

Anaerobic Digesters

Farm Opportunities and Pathways



A PUBLICATION OF
the
MINNESOTA
PROJECT

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ABOUT THE MINNESOTA PROJECT The Minnesota Project is a nonprofit organization championing the sustainable production and equitable distribution of energy and food in communities across Minnesota. The organization focuses on three areas: the development and efficient use of clean renewable energy, promotion of sustainable agriculture practices and production, and consumption of local, sustainably grown food.

Founded over 30 years ago, today's team works toward establishing a sustainable Minnesota by 2039 through policy research, education and outreach, as well as developing key ground-up, grassroots initiatives targeted at empowering communities and their leaders.

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INTRODUCTION



Anaerobic Digestion: A Brief Rundown

Anaerobic digestion is a biological process in which microorganisms break down or, digest, organic material into its various primary components. The organic material to be digested can be anything, really; from food waste, to grass clippings, to animal manure. As the organic material is broken down, it releases biogas. Biogas consists of 60-70% methane, 30-40% carbon dioxide, trace amounts of other gases like hydrogen sulfide and ammonia, along with a very small percentage of water vapor. When captured, biogas is most often used as fuel to power an engine that turns a generator, creating electricity. However, as methane is the primary constituent of natural gas, the biogas can also be burned as a heating or cooking fuel, used in refrigeration, or even potentially scrubbed of its impurities and sold as renewable natural gas.

Biogas recovery systems are the technologies that make the above described process work. Biogas recovery systems couple anaerobic digestion technologies with biogas capture technology to produce, and then utilize, biogas in one contained system. Though a bit of a misnomer, biogas recovery systems are also commonly referred to as simply, 'anaerobic digesters,' the phrase which will be utilized in this document.

So what do these fairly complicated preceding paragraphs have to do with farmers? The Environmental Protection Agency estimates that over 8,000 dairy or swine farms across the United States have the potential to economically sustain an on farm anaerobic digester. In the proper conditions, anaerobic digesters could dramatically decrease farmers' energy, bedding, and waste management costs, produce additional revenue streams, and make farm operations more environmentally friendly.

This publication provides the most relevant information to farmers interested in learning about the benefits, challenges, and opportunities for pursuing an anaerobic digester on their farm. The document discusses the myriad benefits associated with anaerobic digesters, the development of the technology around the world, and early steps farmers must take if they're interested in pursuing such a project. In an effort to provide the most information in the smallest package, this document does not attempt to be exhaustive in all its descriptions and categorizations. Instead, the document provides references to documents providing greater depth of information, for readers interesting in delving deeper into a particular subject.

This publication provides the most relevant information to farmers interested in learning about the benefits, challenges, and opportunities for pursuing an anaerobic digester on their farm.

Chapter 1: Overview of Anaerobic Digesters

Digester History/Implementation

Anaerobic digesters have been used around the world for decades. Some of the earliest users of anaerobic digesters have been tracked all the way to mid-1800s India.¹ Additionally, some experts estimate there are literally millions of small scale digesters operating in places like China and India.² Of course, the digesters found in these areas were often very small and used primarily to capture gas used to heat homes and fuel kitchen stoves. Similar digesters can still be found today across rural China and more locally in rural areas of Costa Rica and Latin America. The successful implementation of digesters in areas like these, often with most limited resources, displays the basic workability of re-using organic waste to increase self sufficiency.

Today, Germany is often looked at as the leader in modern, large-scale anaerobic digester implementation, with over 3,700 digesters in operation.³ Comparatively, as of May 2010, the Environmental Protection Agency estimated there were only 151 on-farm anaerobic digesters operating in the United States.⁴ Wisconsin led all states in digester implementation with 25 anaerobic digesters producing over 95,638 MWh of electricity per year. Minnesota has 5 anaerobic digesters producing 4,084 MWh of electricity per year. To give the current state of the United States' digester implementation some perspective, energy produced from all biogas uses currently accounts for less than one-half of one percent of the United States' energy consumption.⁵ So, while early efforts in anaerobic digester implementation are encouraging, a great deal of expansion potential remains.

Anaerobic Digester Designs

As interest in anaerobic digesters has risen with the gradual change in our energy economy, various types of digester designs and technologies have developed. While there are many different organizations promoting specific types of anaerobic digestion systems, the various designs all generally break down into three or four basic digester types, with variations on a theme providing the diverse array of designs.

The primary digester design categories are: Plug Flow, Complete Mix, Covered Lagoon, and Fixed Film digesters. The latter two of these designs are less suited to Minnesota's climate type, but have seen some (though lesser) implementation in the region. In any event, as of May 2010, over 70% of operational on farm digesters were plug flow or complete mix systems operating at mesophilic temperatures (95–105° F).⁶ While it is helpful to provide a general overview of each technology here, farmers will be best suited in learning the details of particular digester systems by talking to the experts and organizations capable of designing a system best suited to the specific needs of individual farm operations.⁷

¹ *Small Scale Digester Options*, presentation by Andy Moss, BioCycle Conference. (2010).

² *Biogas Production and Utilisation*, Arthur Wellinger, IEA Bioenergy. (2006).

³ *Anaerobic Digester Technology*, William F. Lazarus, University of Minnesota. (2009).

⁴ *Anaerobic Digesters Continue to Grow in the U.S. Market*, AgStar. (May 2010).

⁵ *Biogas: Rethinking the Midwest's Potential*, Peter Taglia, Clean Wisconsin. (June 2010).

⁶ *Anaerobic Digesters Continue to Grow in the U.S. Market*, AgStar. (May 2010).

⁷ <http://www.epa.gov/agstar/tools/directory.html>.

Breakdown of Digester Types Throughout the U.S.⁸

Farm Type	Total Digester Projects	Plug Flow Digesters	Complete Mix Digesters	Covered Lagoon Digesters	Other Digester Types
Dairy	126	74	27	16	9
Swine	24	2	5	15	2
Poultry	5	1	4	0	0
Beef	2	2	0	0	0

Plug Flow Digesters

Using a plug flow digester, animal waste is introduced into one end of a long, tubular digester and moves toward the other end. As the waste is digested and flows out the tail end, more waste is introduced on the front end. Plug flow digesters have mainly been used on dairy farms, due to their ability to handle slightly higher solids contents. Plug flow digesters are workable with manure containing 11 to 13 percent solids, and are well suited for operations that mechanically scrape out manure from barns. As evidenced in the table above, the plug flow design is, of yet, the most popular anaerobic digester design.



Plug flow digester

Complete Mix Digesters

Mixed digesters combine all animal waste into one central tank and use agitation systems to mix the waste while it is digested. Sometimes, these tanks are partially buried, to take advantage of the regulated temperature below ground. Complete Mix digesters generally handle manure with 3-10% solids, and while they can be a bit more expensive than plug flow digesters, they take up a smaller footprint and are well suited for farm operations that wash out their manure.



Complete mix digester

Another Digester Option

Another type of digester design, an Induced Blanket Reactor (IBR), is being used right here in Minnesota. At the Jer-Lindy Dairy, near Brooten, MN an IBR digester was installed due to its quick digestion process (about 5 days), its small system footprint, and modular design. The IBR system propels incoming animal waste upward through a vertical column of bacteria rich liquid sludge. The constant exposure to the digesting bacteria helps speed up the digestion process and ensures thorough digestion of the incoming waste. The Jer-Lindy dairy has been happy with the digester system performance, though constant maintenance of the electricity producing genset has made the project as a whole more difficult.



⁸ Recreated from: [U.S. Anaerobic Digester Status Report](#), AgStar. (October 2010).

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Other Digesters

Other types of digester systems include covered lagoon and fixed film digesters. Covered lagoon digesters, which digest organic material at ambient temperatures, are not well suited to Minnesota's cold winter climate, when ambient temperature digestion would not be viable. Fixed film digesters require very high liquid content animal manure to work effectively. Any significant amount of solids in the incoming waste stream risks plugging, and reducing the digestion effectiveness, of these types of digesters. However, in the right situation, fixed film digesters can be beneficial because of their ability to digest organic material quicker (usually 3-5 days) than most conventional digesters, which generally need anywhere from 10-25 days to digest the organic matter.



Covered lagoon digester



Fixed film digester

Chapter 2: Uses and Benefits of Anaerobic Digestion

Building an anaerobic digester on a suitable farm is certainly a large undertaking. As will be discussed later in this publication, the successful completion of such a project requires high level coordination between multiple stakeholders and a large amount of planning and fine tuning in the implementation of the project. However, once successfully implemented, the potential benefits of an anaerobic digester are substantial. The benefits realized from such a project range from making a farm operation more environmentally sound to providing multiple additional revenue streams to the farm operator. These potential benefits are laid out below.

Farm Quality Benefits

Odor Control

Despite the good potential for significant energy savings using an anaerobic digester, many farmers interested in implementing a digestion system on their farm count high quality odor control as the primary reason they're interested in constructing an anaerobic digester. Farmers looking to expand their operation are often especially intrigued by the odor reducing benefits of anaerobic digesters. Large animal operations often experience significant complaints from neighbors dissatisfied with the amount of unpleasant odor animal operations can emit. Anaerobic digesters stabilize this potential problem as a natural result of the digestion process.

Anaerobic digesters reduce odor on farms by stabilizing the organic materials in animal waste that are responsible for undesirable odor.⁹ Through the course of the digestion process the organic compounds responsible for unpleasant odor are broken down by the bacteria responsible for producing the biogas. The odor reduction from anaerobic digestion is significant, with nearly all unpleasant odors being eliminated in the course of the digestion process.

Stabilized Waste Products

In addition to the almost complete reduction in unpleasant odors, anaerobic digesters also produce a more stable, uniform, and sterile end waste product than that which is simply collected from the animal barns. The benefit of this impact is twofold, at least. First, the heat involved in the digestion process serves to eliminate many of the potential pathogens otherwise found in the solid and liquid waste that accumulates in waste storage facilities. Second, the digestion process turns the large majority of nitrogen contained in the animal manure to ammonium. Because all of the animal waste has undergone the same biological process, it emerges from the digestion process an easier to handle, higher quality fertilizer, more readily utilized by plants in the field. If responsibly applied, the reduced application of this higher nutrient fertilizer has less potential for nutrient runoff.

Farm Quality Benefits as Economic Benefits?

Though environmental/farm quality benefits of digesters are independently important in and of themselves, they could soon become important to more than the environmental community. As a greenhouse gas, methane has 21 times the harmful heat trapping potential of carbon dioxide. By capturing and using the methane produced on farms, anaerobic digesters in the U.S. reduced greenhouse gas emissions by over 1.1 million metric tons of carbon dioxide equivalent in 2009.¹⁰

Any significant state or federal legislation curbing or taxing carbon dioxide emissions would make these gas reductions, and the types of projects that achieve them, quite valuable to the owner operator of the facility. If policies like a cap and trade or carbon tax are ever implemented, the carbon capturing benefits of anaerobic digestion technology will likely become economically, as well as environmentally, valuable.

⁹ *Anaerobic Digester Technology*, William F. Lazarus, University of Minnesota. (2009).

¹⁰ *U.S. Anaerobic Digester Status Report*, AgStar. (October 2010).

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Economic Benefits

The majority of the economic gains from implementing an anaerobic digester will be realized through the utilization, in one way or another, of the biogas produced from the anaerobic digestion process. However, there are multiple ways to utilize this biogas, each with its own particular set of benefits and challenges. A look at each of these utilization techniques helps understand which avenue would work best on each farm operation.

On Farm v. Off Farm Biogas Utilization

While each of the benefits discussed herein has its own particular set of strengths and weaknesses, there is one particular rule of thumb farmers can keep in mind throughout the decision making process: To the extent that farmers are able to utilize the benefits and end products of an anaerobic digester within their operation, they should attempt to do so. In the absence of additional state or federal policies that might increase the sale price of electricity or natural gas to a utility, a farmer will realize the best return on his anaerobic digestion investment not by necessarily bringing in additional revenue, but by offsetting existing expenses. In that regard, the greater the on farm demand for energy and solid and liquid digestion waste, the more appealing a digester project can be to a farmer.

Electricity/Cogeneration

The vast majority (about 85%) of anaerobic digester projects in the United States utilize biogas captured by the anaerobic digester to produce electricity. To that end, currently operating anaerobic digesters produce approximately 331 million kWh of electricity per year.¹¹ In a nutshell, anaerobic digesters that produce electricity feed the biogas captured from the digested organic matter through a specially designed internal combustion engine (usually after some small amount of scrubbing). As the gas fuels the internal combustion engine, the engine turns a generator, which creates electricity. Deceptively simple, this system is designed to minimize problems and inefficiencies by keeping extra steps in the gas-to-electricity process to a minimum.

Electricity produced through the above described process is generally used through one of two, or perhaps a combination of both, processes. First, to the extent that a farmer has a need, the electricity can be used on the farm. Using home made electricity allows a farmer to significantly cut his related utility costs. For any electricity that can't be used on site, a farmer can attempt to sell the electricity back onto the electric grid. Farmers interested in selling electricity onto the grid should contact their local utility early in the planning stages of their process to determine what type of rate they'll be able to obtain for their electricity sales.



Small engine/generator system

Cogeneration

Of the 126 anaerobic digestion projects throughout the country that produce electricity, 78 are cogeneration (or “combined heat and power”) projects. Cogeneration projects are anaerobic digester projects that utilize biogas to produce electricity but, in addition, also capture the heat created by the operation of the engine. The captured heat is subsequently used for various on farm tasks, such as heating water for cleaning or heating rooms on farm buildings. Some digester projects use the waste heat from the engine to warm the manure as it heads into the digester, so less auxiliary heat is needed to bring the manure to the optimum digester temperature.¹² Cogeneration projects are especially valuable because so much of the energy created by an internal combustion engine is lost as heat (more than 60%). Using the benefits of waste heat recovery, less of the energy potential of biogas is wasted, thereby making its utilization more energy efficient.

¹¹ *Anaerobic Digesters Continue to Grow in the U.S. Market*, AgStar. (May 2010).

¹² ~100 degrees Fahrenheit.

Direct Biogas Utilization

On Farm Biogas Combustion

As digester projects developed in the United States, the captured biogas was primarily used to generate electricity. However, recent digester projects have become more interested in using the biogas for purposes other than electricity generation. By 2009, around seventeen percent of digester projects were using biogas for purposes other than generating electricity, up from nearly zero percent in 2000.¹³ Processes involved with direct biogas utilization generally burn the gas on site and use the resulting heat for various farm purposes. While not as versatile as electricity, this process is certainly more efficient, with most combustion applications achieving a 75-80% conversion efficiency, compared to 20-30% efficiency for electricity production.¹⁴

The obvious drawback of direct biogas utilization is its limited uses. Heat can be used for heating farm buildings, or heating water used to wash down animal operations. Some dairy farms even use the biogas to run their refrigeration chillers. However, these scattered uses alone would generally not utilize all of the potential heat that could be produced by burning captured biogas. While some larger hog operations have hypothesized they could use a large majority of the heat produced from direct combustion to warm their barns, this process will likely continue to be used in combination with other types of biogas utilization. Furthermore, for any direct use that will be utilized on a large-scale, consistent basis, modifications to the biogas (in the form of scrubbing), or biogas-burning machinery, would likely be necessary to limit equipment deterioration from corrosive materials naturally found in biogas. Such modifications would introduce additional costs to digester system implementation.

Marketing Renewable Natural Gas

Rather than attempting to find uses for biogas on the farm, some project developers are beginning to explore ways to export the natural gas in a form other than electricity. Experts in the industry have established that if processed correctly, biogas captured from an anaerobic digester could also be used as a substitute for commercial natural gas. Renewable natural gas or, biomethane, has the potential to meet all necessary quality standards to be bought and sold into a utility's natural gas pipeline for all manner of household, commercial or industrial uses.

So far, the process of cleaning and compressing natural gas is still fairly cost intensive. As stated, biogas captured from an anaerobic digester generally contains around 40% carbon dioxide. In contrast, pipeline quality natural gas contains less than 1% carbon dioxide. While there are scrubbing technologies designed to purify the biogas, they remain quite expensive. However, the continued economization and development of this process will be important to biogas producers because of the widespread use of natural gas across the country and the past volatility of natural gas prices.

Innovative Greenhouse Systems

In addition to traditional waste heat recovery outlets, some project developers have begun to look at greenhouses as an innovative way to get more out of an anaerobic digester system. Greenhouses provide their growers with a year round environment to grow many different types of crops. In combination with an anaerobic digester, a greenhouse could significantly reduce its operating costs by utilizing the waste heat recovered from the gas to electricity process to warm its growing environment.

Additionally, some of the carbon dioxide released during the combustion process could also be piped into the greenhouse to enrich the air the plants 'breathe' during their growing process. While this type of integrated system hasn't been implemented on a widespread scale, ideas like these will likely be used to continue to increase profitability of renewable energy systems like anaerobic digesters.

¹³ U.S. Anaerobic Digester Status Report, AgStar. (October 2010).

¹⁴ AgStar Handbook, Roos, Martin, Jr, and Moser, AgStar. (2004).

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On a related front, other developers have begun designing systems that compress biogas for future use as vehicle fuel. Aside from the cost issues surrounding natural gas compression systems, this type of gas utilization could be valuable because of its ability to access a wholly separate market, the transportation industry. The production of compressed natural gas at a biogas facility could be additionally advantageous because most vehicles designed to use compressed natural gas can utilize gas of a much lower quality (in terms of cleanliness) in their operation, thereby lowering any associated scrubbing costs.¹⁵

Hilarides Dairy

In Lindsay, California the owners of the Hilarides Dairy are successfully showing that turning biogas into compressed natural gas can be done. In addition to capturing some biogas for electricity use, the Hilarides are using the biogas captured from their 10,000 head dairy operation to produce 226,000 cubic feet of biomethane per day. After compressing the gas into usable form, the resulting compressed natural gas reduces their diesel fuel demand by 650 gallons per day. The compressed natural gas powers the dairy's delivery trucks, which use traditional compression ignited Cummins diesel engines that have been converted to spark ignited methane burners. While the cost of the technology was high, the dairy received a sizable grant from the state alternative fuel incentive program. As a result, the Hilarides now have a reliable fuel source, insulated from volatile price fluctuations of the past.

Post Digestion Waste Utilization

The waste material that remains after the anaerobic digestion process has taken place is often separated (usually via a screw press separator) into its two basic components – solid waste and liquid waste. Each of these components can be used individually to produce additional income streams for farmers. While more an added benefit to anaerobic digesters than a motivating factor, post digestion waste utilization provides a number of positive economic benefits that help make anaerobic digesters more attractive to interested stakeholders. And, as innovators in this area continue to emerge, these waste streams have the potential to become more and more valuable.

Solid Waste

Post-digestion solid waste is most commonly utilized as bedding for animals on the farm. By utilizing the solid waste from the digester, most farms are able to eliminate most, if not all, of their bedding costs. Importantly, these costs can be significant. Dairy farms in Minnesota spent \$50/cow on bedding in 2007, which means significant cost savings for operations that implement barn ready bedding producers like anaerobic digesters.¹⁶ Most farmers report that the bedding is great for cow comfort and livability. Further, since the digestion process eliminates most of the digestible organic matter, the bedding is less susceptible to disease spreading bacteria.¹⁷



Post-digested solids

¹⁵ Biogas: Rethinking the Midwest's Potential., Peter Taglia, Clean Wisconsin. (June 2010).

¹⁶ Anaerobic Digester Technology, William F. Lazarus, University of Minnesota (2009).

¹⁷ Biogas/Anaerobic Digesters., USDA/NRCS. Retrieved at: http://www.ruralenergy.wisc.edu/renewable/biogas/default_biogas.aspx.

Other Solid Waste Opportunities

In addition to conventional use as a high quality bedding material, post digestion solid waste presents other enticing value added opportunities. Some farms with anaerobic digesters sell their solid waste to local gardening centers as garden soil amendment. Others have taken the next step and molded the waste into biodegradable pots used in early season gardening. Still others have started using the solids to manufacture fiber board building materials, similar to plywood and particle board. The solid waste fiber board is made by combining fibers from the solid waste with a chemical resin, then subjecting the mixture to heat and pressure. So far, fiberboard made with digester solids seems to match or beat the quality of wood-based products.¹⁸ As these value added products develop, they may be a true driver for further anaerobic digester implementation.

Liquid Waste

The other remaining component available for use after the digestion process has taken place is the liquid waste. After running through the digester this liquid waste is generally pumped to a traditional waste storage facility, such as a lagoon. Like traditional animal liquid waste, digested liquid waste may still be used for liquid fertilizer. However, this liquid waste is generally more stable and easily applicable than normal animal waste. In fact, during the digestion process, nitrogen contained in the liquid manure is mostly converted to ammonium. As most operators likely know, ammonium is the primary ingredient in commercial based fertilizers. Thus, with a more consistently uniform waste available for application, farmers are able to reduce over application, saving additional liquid waste for future application or sale to neighbors.



Typical liquid waste application

¹⁸ Use of Anaerobically Digested Bovine Biofiber as a Fiber Source for Wood Composites., Jerrold Winandy and Zhiyong Cai. (2008).

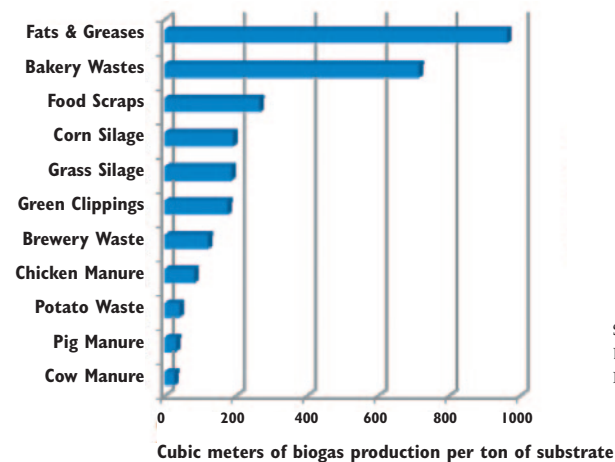
Chapter 3: New Developments/Potential Revenue Streams

In addition to the conventional technologies and anaerobic digestion applications described above, new technologies and processes are beginning to emerge that will help make anaerobic digestion an attractive option for an even broader audience. These emerging technologies will help expand the number and types of farms able to sustainably implement an anaerobic digester on their operation, and expand the types of materials available as feedstocks. Continued development in the areas outlined below will ensure digesters have a place in agricultural areas for the foreseeable future.

Codigestion

Though the most widely recognized feedstock for anaerobic digesters, animal manure actually provides a relatively small amount of biogas per pound of material when compared to other potential feedstocks. Nonetheless, animal waste has continually been used in digesters because of its widespread availability, handling/management issues, and its previously mentioned ancillary benefits. However, digesting organic materials with higher biogas potential than animal manure, or even combining such waste with animal manure, would greatly increase biogas production and make many facilities previously thought to be unworkable, newly viable.

Biogas Potential of Substrates



Source: Data derived from www.biogasenergy.com, ©2007 Biogas Energy, Inc., translated from: Basisdaten Biogas Deutschland, März 2005, Fachagentur Nachwachsende Rohstoffe e.V.

Such is the basic premise behind codigestion. Codigestion facilities mix traditionally digested animal waste with other organic matter such as Fats, Oils and Grease (FOG), food scraps, cheese waste, or even brewery waste in their anaerobic digestion facilities. Anaerobic digesters can not only use, but indeed thrive on, these other types of organic matter, which have a much higher waste-to-gas ratio than animal waste. While 22% of operating digesters currently employ some form of codigestion, the discussion of benefits to codigestion laid out below indicates why this number is likely to grow in the near future.¹⁹

¹⁹ U.S. Anaerobic Digester Status Report, AgStar. (October 2010).

Codigestion Benefits

Increased Array of Feedstock

The most obvious benefit of codigestion is an increase in available feedstocks for those digester operations who want to expand their biogas production beyond their animal waste capacity. Any organic material can be digested, but past operations have used cheese whey, spoiled corn, spoiled animal feed, and FOG. Often, the parties responsible for producing this waste are eager to dispose of these materials any way they can, and will even pay interested parties for help disposing of it. Of course, the initial issue with this benefit is finding the right combination of availability and location, so that the cost of transport of the added feedstocks would not outweigh their added benefit. However, as solid waste disposal regulation becomes increasingly strict, large scale commercial and industrial waste producers will continue to search for alternatives to their traditional landfill-type methods of waste management, including codigesting anaerobic digester facilities.

Increased Biogas Production

With the right combination of animal waste and other organic feedstock, biogas production levels have been known to jump anywhere from 200 to 500%.²⁰ While increased biogas production is useful to any operating facility, it could prove vital to one particular segment of the farm community: small and medium sized farms. Currently, AgStar estimates that anaerobic digesters are only viable on farms with 500 or greater cows or 2000 or greater pigs. They base their estimate on the amount of animal waste farms of this size would produce and how much gas, in turn, could be captured through the digestion of said waste. However, with the increase in biogas production found in co-digestion, many smaller farms could have the opportunity to economically implement an anaerobic digester at their facility. In fact, at the Jer-Lindy Dairy near Brooten, MN, the owners of an anaerobic digester have recently added cheese whey as a substrate to their digester and report an increase in biogas production of about 300%.

Tipping Fees

In addition to increased biogas production resulting from codigestion of alternative feedstocks, many organizations pay tipping fees to the disposing party just to rid themselves of the organic waste materials. In the case of an anaerobic digester, farmers could be paid tipping fees to dispose of (digest) other companies' organic waste. While tipping fees alone would not likely be the determining factor for constructing a digester facility, they certainly provide added incentive for the construction of such a facility.

Nutrient Balancing

One problem with field applying liquid waste as fertilizer on farms throughout the region is the relative imbalance of nutrients it contains. While this waste is very high in ammonium, it is relatively deficient in other valuable field nutrients. However, by introducing other types of organic wastes through codigestion, more nutrients could be mixed in to help balance these potential fertilizers from the outset.²¹ With the right mix of various organic wastes, the nutrient mix in post digestion waste could be optimized, creating a more useful, less environmentally harmful field applied fertilizer. Such a fertilizer would save farmers costs on additional fuel and fertilizer costs that would otherwise be necessary to supplement the soil.

²⁰ Co-digestion of Food Waste and Dairy Manure for Biogas Production., El-Mashad and Zhang. (2007), *Biogas: Rethinking the Midwest's Potential.*, Peter Taglia, Clean Wisconsin. (June 2010).

²¹ Characterization of the Biomethanization Process in Selected Waste Mixtures., Montusiewicz, et. Al. (2008)

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Community Digesters

In 2003, the Minnesota Department of Commerce estimated that 99% of dairy farms in Minnesota had less than 300 cows.²² However, most experts estimate that typical one farm anaerobic digesters are most economically viable on farms with more than 500 cows. A community based digester, like codigestion, is another anaerobic digestion model that could enhance the economic viability of utilizing small farms' animal waste to fuel an anaerobic digester. Technology-wise, a community digester operates the same way as any other large scale anaerobic digester. The primary difference, and main selling point to small farms, is how the digester secures feedstock to keep the digester running. Operating in a cooperative fashion, centrally located community digesters harness the waste from multiple surrounding farms, rather than one large farm operation. If properly designed, such a community digester could also receive organic waste from neighboring communities and local businesses.

Community digesters have begun to receive greater attention as smaller farms and communities begin to examine ways to make their operations more sustainable and economically viable for a future generation. As of October 2010, 14 community-type anaerobic digesters were receiving manure from multiple area farms.²³ The majority of these digesters are located in a central, non-farm, location. Two of the community digesters are located on one of the farms that contributes waste to the project. The primary obstacle to increased community digester development is the transportation costs of getting the animal waste to the facility. Without a state policy supporting increased rates for electricity production or some other tipping fee, it is estimated farms would need to be within one to two miles of the digestion facility to make a community-type digester most successful.

²² *Minnesota's Potential for Electricity Production Using Manure Biogas Resources*, Minnesota Department of Commerce. (April 2003).

²³ *U.S. Anaerobic Digester Status Report*, AgStar. (October 2010).

Chapter 4: Evaluating On Farm Anaerobic Digester Feasibility

Through many years of both good and bad experiences, experts in anaerobic digestion project development have acquired a significant amount of information regarding what types of projects are best suited for anaerobic digesters and how interested stakeholders can become involved. This chapter outlines some of the preliminary issues interested farmers should take into consideration, along with a list of parties who are best contacted from the outset of the project evaluation process. While each of the considerations listed herein has been developed drawing on past experience, none of them should be construed to discourage interested parties. As farm conditions and the digester industry continue to evolve, even these considerations will likely be revised. Use the points discussed below as jumping off points, not as roadblocks.

Determine Digester Viability²⁴

AgStar lists a number of preliminary considerations farmers should take into account as they think about whether an anaerobic digester is right for their operation. A quick rundown of this list provides a nice starting point for the evaluation process.

- **Farm Size.** Using the conventional means of constructing an anaerobic digester on a farm, AgStar estimates that a dairy or swine farm should have herd sizes of 500 cows or 2000 pigs, respectively, to produce enough manure to make a project economically viable.²⁵
 - **Other Considerations.** AgStar is quick to note, however, that any number of site specific variables could make smaller projects practical. Such variables could include above average utility rates, opportunities for codigestion, opportunities for a community-type digester, or above average on farm energy use.
- **Manure Handling.** Predictably, one of the most important factors for predicting digester viability is a farm's manure handling system. Manure production needs to be stable the entire year, needs to have a fairly low solids content (0-15%), and should be free from large quantities of bedding or other materials that might plug up the digester input valves and pipes.²⁶ Additionally, the manure should be collected on a regular (daily, weekly) basis and would work best if collected from a single point.
 - **Other Considerations.** Manure production and collection needs to be consistent to ensure the digestion process remains healthy. High solids manure facilities could be adapted to better suit the digester process, but such modifications would be expensive. However, new developments in dry digestion technology should be investigated as an alternative to the conventional high liquid digestion process. These systems can handle significantly higher solids contents through their adapted digestion processes.

²⁴ This chapter is primarily comprised of information contained in AgStar's superb: AgStar Handbook, 2004. This guidebook gives a great amount of detail on all aspects of digester development, from the early planning stages to securing power purchase agreements. There is no better place to start than this guidebook. A companion tool, AgStar's FarmWare computer program can take information from specific farms and give estimate of digester feasibility based on the customized data. For parties just beginning the early planning stages of their project, each of these tools is a vital resource.

²⁵ AgStar Handbook, Roos, Martin, Jr., and Moser, AgStar. (2004).

²⁶ Managing Manure with Biogas Recovery Systems., AgStar (2002).

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Additional Digester Viability Factors

In addition to the issues discussed above, these unique factors might also raise the usefulness of a digester on a given farm, even in the face of hindrances or economic limitations in other aspects.

- Severe odor management concerns
- Particularly environmentally sensitive areas
- Exceptionally high local energy/fertilizer costs
- Climate change/carbon regulation state or federal policy developments

- **Gas Use.** Though discussed in greater depth above, farmers should have an idea early on about how they plan to use the large amounts of biogas that an anaerobic digester will produce. Farmers should take account of their on farm electrical and/or natural gas use, along with any heating or water heating costs they may be able to eliminate through the use of the anaerobic digester's captured biogas.
 - *Other Considerations.* Heat will be generated regardless of whether a farmer ultimately decides to produce electricity or use the biogas directly. As such, a farmer should consider plans to utilize captured or produced heat to warm buildings or preheat water systems. While on farm energy use is most economical, farmers should also consider what other stakeholders might be interested in purchasing the biogas or electricity.
- **Additional Cost Savings.** In addition to utilizing the digester's biogas production, farmers also need to consider the specific cost savings to their operation through the use of the post digestion solids (for bedding) and liquids (for fertilizer). These cost savings will be a significant part of the economics of the project and should not be undervalued.
 - *Other Considerations.* If on farm uses for either of these digestion by-products is low, or if additional revenue streams are sought, farmers could consider marketing either of these products as a more central part of a business plan. Producing value added products such as biodegradable pots would add to start up costs, but could increase the long term economic value of installing an on farm anaerobic digester.
- **Time Commitment.** Though a seemingly simple consideration, this issue should not be underestimated. Anaerobic digesters are dynamic systems requiring consistent maintenance and adjustment. Especially in the early stages of the project, these systems will require significant time and attention to optimize biogas production. Once established, the systems will be running 24 hours a day and may require assistance at any time. In addition to daily maintenance (15 – 45 minutes), routine maintenance to the genset and other ancillary systems will also be required.
 - *Other Considerations.* Unless a standalone digester operator is hired, the digester owner/operator should undergo digester system training from the system designer. The owner/operator should have basic mechanical repair ability and should possess (or learn) some technical knowledge about how to operate and maintain the anaerobic digester.

Contacting Professionals

Aside from the preliminary self screening and considerations outlined above, most of the significant process toward implementing an anaerobic digester on the farm will be accomplished in conjunction with professionals who work with surrounding development issues on a daily basis. Professionals in project development, utilities, permitting, and finance will all be instrumental in helping to develop an economically viable facility that is the right fit for a specific farm's operation. Farmers should utilize the expertise of these individuals while still keeping their individual goals in mind. Above all other advice, early contact with each of these parties will provide the greatest chance of a successful planning process.

Project Development/Design

Working with Experts

While many farmers are used to managing large farm projects from start to finish, the high degree of technical expertise necessary to implement a successful digester project would likely make hiring a consultant or project developer a worthwhile endeavor. Depending on the level of involvement the farmer wishes to have with the process, outside consultants can be hired to serve an advisory role throughout the process, or a project developer can be brought on to take the project from start to finish.

In either scenario, the outside professionals will be useful in providing guidance on what type of digester system would work best on the specific farm in question; considering the farm's herd size, farm space, and current manure handling system. A consultant can also serve as an additional point of contact between the farmer and all other involved parties, like the utility, bank, and permitting officials. Essentially, the project development team and the farmer are working toward the same common goal – installing an anaerobic digestion system – and the developer's experience in the industry should be utilized as a partner in this respect.

There are many different system designers and providers, so it's important to perform due diligence investigating all of the practical options. However, the high level of competition among digester designers should work in farmers' favor in terms of receiving a high level of customer service and technical assistance, combined with a level of involvement the farmer is comfortable with.

What To Expect

Upon first contact, developers will likely ask a number of questions to get a feel for the specific circumstances of the farm operation in question. A farmer should have information such as farm size and type of manure management system readily available. In talking with various consultants and project developers, this initial exchange of information is generally quite informal and low-pressure. As communications develop, it's likely the developer will ask for more detailed information such as on farm energy use and other information related to economic feasibility. With each added communication, the farmer can expect to receive more detailed information as to how a digester might work on his operation. After establishing a good rapport, the developer may even perform a site visit to best understand the potential setting for its digester system. Finally, after gathering sufficient information, the digester professionals will likely be able to provide a rough project cost estimate laying out the economics of a potential project, and the path for proceeding in an official consultant/developer capacity.

Industry Directory

The best way to meet high quality system designers is to talk with peers who have gone through or investigated the process. However, the number of available peers who have this type of experience may be limited. For a list of industry professionals with good experience in the anaerobic digestion business interested parties should access AgStar's anaerobic digester industry directory. The directory provides a list of contacts who perform service in all aspects of project development. To access the directory visit:

■ <http://www.epa.gov/agstar/tools/directory.html>

Unsure of Who to Talk to First?

Feel free to contact the Minnesota Project. Aside from putting together publications such as this, The Minnesota Project has experience with planning and developing digester projects. The Minnesota Project can provide additional information resources, help review business ideas, or simply offer a second opinion. Farmers should not hesitate to be in touch. The Minnesota Project's mission is to promote the sustainable production of energy in rural communities.

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Potential Utility Incentives

Renewable Energy Standard.

In Minnesota, all electric utilities in Minnesota are required to use renewable energy projects to produce 25% of their electricity sold by the year 2025. Because of this mandate, utilities are often, though not always, willing to pay a slightly higher rate for the electricity produced at a renewable energy project such as an anaerobic digester.

Net Metering. Net metering requires utilities to purchase electricity produced by renewable energy projects with a nameplate capacity of 40 kWh or less at the utility's average retail rate. This added price is a great value, but the 40 kWh facility size limit will likely foreclose many facilities from qualifying for the policy, unless projects are developed using a combination of electricity production and on farm use.

Conservation Improvement Programs (CIP). In order to fulfill their state mandated requirement of conserving 1.5% of energy sales through energy efficiency, most utilities provide financial incentives for on farm practices that conserve energy use. Though not well established, it's possible that replacing on farm natural gas use with biogas could qualify as a CIP project, eligible for financial incentives.

Utility

After contacting a project developer, if not sooner, the next point of contact an interested farmer should make is with the local utility. If planning to sell electricity or biogas, the electric and/or gas utility will be involved in some of the most intensive design and analysis efforts parties will have throughout the entire planning process. As such, it's important to involve utility staff at the preliminary stages of the planning process so any potential project will be designed with utility related issues – such as interconnection, rate structures, and renewable energy incentives – figured into the plans.

Utilities serve a unique role in the digester development process because of their role in the financial, technical, and practical aspects of the anaerobic digester. Financially, if a farmer is planning to sell electricity or biogas, utilities will be the primary contact when attempting to secure a purchase agreement. The price secured for this energy production will be determined by a number of different factors including the current rate of other energy options, the amount of energy being produced, or the utility's progress towards meeting its renewable energy standard requirement. A list of important contract considerations, too numerous to list here, are contained in the AgStar handbook. The list provides a good compendium of issues to keep in mind when negotiating a contract, as well as a quick rundown of the positive benefits these types of projects can provide utilities, to keep things in perspective.²⁷

Technically, a utility will be involved with connecting the anaerobic digestion project to transmission lines or pipes (depending on whether gas or electricity is being sold) necessary to get the energy to customers who need it. Facility design and layout will obviously have a significant impact on keeping this process as inexpensive and painless as possible. Practically, utility staff have a good understanding of issues related to electricity production and use. Their advice and involvement in the development of on farm digester projects is likely to provide a good blend of localized knowledge and industry experience.

Permit Offices

It is vitally important to contact all relevant permitting authorities early in the project development process to ensure any digester project moves forward in a timely manner. For farms with any substantial preexisting waste management facility, farmers will likely be familiar with the individuals necessary in providing guidance on an anaerobic digester project. However, if codigestion is being considered, farmers should also contact all relevant solid waste management officials. Keep in mind that permitting officials, like any other individuals not involved in the business, likely have little experience working with anaerobic digesters. Therefore, it may take a good amount of time to work towards a permitting plan that is acceptable to all parties. Involving these officials early in the planning stages ensures they will be allowed to provide guidance on an acceptable course of action, which will likely eliminate future obstacles as the project begins to take shape.

²⁷ AgStar Handbook., Roos, Martin, Jr., and Moser, AgStar. (2004).

Design a Business Plan

As discussed above, because of the myriad non-economic benefits of anaerobic digesters, farmers are often pleased with their digester project if they can break even financially. However, stakeholders with capital available to finance such projects want to see a positive rate of return or at least assurances that a farmer will be able to pay back his debt. Therefore, in designing a business plan, farmers must work toward assuring potential investors that an anaerobic digester is not only economically feasible, but economically desirable.

Farmers undoubtedly have experience working on projects that require large amounts of financing. A digester project is no different. Farmers need to show how the project plans to generate revenue and defray farm operation costs on its way to economic sustainability. However, because anaerobic digesters are fairly uncommon to most conventional financing organizations, the farmer will likely have to work harder than normal at addressing project risks attendant with any large project. Issues typically addressed in a solid digester business plan include, among others:

- Biogas production stability
- Equipment performance
- Utility agreements
- Financial performance
- Environmental permitting²⁸

Though traditional financing models will likely provide for the majority of projects costs, anaerobic digesters may be eligible for a number of favorable loan or grant programs that can help alleviate the often substantial financial burden these projects can create. These incentives, combined with solid, predictable project payback timelines, work together to promote digester development across the Midwest. A few of the most notable programs include:

Rural Energy for America Program (REAP)

<http://www.rurdev.usda.gov/rbs/farmland/>

- This federal program funds renewable energy and energy efficiency projects located in rural areas. The program provides grants of up to 25% project costs and loans up to 75% of project costs. Since 2003, \$37 million has been awarded to anaerobic digester projects alone.²⁹

Environmental Quality Improvement Program (EQIP)

<http://www.nrcs.usda.gov/programs/eqip/>

- This federal program run through the USDA and Natural Resource Conservation Service (NRCS) is most often utilized for traditional conservation practices that help improve soil quality and runoff issues. However, this program contains provisions for helping to fund qualifying anaerobic digester projects as well.

²⁸ AgStar Handbook, Roos, Martin, Jr., and Moser, AgStar. (2004).

²⁹ Anaerobic Digesters Continue to Grow in the U.S. Livestock Market, AgStar. (May 2010).

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Conservation Innovation Grants (CIG)

<http://www.nrcs.usda.gov/technical/cig/index.html>

- Conservation Innovation Grants (CIG). Another NRCS run program, CIG grants are designed to stimulate the development and adoption of innovative conservation approaches and technologies. Past CIG grants have included projects related to anaerobic digestion technology.

So What's it Cost?

Because of their unique design on a farm by farm basis, the costs of anaerobic digester projects have been notoriously hard to estimate without site specific information. However, upon analyzing a number of projects across the country, experts have developed some data that can serve as a ballpark estimate of what types of costs farmers can expect to see in a typical digester project. These estimates should, obviously, be taken as estimates only, as actual project costs will vary from situation to situation. As digester technology continues to develop these systems will become increasingly cost effective.

■ **Formulas to figure capital costs of digesters:**

- Complete Mix: $563 \times \# \text{ of dairy cows} + 320,864$
- Plug Flow: $617 \times \# \text{ of dairy cows} + 566,006$
- Covered Lagoon: $400 \times \# \text{ of dairy cows} + 599,556$

■ **Average costs of ancillary digester equipment:**

- Post digestion solids separators: ~ 6.4 % of total capital costs (range from: 1.5 – 12%)
- Biogas treatment system: ~ 3.1% of total capital costs (range: 0.3 – 6.0 %)
- Estimated utility charges ~ 5.3% (range: 1.7 – 13.5%)

■ **Other general rule of thumb economics:**

- Engine-Generator costs usually account for 40% of project costs
- 14% for O&M and Capital costs per year³⁰

³⁰ Anaerobic Digester Technology, William F. Lazarus, University of Minnesota (2009).

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