIA, 2013). This means that installing a digester that produces and sells natural gas would bring in less income now than it would in previous years. For this reason, using the methane produced from digestion for other purposes is often more profitable.

Climatic conditions

Small digesters are very common throughout the world. In areas that have year around mild climates, small digesters are very easy to operate and cost efficient to implement on farms of any type. However, dairies located in more temperate climates have to deal with the unfavorable relationship between low temperatures and the speed of anaerobic digestion. This is a technological barrier that impedes implementation of digesters in cold climates. Anaerobic digestion requires a continuously high temperature to work. When the temperature drops below 35°C during mesophilic anaerobic digestion, the bacteria do not function efficiently and digestion slows down. Thermophilic digestion requires an even higher minimum temperature of 55°C (Zupancic, 2003). This inherent trait of anaerobic digestion causes the cost of digesters to escalate as the latitude increases because the cost of materials and maintenance increases in cold climates. In states like Wisconsin and Michigan, where the temperature often drops below

0°C for a large part of the year, digestion requires more expensive materials, more insulation, and more maintenance, thereby increasing the cost of digestion.

Electricity and connecting to the grid

Generating electricity and connecting to the grid are expensive. For digesters that produce electricity, 36% of the total capital cost is associated with electrical generation equipment. The majority of yearly maintenance costs relating to digestion come from the upkeep of electrical equipment (NRCS, 2007). Gloy and Dressler (2010) state that the variable operating costs of generation for a large anaerobic digestion system are 4.22 cents per kWh, which often exceed the utility's avoided cost of generation. In the same report, Gloy and Dressler conclude that small digesters, which produce less electricity than large digesters, will have an even a harder time achieving a positive balance between income and expense. Metering and regulation may vary from provider to provider, so contact with individual power companies is necessary. For information on safety regulations regarding grid connection and home electrical generation, view IEEE 1547-2003, UL 1741, and The National Electrical Code (UDE, 2012).

C. Factors that encourage small digester adoption outside the United States

Feed-in tariffs

Feed-in-tariffs are off-shoots of carbon restrictions initiated by governmental organizations in which electrical companies pay reimbursement per kWh to citizens who produce clean electricity in their own homes (Gov.UK, 2013). Producers sign long term contracts with companies to ensure premium price for their produced electricity. Electrical companies in other countries do this in order to fulfill stricter carbon regulations enacted by the government, which do not yet exist in the United States. Feed-in-tariff pricing greatly augments the price of locally produced electricity. In Ontario, Canada, feed-in-tariffs increase the price of electricity to \$0.195 per kWh for farm biogas-based energy for projects under 100 kW and \$0.185 for projects over 100 kW (Ontario Power Authority, 2010). In Germany, the feed-in-tariff rate for biogas-based electricity translates to \$0.31 USD/kWh. Large digesters can take more advantage of this due to greater electrical output, but the price remains consistent throughout all sizes of digestion. In comparison, without feed-in-tariffs, electricity producers must sell their electricity at wholesale prices, which in the United States can be as low as \$0.05 USD/kWh (Shelford, 2012).

Carbon credits

Although carbon credits exist in the United States, their rates are much lower than the rest of the world. This is because the U.S does not have a cap and trade law like other nations. California passed a carbon cap and trade law in 2012, but is the only state in the nation to have this limit currently. The law requires a 25% reduction in state CO₂ emissions by 2020 (Eye on

Earth, 2013). If other states follow suit there could be a large increase in carbon credit prices. Currently, carbon prices in the U.S are very low due the recent low costs of natural gas, and hardly rise above \$0.14 USD/mT (ICE, 2013).

Weather

Weather plays a large role in digestion outside of the United States. Warmer allows digesters to be built of less expensive material function and year round. In Mexico, most digesters are made from a durable plastic material. This makes them extremely inexpensive with respect to U.S. digesters. If properly managed, Mexican digesters are thought of to have a life of 50 years (Gould, 2013).

Biogas use

Biogas use for cooking is another incentive for digester installation. Wood has become scarce and presents health issues when burned in a stove. In China small-scale home digesters are common. These digesters exist at residential locations as micro-scale digesters. Micro-scale digester designs include an underground clay and brick pit, oil barrel with a floating or sealed lid and the ditch or tunnel with a rubber membrane to capture methane (Gell, n.d.). These digesters do not contain a generator as part of their design so no electricity is produced. The biogas is used in homes as cooking fuel.

IV. Discussion

Of all the factors that inhibit rapid adoption of anaerobic digestion on farms, the cost of a digester system is the most prohibitive. Farmers are not going to install a digester system on their own at their own expense if it costs them \$1,400 per head to do so (USEPA, 2010). Farmers are no different than any other business – if the farm is not profitable it is not sustainable. Digesters have to generate income, either by bringing income in or replacing an existing expense. The cost of a digester system can be reduced by redefining biogas use, using less expensive building materials, implementing policy conducive to digester systems and through developing markets for digester products. Biogas traditionally has been used to generate electricity. Lansing (n.d.) states that removing electricity production from a small digester project would reduce the initial capital investment by about 44%. Instead of generating electricity, use the biogas to produce heat, and use the heat to heat and cool. Making digesters out of less expensive materials such as PVC or high density polypropylene decreases the initial cost of a digester. These types of digesters have a proven track record for biogas production around the world (Gould and Taglia, 2012; Gell, n.d.). Adapting these digesters to colder climates may be as simple as installing them in series in insulated cargo containers. Such a system should be inexpensive enough to install without a grant and built with off-the-shelf parts. Finally, a small digester system needs to be simple, easy to repair, and low maintenance.

Policy on the Federal level seems to encourage growth in the wind and solar sectors rather than the digester sector. Lack of Federal funding has retarded digester research and education among the agricultural community. However, some states like Wisconsin have implemented policies conducive to the proliferation of on-farm digesters. These policies were coupled with the private industry, funding and technical support necessary to build digesters and grow the digester industry. The Federal government could learn much from Germany's example. Germany has a climate very similar to the United States, yet the number of digesters in Germany is much higher than the U.S. Regulations implemented by the government heavily favor the adoption of anaerobic digesters on farms by increasing the profitability of digesters. This governmental emphasis on green energy has caused attitudes towards digester technology to be more positive, resulting in greater digester adoption. This also helps overcome the other limiting factors relating to digestion.

Maximizing the functionality of a small digester system will take a new way of thinking about digesters. Heating a digester with solar collectors, covering a digester with a greenhouse, and darkening the ground around a digester to increase solar adsorption are examples of this type of thinking. Finding new ways to utilize the biogas on the farm will require non-traditional thinking. Developing less expensive equipment to produce a vehicle fuel (CNG) is one way to increase the utilization of biogas on the farm. Developing local biomass depots that take the separated fiber and convert it into ethanol, medium density fiberboard or feed has the potential to be a source of income.

Conclusions

A. Factors that encourage digester adoption on small dairy farms in Michigan and Wisconsin.

Right now there are really no factors that would encourage small dairy farms to install a digester. In Michigan there is no incentive to produce electricity because the goal for the State's Renewable Portfolio Standard has been met (as of 2013). Digesters are still too expensive for small dairy farms to afford without government grants, and those dollars are scarce. Digester vendors are not motivated to work with small dairies due to economies of scale. Farms with large quantities of feedstocks are preferred. Small dairy farms are more likely to install a digester when doing so results in a profit. This will occur when policies support small digester systems, small digester systems become affordable without grants, and revenue streams from biogas and digestate generate profit for the farm.

B. Summarize barriers to digester adoption on small dairy farms in Michigan and Wisconsin.

The largest barrier for small farmers is digester capital costs. Other barriers include low digester revenue due to volatile market prices, state policies and permitting, and farmer opinions of digesters. Also, although digesters are thought to be scalable, smaller farms have a much harder time of implementing digester technology.

C. Identify knowledge gaps that need to be addressed through education and by applied and basic research to remove barriers to adopting digesters on small dairy farms in Michigan and Wisconsin.

Areas of applied and basic research that would enhance digester adoption on a small scale include the following:

- Develop a digester system for small dairies that is cold-tolerant, simple, low maintenance, and inexpensive.
- Develop a small dairy digester system model that can be implemented across Michigan and Wisconsin.
- Identify psychrophilic methanogens that could produce sustainable amounts of biogas at lower temperatures.
- Identify or develop less expensive materials that reduce the capital costs of the digester vessel.
- Develop low cost technology or methods to break up the scum layer in the digester.
- Identify low cost solutions to heating a digester.
- Increase the electricity production efficiency of a genset.
- Identify new profit centers for biogas and digestate.
- Identify synergies with other forms of renewable energy that generate profits for the farm.

Educational opportunities that would enhance digester adoption on a small scale include the following:

- Develop a digester operator training program targeting small dairy farms with digesters.
- Help policy makers understand the role of digesters in removing organic waste streams going into landfills.
- Help policy makers understand the opportunities and barriers that exist for small dairy farms that want a digester.

- Digester vendors seem to repeat the same installation mistakes, especially new vendors. Sponsor a conference where information is shared that will avoid these costly mistakes.

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Acknowledgements

The author would like to thank [The North Central Regional Center for Rural Development](#) (NCRCD) for funding in support of this work. Any opinions, findings, conclusions or recommendations expressed in this publication are those of the author and do not necessarily reflect the views of NCRCD, Michigan State University or Michigan State University Extension, and reflect the best professional judgment of the author based on information based on information available as of the publication date. A sincere thanks to Johnathan Rivin (University of Wisconsin Extension) and Charles Gould (Michigan State University Extension) for their critical reviews of this paper.

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