Wisconsin Biogas Survey Report

Wisconsin Office of Energy Innovation
610 N Whitney Way, 2nd Fl
Madison, WI 53707
OEI@wisconsin.gov

Acknowledgements

The information, data, or work presented herein was funded in part by the Office of Energy Efficiency and Renewable Energy (EERE), U.S. Department of Energy, under Award Number DE-EE0006222 and DE-EE0006486.

The Wisconsin Office of Energy Innovation (OEI) would like to give special acknowledgement to those organizations and individuals that provided the source information for anaerobic digestion (AD) systems in Wisconsin, in particular Dennis Totzke of Applied Technology, Inc. and Allison Costa at the US Environmental Protection Agency and AgSTAR for complete preliminary data to begin reaching out to AD system operators. We were also very grateful for the additional essential support provided by the Wisconsin Wastewater Operators Association, Dairyland Power Cooperative, BIOFerm, RENEW Wisconsin, the Water Environment Federation, the US Department of Energy, the US Energy Information Administration, the International Energy Agency, and the American Council for an Energy-Efficient Economy. A special thank you to Clint Fandrich, Amanda Mott and Joe Kramer for your hard work in collecting, analyzing and organizing the survey information to the benefit of the AD industry in WI.

Of course, this study would not have been possible without the participation of AD system operators, managers, and owners across the State of Wisconsin. Your time and willingness to share information about your systems was essential to this study, and this report is an amalgam of your responses. Again, thank you, and we hope these findings can be used to improve your operations.

Disclaimer

Photo Credit

Executive Summary

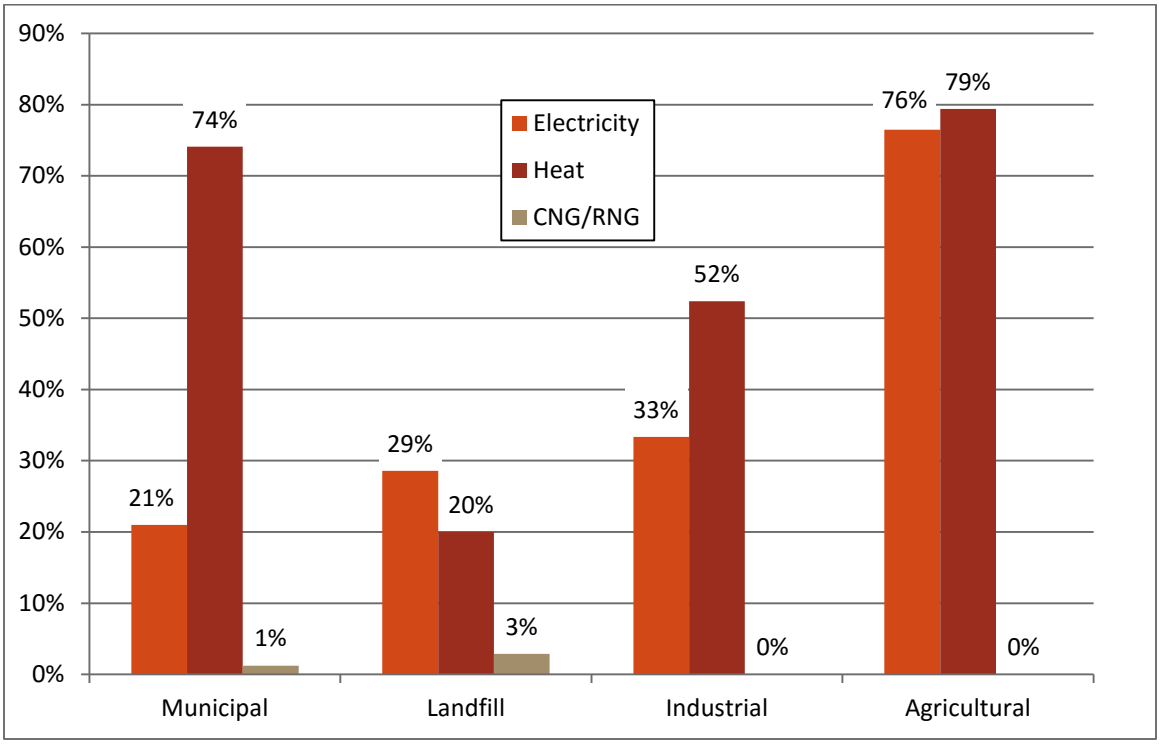
There are 136 operating anaerobic digester (AD) systems and 35 landfill sites that capture gas in Wisconsin. AD systems are used to treat manure at livestock operations, and wastewater at industrial and municipal facilities. The total systems are broken down in Table 1.

Table 1 - Biogas Systems in Wisconsin

Sector	Number of systems
Municipal wastewater with digester	81
Landfill with gas capture	35
Industrial wastewater with digester	21
Agricultural with digester	34

These systems produce a renewable gas, commonly called biogas, which is converted to millions of Btu in heat, used to power 140 MW of electrical generation capacity, and used to offset thousands of gallons of diesel fuel per year. The proportions of biogas systems used for energy or fuel are illustrated in Figure 1 below. Some of these systems also offer other co-products such as crop fertilizer and bedding for farm animals.

Figure 1 - Biogas Uses by Sector



The Wisconsin Office of Energy Innovation (OEI) conducted a survey to examine the current status of the state's anaerobic digester industry. The survey sought to identify primary operational challenges, key financial barriers to project development, and opportunities for future industry development. A healthy AD industry would create jobs and economic opportunity for communities around the state while improving environmental quality.

In total, OEI surveyed representatives from 146 facilities including the majority of those in each of the four sectors. The survey responses outlined four primary challenges:

- Need for proper **maintenance and support** for cost-effective and safe operation of electricity generators,
- Lack of **inter-sector collaboration** and information sharing,
- Insufficient **revenue generation** for successful biogas project implementation, and
- The establishment of and adherence to effective anaerobic digester system **operation and maintenance** procedures.

Still other challenges exist, such as those related to environmental regulatory compliance, (negotiating?) establishing fair tipping fees, and project financing, but these are intimately connected to the four primary challenges outlined above and may be addressed in concert.

Energy generation equipment. A primary challenge highlighted by survey respondents is the failure of AD system design to protect electrical generation equipment from impurities in biogas that can lead to premature equipment failure and increased maintenance costs. Survey respondents recommended allocating equal capital expense for biogas scrubbing as for electricity generation and contracting with an outside operator to perform regular maintenance of the generator equipment.

Inter-sector collaboration. Respondents in each sector (industry, landfill gas, agriculture, and municipal wastewater treatment) noted they had no forum to discuss technical and operational issues so that lessons learned might promote better overall performance of the technology. The second challenge identified lacking collaboration between the four main biogas industry sectors which inhibits information sharing about feedstock availability and shared maintenance challenges. In response to this, the Wisconsin Office of Energy Innovation (OEI) has dedicated itself to providing a forum through which AD facility owners and operators, along with developers and engineers, can meet to discuss the barriers they face and coordinate the industry's efforts in solving unsettled challenges and disputes.

Revenue generation. The third challenge was a result of the biogas industry's heavy reliance on renewable power generation via the state's Renewable Portfolio Standard, but have recently not been given favorable Power Purchase Agreements for renewable power generation. A possible solution is finding alternative revenue streams such as the further development of biogas as a transportation fuel by installing compressed natural gas (CNG) infrastructure and the simultaneous conversion of key commercial trucking and municipal vehicle fleets that AD systems are affiliated with to use the fuel.

Operation and maintenance. The fourth and final challenge lies in proper system maintenance and operation. Implementation of community digesters to share the costs and expertise for effective system operation and maintenance could be a solution.

There are significant challenges remaining to ensure the sustainable and economical operation of biogas facilities in Wisconsin, but there are highly successfully operating projects to learn from and emulate. In this capacity, the survey has helped OEI to identify these success stories to share them with the biogas industry and policymakers.

Contents

List of Illustrations

Background and Purpose

Wisconsin has long been a leader in use of biogas systems and anaerobic digester (AD) technology. Renewable energy legislation, tax incentives, resident industry composition and technical and financial resources have all contributed to expansion in biogas system use in multiple private and public sectors. In response, Wisconsin has also become home to numerous AD design companies and affiliated businesses that support biogas systems and equipment.

These businesses are important to the economic base of the state. Furthermore, the use of biogas systems is recognized as desirable because they improve economic and environmental outcomes for wastewater and manure treatment operations and the surrounding communities, and can produce renewable energy.

The Wisconsin Biogas Survey is the most comprehensive look at the Wisconsin biogas industry to date, and can serve as a baseline for measuring industry changes going forward. OEI hopes to use the information to help the industry improve biogas system maintenance, operation, and best practices. This information can help farmers, municipalities, landfills and private companies across Wisconsin with existing or planned biogas systems serve their particular waste, resource, and/or energy needs. This information will also be used to inform discussions about organic waste management in Wisconsin and how these materials can be used to produce energy or serve other roles in economic development through greater collaboration between organic waste producers and the AD systems in their communities. Study findings will be shared with biogas industry stakeholders to continue discourse and move toward potential solutions to the industry's challenges.

Methodology

The Wisconsin Office of Energy Innovation (OEI) surveyed owners and operators of biogas systems to better understand the state-of-play of Wisconsin's biogas industry. Analysis of responses has helped OEI identify challenges to biogas use to inform development of policies and programs that can improve conditions for the biogas industry in Wisconsin.

The survey was designed to provide updated information in the following areas:

1. Operational status of the AD system;
2. Current use of the biogas produced by the AD system;
3. Primary challenges to project development and optimal system operation;
4. Solutions to these challenges; and
5. Short-term (1-2 year) outlook for system operation, regulatory compliance, biogas utilization, etc.

Sources of Facility Information

OEI has a history of working closely with other organizations supportive of the biogas industry. These include: the Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP), the American Biogas Council (ABC), the Environmental Protection Agency's AgSTAR Program, and others. As a starting point, OEI gathered facility information from the following sources.

- **Farm digesters and systems categorized as agricultural**- US EPA's AgSTAR website. This list is well maintained and frequently updated by EPA staff with help from state agencies.
- **Municipal wastewater treatment plants** - Wisconsin Wastewater Operator's Association (WWOA) website. WWOA also maintains up-to-date information on all wastewater treatment plants throughout Wisconsin and offers several different criteria to search for specific plants, including the use of anaerobic digesters. Other summary and supplemental lists were acquired through the Water Environment Federation and the Federation's resource recovery site. www.resource recovery data.org.
- **Landfill sites** - EPA's Landfill Methane Outreach Program website. These datasets are also frequently updated and offer details about volumes of waste materials at monitored sites that could be useful in future studies related to organic waste diversion.
- **Industrial facilities** - Multiple sources including a private list maintained by Dennis Totzke at Applied Technology, Inc. Mr. Totzke's list was cross-referenced and expanded using information from the second source that was gathered by our partners at RENEW Wisconsin, a renewable energy advocacy and education organization.
- **Multiple-sectors** - Dairyland Power Cooperative, US Department of Energy (DOE), US Energy Information Administration (EIA), International Energy Agency (IEA), and American Council for an Energy-Efficient Economy (ACEEE). Information from these organizations allowed OEI to cross-reference and confirm AD system information.

Data from these sources on size, location and feedstock of AD systems was modified by OEI staff in the following ways:

- Updating and completing location information such as county, city, and street address for each system;
- Updating contact information for system operators or managers;
- Removal of duplicate system entries; and
- Simplification of relevant data for the purposes of this study

Timeframe and Scope:

Beginning in August of 2014, OEI staff began contacting all known AD facility managers by sector. These sectors include municipal wastewater treatment plants, landfill facilities, industrial food or biofuel producers, and farm facilities. Table 2 below details the number of facilities contacted in each sector and the timeframe during which these facilities were contacted.

Table 2 - Facilities Contacted and Timeframes

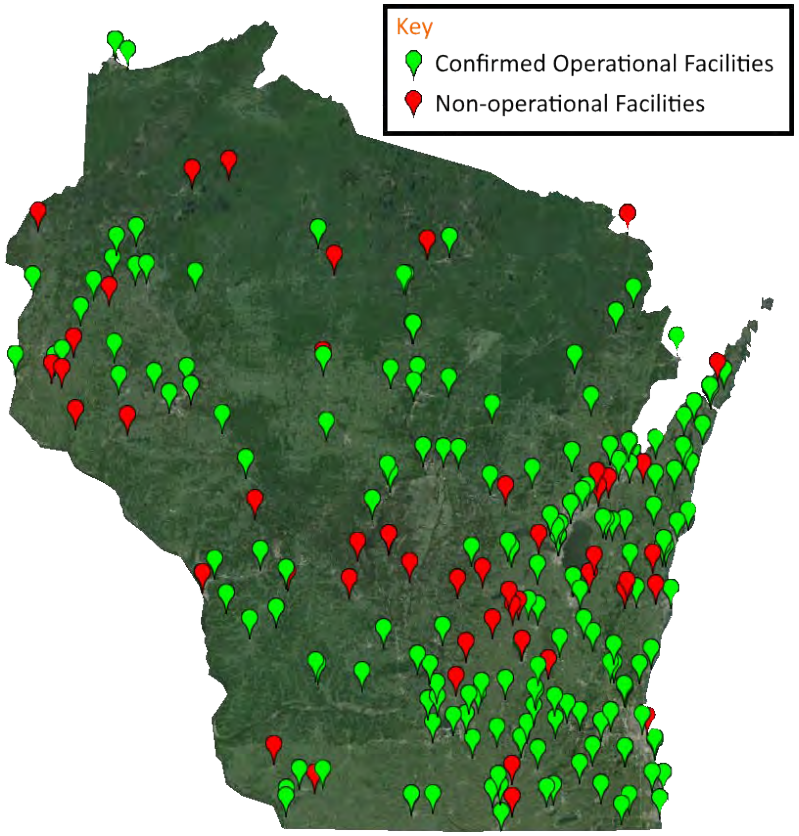
Sector	Contact Timeframe	Number of Facilities
Municipal Wastewater Treatment Plants	August – November 2014	83
Landfills	October – December 2014	42
Industries	December 2014 – March 2015	31
Agriculture	December 2014 – March 2015	64
Total number of facilities contacted:		220

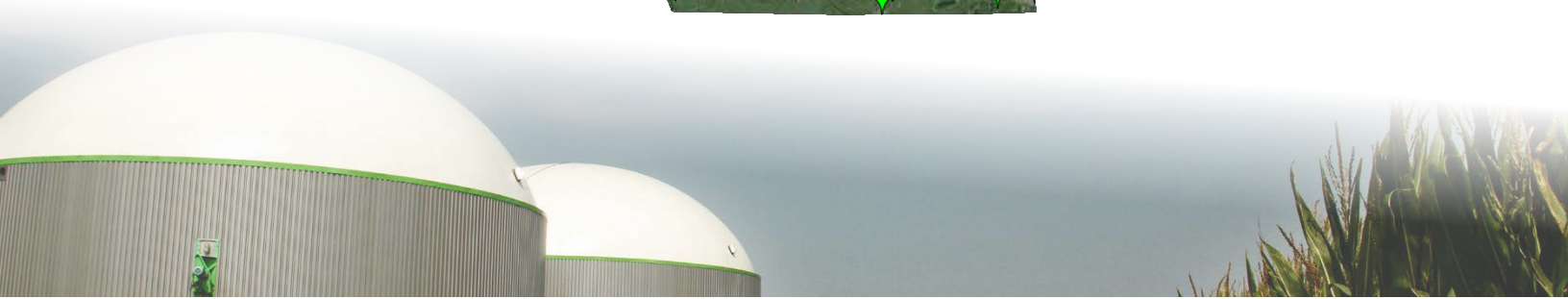
Note: Not all facilities contacted currently or ever had biogas systems installed. In some cases, contact allowed erroneously listed facilities to be removed from the preliminary system lists.

The geographic distribution of these facilities is state-wide, but a majority of the facilities (with the exception of farms) are situated in the south-central, south-eastern, and east-central regions of Wisconsin. OEI staff conducted several on-site visits to AD facilities that are clustered in or near major population centers and industrial regions of Wisconsin.

Figure 2 is a map of Wisconsin showing the distribution of AD systems across the state. The green icons indicate facilities that were confirmed to be in operation and the red icons represent sites that were on preliminary lists but were found to not have AD systems either because they had an operating system but no longer do, or they had proposed facilities but they were never built.

Figure 2 - Distribution and Status of AD Systems





Survey Method

OEI staff contacted each facility by phone to determine willingness to participate in the survey and to schedule the actual survey of the biogas operation. Completed surveys were conducted in one of three ways: by telephone, in-person, electronically via email. Most often, the surveys were conducted over the phone and lasted 15 to 60 minutes. In-person surveys were conducted during facility visits. These in-person visits lasted 30 to 90 minutes. Additionally, one facility representative chose to respond to the survey electronically by filling out the survey questionnaire and returning it to OEI staff (the survey questionnaire is located in APPENDIX A – Survey Instruments).

OEI was only able get partial or informal responses from 74 contacts most of which did not currently have, or never had, an operating system. Contact with those facilities allowed OEI to refine the number of biogas systems in operation in Wisconsin and gather information about why facilities are shutdown. Table 3 below details the number of facilities by sector that gave detailed responses to the survey either over the phone, in-person, or electronically, as well as those for which only partial information was obtained.

Table 3 - Sector and Survey Methods Used

Sector	Phone Survey	In-Person Survey	Electronic Survey	Partial or Informal responses
Municipal Wastewater Treatment Plants	45	18	0	20
Landfills	17	1	0	24
Industries	16	6	0	9
Agriculture	35	7	1	21
Totals	113	32	1	74
	Total Complete Surveys: 146			

Note: The number of surveys conducted does not reflect the actual number of AD systems in operation in Wisconsin as many facilities are represented by a shared entity that fielded questions about the multiple systems they operate.

Survey Results

The interactions with biogas system owners and operators are summarized in the following sections.

Wisconsin Biogas Industry Snapshot

Wisconsin is one of the highest biogas using states in the U.S. It is home to 136 AD systems at municipal wastewater treatment plants, industrial food or fuel producers, and agricultural livestock operations. In addition, Wisconsin has 35 landfills that capture gas so that it could be used for energy. Table 4 below lists the count of systems for each category.

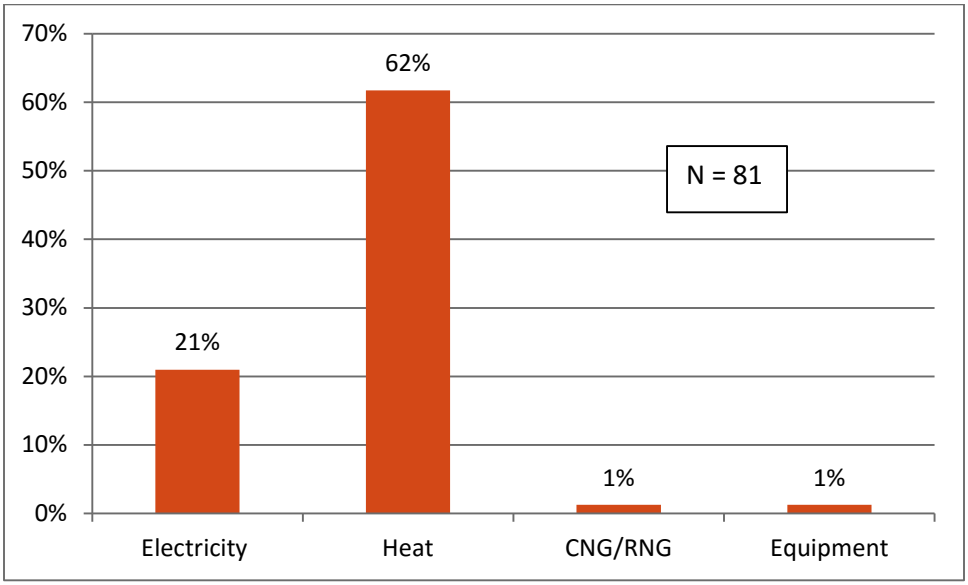
Table 4 - Biogas Systems by Sector

Sector	Number of systems
Agricultural with digester	34
Industrial with digester	21
Municipal with digester	81
Landfill with gas capture	35

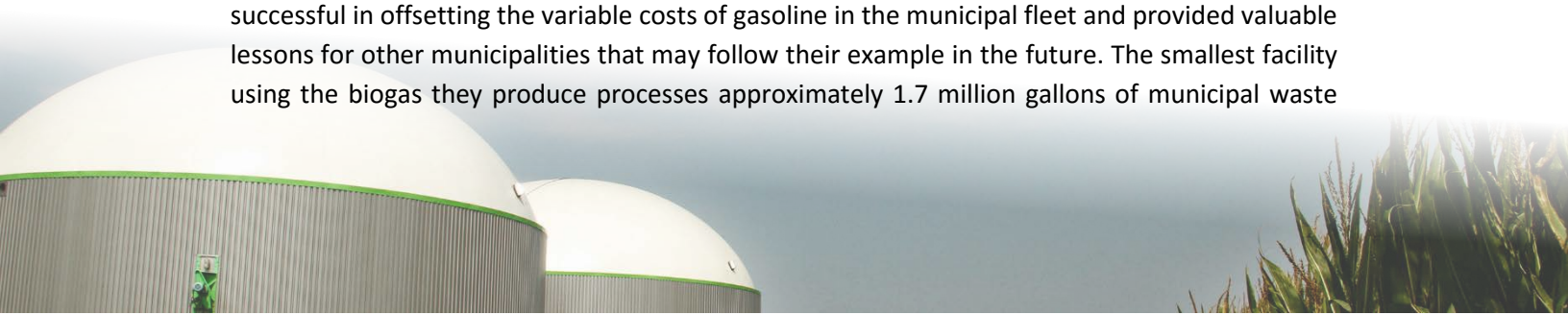
Municipal Wastewater Treatment Facilities

There are 81 municipal wastewater treatment facilities that operate AD systems in Wisconsin. These systems vary dramatically in size and output, and some bring in additional waste from offsite to be co-digested with the municipal waste stream. Sixty of these facilities use biogas in some way other than flaring it and many use it for multiple purposes. Figure 2 shows the proportions of facilities using biogas for different purposes.

Figure 3 - Biogas Uses at Municipal Treatment Plants



Electricity and heat generation were the most common biogas uses in this sector. Together, municipal wastewater treatment plants in Wisconsin have an installed electrical generation capacity of more than 14 megawatts (MW). Often, the heat produced was used to maintain the AD system's required temperature and also for space heating in surrounding buildings. Facilities that produced electricity had power purchase agreements (PPA) with the local utility company to offset the plants' energy or operating costs. In addition to heat and electricity production, one facility is further refining excess biogas and compressing it to use it as transportation fuel, known as compressed natural gas (CNG), for the city's vehicle fleet. In this case, the city has been successful in offsetting the variable costs of gasoline in the municipal fleet and provided valuable lessons for other municipalities that may follow their example in the future. The smallest facility using the biogas they produce processes approximately 1.7 million gallons of municipal waste

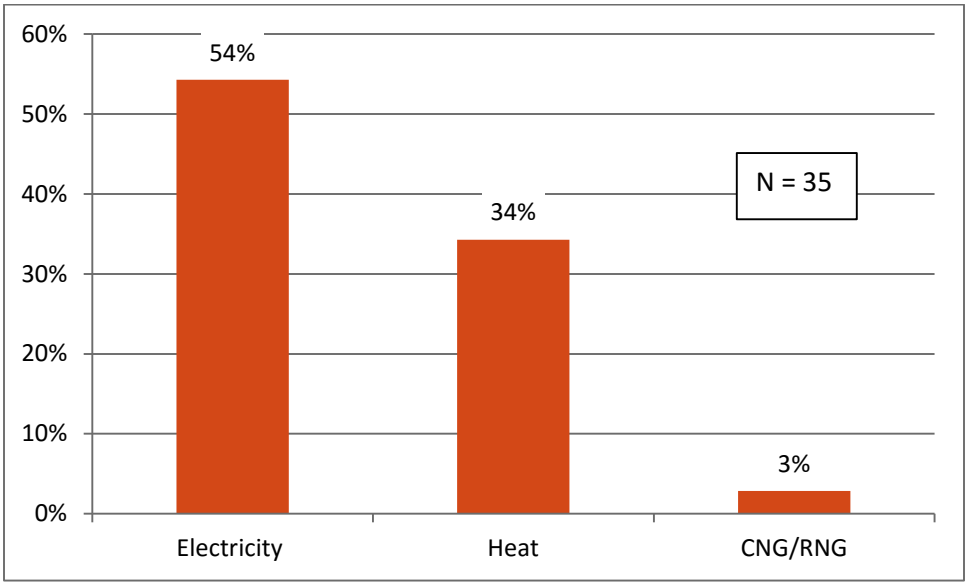


every day suggesting this may be a practical baseline for biogas uses beyond digester heating. These are the first steps in developing Wisconsin's CNG fueling network, a substantial economic growth opportunity.

Landfill Biogas Capture Programs

Of the 35 distinct landfill gas capture programs operating in Wisconsin, only 10 use the gas to produce heat, electricity, and/or CNG vehicle fuel. Many other landfill facilities expressed interest in using the biogas, but have been unable to do so to date. Figure 3 below shows the proportions of utilities using biogas split out by application.

Figure 4 - Biogas Uses at Landfill Sites with Gas Capture



All sites that use biogas for heat or CNG also use it to generate electricity (i.e., none use it for heat or CNG alone). This sector represents a good opportunity to generate energy from biogas in that fuel is consistently and predictably produced and just needs to be used. Currently, 46% of these facilities (i.e., 16 out of 35) flare all their biogas. One of the largest of the landfill capture sites has installed electric generating capacity of nearly 13 MW and two other facilities have nearly 10MW each. In all, Wisconsin's landfill gas capture programs have more than 91 MW of electricity generation capacity and feed into the grid, enough to power about 57,800 average American homes[1].

Industrial Food and Fuel Producers

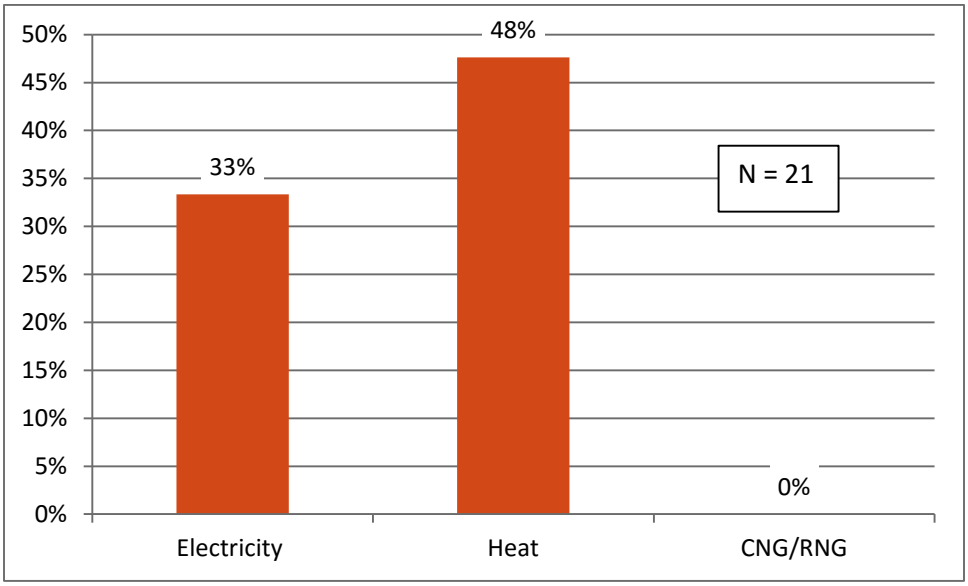
There are 21 industrial food and biofuel facilities in Wisconsin with operating AD systems. The majority of these systems were installed to reduce fees paid to local wastewater treatment plants.

---

[1] This is based on a waste-to-energy system calculation by the Solid Waste Association of North America (SWANA) that comes to 636 average American homes per MW of electricity generation capacity.

However, many of these facilities have been designed to also offset other costs for the facilities such as facility heating and energy use. Figure 4 below shows the proportion of these facilities using biogas by end use.

Figure 5 –Biogas Uses at Industrial Treatment Plants



About half of these facilities use biogas for process heat and a third of the facilities also create electricity to offset the plant's electricity load. The remaining facilities flare their biogas.

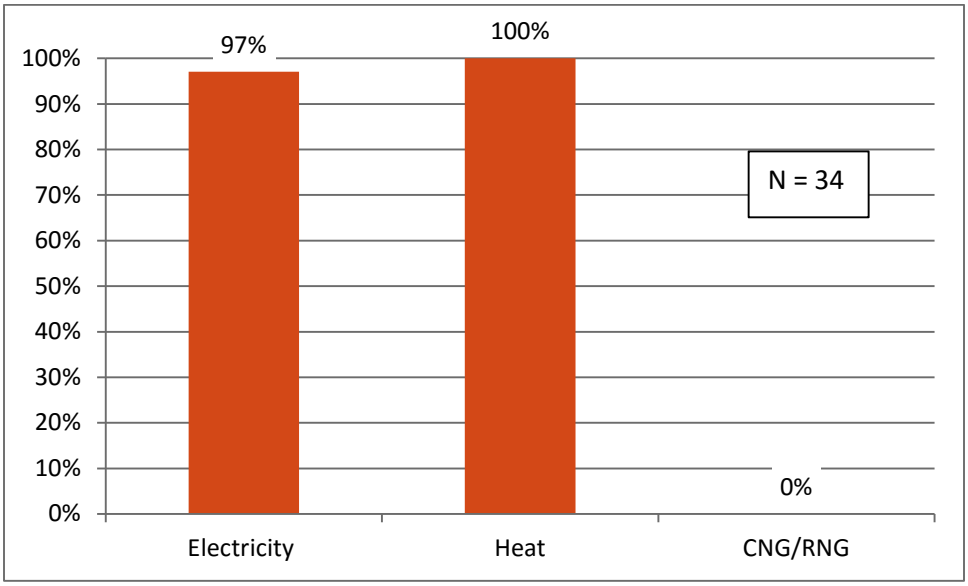
Altogether, industrial facilities have just over 10 MW of installed electric generation capacity. Of the six facilities that generate electricity, two of them were originally built with electricity generation in mind. One of those facilities accounts for nearly one-third of this entire sector's installed capacity. Because of their reliance on off-site wastes and the size of their operations, these two facilities have changed the regional landscape of organic waste management in Wisconsin. The representatives from these facilities expressed concerns about the lack of industry cooperation and collaboration to ensure that entities that rely on the abundant organic waste resources in the state can continue to thrive and contribute to economic development, particularly in rural communities.

The number of AD facilities in this sector appears to be held back by three primary restraints: (1) lack of industrial facility interaction and discussion of options with local wastewater treatment facilities; (2) long return on investment (ROI), and (3) rumored difficulties in constructing and operating AD facilities. Project growth in this sector will require addressing these challenges.

Agriculture Operations

There are 34 agricultural facilities with operating AD systems in Wisconsin. This sector represents the largest growth potential of any of the examined sectors. Agricultural systems are much more likely to use biogas to generate electricity. Figure 5 below shows the biogas uses at farm systems.

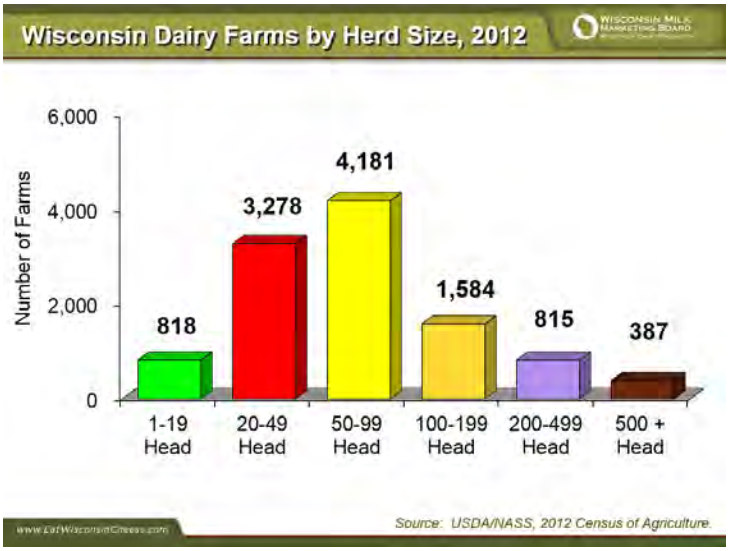
Figure 6 – Biogas Uses at Agricultural Operations



All system representatives interviewed said their systems were using biogas for heat, and almost all said they were generating electricity. However, many predicted they would shut down their electric generation and possibly the digesters as well if recent or predicted reductions in buyback rates with utilities became the norm. Most digesters use captured heat from the engine generator set to maintain digester heat, so ending electricity generation would require purchase of new equipment to heat the digester.

There is currently a large amount of growth potential for AD use at Wisconsin dairies. The US Department of Agriculture (USDA), National Agricultural Statistics Service 2012 Census of Agriculture stated that in Wisconsin there are 387 dairy herds of greater than 500 head, and 815 herds of between 200 and 499 head. Figure 6 below shows the breakdown in herd sizes.

Figure 7 - Wisconsin Dairy Farms by Herd Size

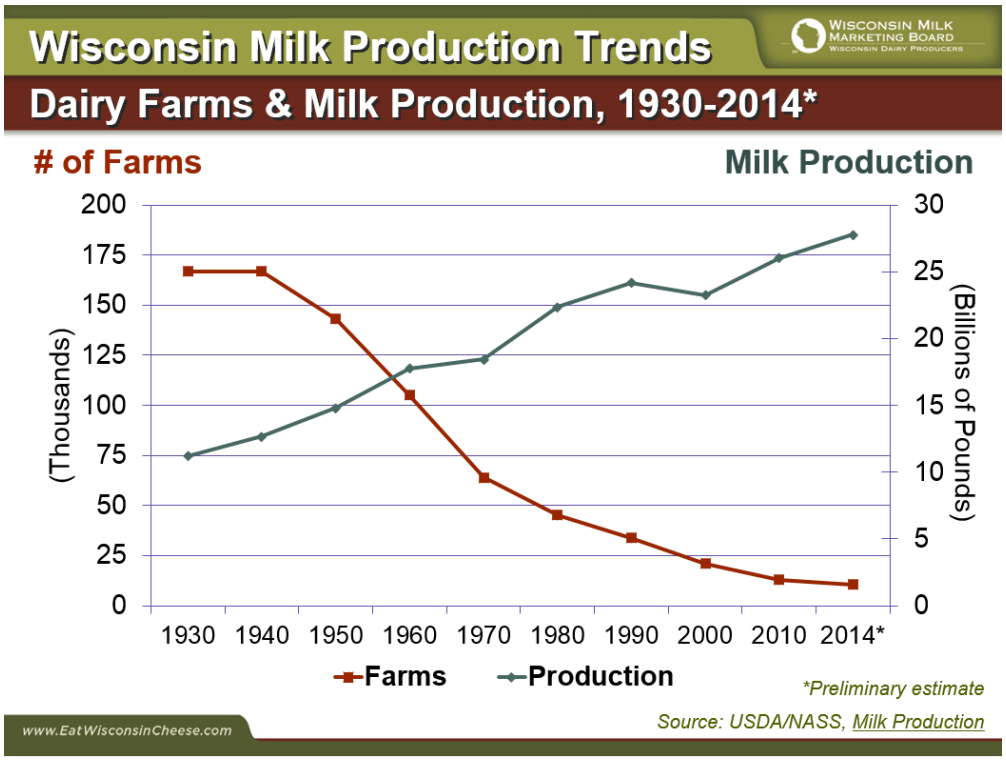


Graphic: Courtesy of Wisconsin Milk Marketing Board.

Therefore, whether the minimum size of a dairy herd for digester use is 500 head (the general minimum size for digester feasibility typically suggested by AgSTAR), or 200 head (Wisconsin currently has two dairies with digesters in this size range), there is potential for between 353 and 1,168 additional digester systems on dairy farms alone.

There are nearly 1.3 million dairy cows in Wisconsin. Beyond current potential, trends in the industry suggest that the potential for using AD systems will continue to grow as more farms become large enough. Figure 7 below shows the trend in milk production and number of farms suggesting farms are getting fewer and larger.

Figure 8 - Wisconsin Dairy Farm Size and Milk Production

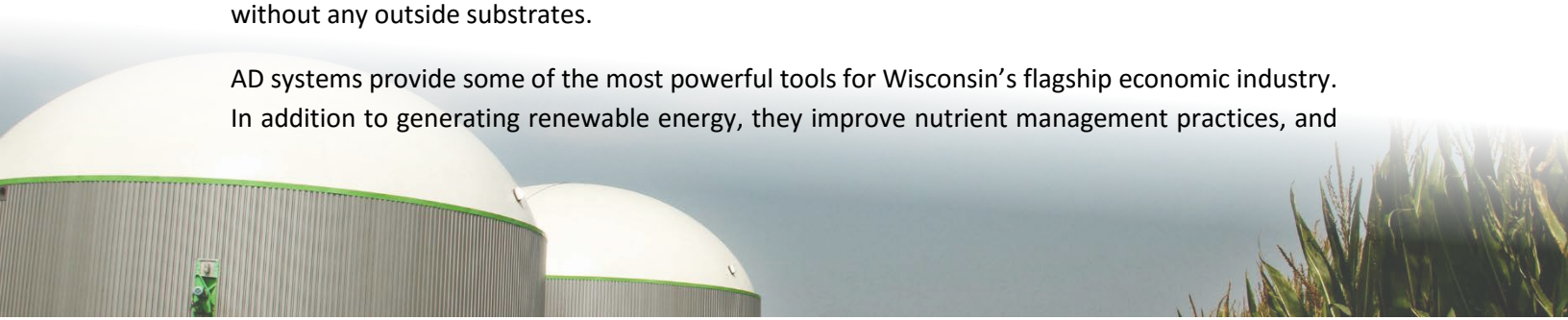


Graphic: Courtesy of Wisconsin Milk Marketing Board

In addition to processing cow manure, many of these digesters have incorporated industrial organic waste (from food or ethanol production), or substrates, as a co-digestion resource. These can greatly increase the amount of biogas produced.

The smallest dairy farm with an operating AD system has around 200 cows and co-digests outside substrates. It runs a 60 kW generator and provides space and water heating. The largest farm with an operating AD system has more than 9,000 dairy cows and produces about 1.4 MW of electricity without any outside substrates.

AD systems provide some of the most powerful tools for Wisconsin's flagship economic industry. In addition to generating renewable energy, they improve nutrient management practices, and



provide leadership in environmental stewardship and community goodwill. While there is enormous growth potential for this sector, it remains one of the most challenging to establish systems. These challenges include:

- Achieving economically sustainable operation;
- Incorporating new systems into the existing on-farm framework of waste logistics and labor allocation; and
- Insuring farm personnel are equipped to operate and manage these complex biological and energy generation systems.

Farms have seen some of the highest rates of failed projects, discontinued projects, or projects that do not emerge from the planning phase. In order to protect one of Wisconsin's leading industries, innovative policies could help the dairy sector and rural communities realize the potential benefits of having AD systems on Wisconsin farms.

Facilities Shut Down or Never Constructed

Some 60 facilities listed in existing data sources were found not to have AD systems or biogas capture programs in place. For agricultural facilities, 29 AD systems referenced in our data sources either had not emerged from the planning phase or were simply shut down after changes in state energy regulations that reduced energy buyback rates. In fact, two of those facilities ended their AD operations in the last three years because of changing PPAs with their local power company, and one system was never realized because of what they described as the power company's excessive costs associated with the interconnection requirements.

To a lesser degree, the other surveyed sectors had fewer AD systems in operation than was included in our preliminary data for a wide variety of reasons. Three municipal wastewater treatment plants had recently switched from anaerobic to aerobic digestion citing cost and safety concerns. Several industrial facilities reported not using an AD system for a number of reasons including:

- Halted digester operations after experiencing cost overruns and/or lack of adequate performance;
- Shut down after a change in facility ownership;
- Made arrangements with local municipal treatment plants to handle their organic waste; or,
- Never actually had operating digesters.

Arrangements between industries and their local treatment plants for digestion of high strength wastes were report as being beneficial to both entities allowing the industry to continue to grow and the city government to gain additional revenue. These types of public-private collaborations are discussed in Appendix C – Detailed Issues Discussion.

Primary Challenges and Potential Solutions

The most significant challenges to the expansion of Wisconsin's biogas industry for survey respondents are listed in the Table 5 below and summarized in the issue summaries that follow. More detailed discussions of problems and potential solutions can be found in Appendix C – Detailed Issues Discussion.

Table 5 - Primary Biogas Industry Challenges and Symptoms

Primary Challenge	Symptoms
Weak Wisconsin market for biogas-based electricity	• Utilities generally offer avoided cost for electricity purchases • Interconnection agreements put financial burden on generators
Regulatory compliance and policy support	• Permitting and compliance requirements can be complicated and unfamiliar • Energy policy in Wisconsin has put biogas systems at a disadvantage • Need for biogas related research not being met
Availability of capital for project implementation and system upgrades	• Insufficient availability of viable project financing options and insufficient and flawed assistance programs • Insufficient communication of issues and systems within communities • Scale issues preclude biogas development for many operations
Market barriers for biogas system non-electricity products	• Refinement into CNG or RNG are not yet lucrative or viable options • Smaller operations are flaring all biogas • Digester use does not eliminate all effluent disposal issues • Digested biosolids are low value and markets are local
Inefficiencies due to lack of biogas industry communication and cooperation	• Projects do not take big view, consider regional supply of feedstocks or partnering opportunities • Industry lacks shared knowledge base that could improve economics for all • Difficulty in finding qualified, experienced staff to operate and maintain complex systems • Industry and technology is not understood or favorably viewed by legislators, regulators or the public

Weak Wisconsin Market for Biogas-based Energy

Issue summary. The market for biogas-based energy or fuels is weak in Wisconsin. This is due primarily to the state's relatively low renewable portfolio standard (RPS) with which the state electric utilities have already complied. This combined with the lack of state or national policies putting a price on carbon emissions or other environmental goods means biogas energy competes directly with coal-fired and natural gas-fired generation. Electric utilities, the primary buyers of this electricity through PPAs, are more frequently offering their "avoided cost" of generation rather than a premium price for biogas generation. PPAs at avoided cost rates are not high enough to support these systems, and will likely result in many agricultural and municipal system shutdowns as they become too costly to run and maintain. Utilities are also not inclined to invest in infrastructure or provide assistance to enable more biogas generation to connect to their distribution systems. Utilities currently require generators to pay large portions of these costs discouraging project development.

How can this be addressed? One option for strengthening the market for biogas-based electricity is legislative or regulatory action to raise the RPS which would increase demand for all types of renewables prompting higher PPA offerings. Another is to adopt policies that monetize the value of carbon emissions and other environmental goods, such as the federal Clean Power Plan (CPP). Implementing the CPP would simultaneously increase the value of biogas energy and decrease the value of fossil fuel based energy especially electricity from coal. Another option is for system developers to configure their generation to meet their own demand and not feed energy back into the grid. However, recent utility rate cases have begun undermining the value of such self-generation or "behind the meter" systems. Other options could include developing a voluntary pricing program to support biogas energy like utility green power offerings.

Regulatory Compliance and Policy Support

Issue summary. Facility representatives felt certain environmental permitting requirements, in particular the formaldehyde emissions from combustion, were too restrictive for biogas systems and not consistently applied. Landfill operators suggested these requirements discouraged biogas use and encouraged flaring. Also, many agriculture digester system operators felt that Wisconsin regulations for concentrated animal feeding operations (CAFO) limit import of other substrates for co-digestion to ten percent by volume blocking opportunities for greater energy production and other benefits. In many cases, regulators are open to a greater share (up to 30%) of outside substrates after an evaluation of a particular farm's waste handling capability. CAFO operators also complained about the complexity of environmental compliance for AD systems. Finally, representatives complained about getting little policy support for biogas energy efforts, and lack of resources for research to improve outcomes.

How can this be addressed? Respondents suggested applying formaldehyde emission regulations evenly to all methane burning sources so as to not put biogas systems at a disadvantage. They also favored setting up a fund or other assistance to help sources such as landfill capture sites put the biogas to a higher use than flaring while still minimizing formaldehyde emissions. Raising (or eliminating) limits for import of off-farm wastes for co-digestion was also suggested as a way to improve operational economics for farm digesters. Finally, establishing an advocacy organization

for Wisconsin biogas industry members would help in getting better policy and compliance support.

Availability of Capital

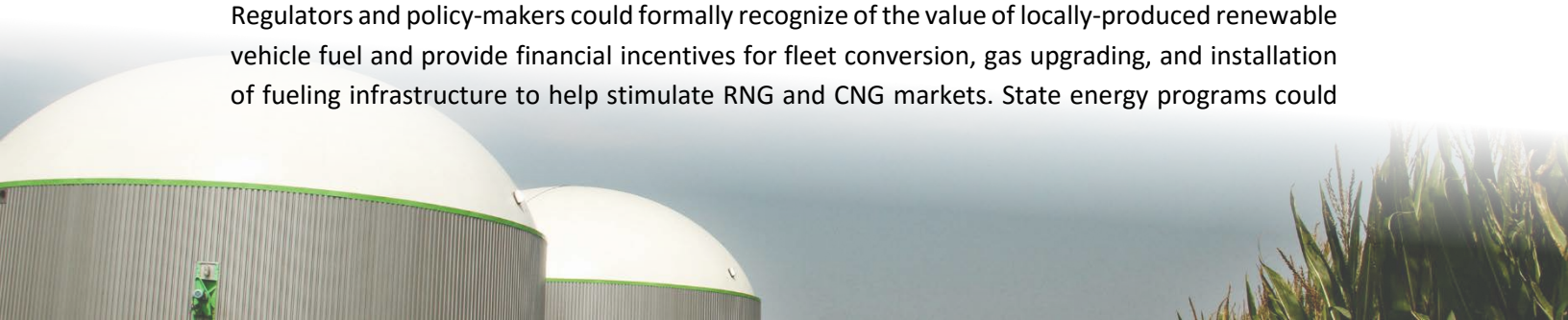
Issue summary. Project developers have found obtaining capital to implement biogas systems to be difficult because of a combination of financial institutions unwillingness to provide favorable loans, and insufficient incentives offered with problematic eligibility requirements. Also, local communications between system owners or developers and local governments is not as effective as it could be. As was illustrated in Figure 6, many agricultural (as well as municipal and other) systems are not large enough to host their own biogas system. Finally, the legality of third-party ownership of renewable generation systems selling electricity to customers is unclear in Wisconsin, making efforts to expand using that business model risky.

How can this be addressed? A large number of respondents felt increasing access to financial assistance for building, operating, and maintaining systems would do much to encourage development. This may include expanding in state resources and/or adjusting eligibility requirements so they are more broadly applicable. It may also include OEI continued assistance to help residents get access to national programs such as the Renewable Energy for America program (REAP). Local governments and developers need better communication and organized messages to the community to help avoid unnecessary delays or barriers to development due to misunderstandings about AD technology or facilities. Finally, to overcome scale issues for smaller operations, OEI could encourage further definition and refinement of permitting and business models for centralized digester systems or regional resource recovery centers (RRRC). Clarification on the legality of third party ownership on these systems would also solidify possibilities for using that business model.

Market Barriers for Non-Electricity Biogas System Products

Issue summary. Anaerobic digesters provide several outputs that present opportunities from energy production to nutrient management. However, refinement of biogas to RNG or CNG, both of which would give producers access to tradeable incentives called RINs that add value to the gas, is stymied by extreme difficulty of pipeline injection in Wisconsin. The state does not have standardized definitions of what constitutes “pipeline quality.” Local demand for CNG for vehicle fuel is small and growing slowly, not providing sufficient market pull to encourage investment by biogas producers. Costs of converting fleets to CNG and development of CNG fueling infrastructure are still seen as a deterrent. In addition, many facilities flare off large amounts of biogas they produce. This can be seen as a missed chance to use an opportunity fuel, but many organizations lack the resources to fully explore options for using it. Beyond biogas, the nutrient-rich digestate still requires management and disposal.

How can this be addressed? Wisconsin could establish uniform gas quality and interconnection guidelines, and identify acceptable injection sites, to reduce risk for developers and producers. Regulators and policy-makers could formally recognize of the value of locally-produced renewable vehicle fuel and provide financial incentives for fleet conversion, gas upgrading, and installation of fueling infrastructure to help stimulate RNG and CNG markets. State energy programs could



explore options for providing resources to biogas producers to help them evaluate options for optimizing their productive use of the biogas they produce. Resources to help facilities evaluate and invest in equipment to remove and process nutrients into useful fertilizers, bedding and other products, or assistance in organizing markets for these products, could help overall project economics for biogas systems.

Inefficiencies Due to Lack of Biogas Industry Communication and Cooperation

Issue summary. The biogas industry has difficulties due to the lack of communication and cooperation of industry stakeholders. Proposed projects often have only one option presented and may not consider regional or feedstock market options or competition, potentially missing out on beneficial opportunities. Existing projects may continuously reinvent the wheel by figuring out how to address operational or feedstock problems that others have solved. This may be compounded by the difficulty many experience in finding knowledgeable and experienced staff to operate, manage, and maintain digester and biogas utilization systems. Finally, the biogas industry lacks a unified voice in Wisconsin to represent them and educate legislators, regulators and the public on biogas system benefits.

How can this be addressed? Creating a statewide biogas coordinating council or industry trade association to facilitate internal industry communications on all aspects of project development, best practices, feedstock coordination, partnering, contracting, and development of regional infrastructure would be a first step toward improving efficiencies. Development of a knowledge base for digester or generation equipment operators to refer to could help minimize time and cost of maintenance activities and help improve the capabilities of staff allowing them to develop into the competent and experienced personnel their operations need. An industry organization could also produce materials and act on behalf of industry groups to educate government and public interests on biogas technologies and companies in Wisconsin.

Appendix A – Survey Instruments

What is the end-use for the biogas/biomethane produced by the system?
Electricity
Heat
Compressed Natural Gas (CNG)
Pipeline Natural Gas
Flare
Other

How did you decide which end-use of the biogas was most appropriate for your operation?

Were there considerations municipal leaders had to take into account that were problematic/supportive?

Would you make the same decision today? Why or why not?

What do you feel was the ultimate 'selling point' in your decision to construct and operate an anaerobic digester/gas recovery system? What was it that really pushed you over the threshold in making the decision to build a digester?

Maintenance and Operation
How would you characterize the burden to overall system costs of maintenance and operation staff?

Are there any reasons to believe that better training is necessary for anyone who may directly or indirectly interact with the digester?
What training has your staff been given about AD system operation and from where (system provider/designer, from the Wisconsin OEI or other state agencies, private organization or business, university or technical school)**? And what additional training do they wish to receive?**

Training aside, are there other resources available through the university you feel would be helpful to your operations and/or the biogas industry in Wisconsin?

What are the top three causes of system malfunction?

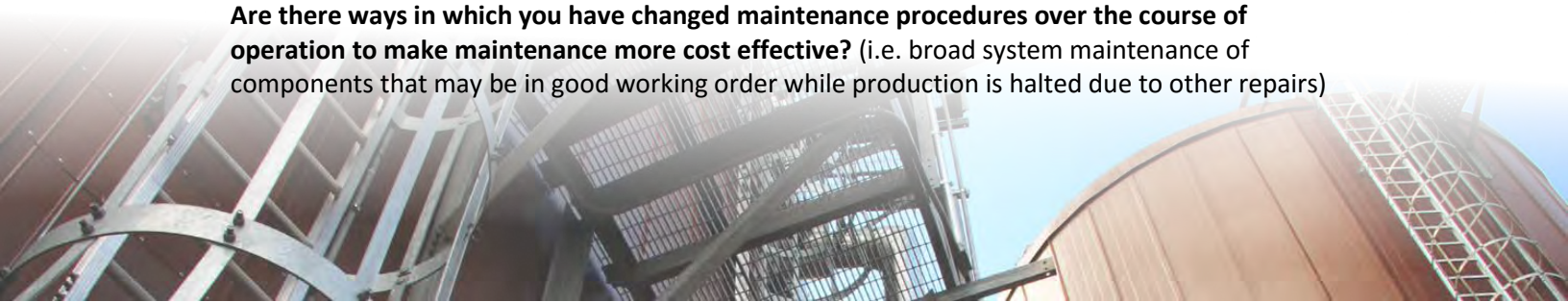
What major operational setbacks (e.g. fires, leaks, or system failures**) have occurred and what have you found to be the best way to prevent/address these issues?**

Would you be open to someone coming on-site to conduct an evaluation of a significant problem or setback?

Approximately what percentage of time is the system down for repairs?

Do you have the support you need to troubleshoot such issues? What resources/agencies/businesses do you rely upon in such circumstances?

Are there ways in which you have changed maintenance procedures over the course of operation to make maintenance more cost effective? (i.e. broad system maintenance of components that may be in good working order while production is halted due to other repairs)



Are there maintenance-related issues that you see as opportunities to further increase system production and output?

Feedstocks and Waste Logistics/Agreements

What is the type and source of feedstock used in the digester?

For agricultural operations:

***If it is animal waste slurry*, what type of bedding is used for the animals?**
Have you noticed any effects of using bedding from digested bio-solids on the occurrence of mastitis in your herds? Have you heard of any effects at other farms of bedding-related issues regarding mastitis?

Do you have a contracted agreement with provider(s) for feedstock?

If so, **is there a long-term agreement** (greater than 5 years)**?**

Have you found that there is difficulty in communicating or interacting with your feedstock providers? Are there opposing missions/intentions/needs/wants/objectives? Are there ways to clarify roles, responsibilities, and expectations with feedstock providers that would make the relationship more beneficial for all parties?

What are the biggest challenges you face with feedstock acquisition? Is it made difficult, for example, due to competition, inconsistent waste streams, or other potential complications?

Feedstock Management

What kind of pre-processing or pre-treatments do feedstocks go through before entering the digester?

Is there a lab on-site that is capable of testing feedstocks before they enter the digester?

***If no lab*, is there a primary reason no on-site lab or feedstock testing capability is present? Do you conduct your own tests or inspections of the feedstock as it arrives or only when problems are detected?**

If not, **do you think additional testing of feedstocks would be helpful for your digester? What tests would you like to see done? In what ways might testing be helpful?**

If there are known contaminants or problematic compounds in the feedstock, who is responsible for removing them/refining the feedstock to make it suitable for digestion and how is this done?

Is there a specific instance of a drop in gas production due to contaminants in feedstock or some other reason? What were the abnormal circumstances? What steps did you take to resolve those issues?

What do you know about the state of the art of advanced methanogens (microbes that produce methane) **that might produce more biogas? Are they affordable? Who is making them? Could they be used with your system/have you tried to use them? Is there anything**

that UW could be doing to produce better microbes for AD systems in the state? What, if anything, have you heard?

Are there any other technologies that could stimulate more efficient gas production? Do you use them? If not, why?

Co-Products of AD Systems

What is done with solid digestate? Are there other products besides the biogas and/or biomethane that you use or sell? (e.g. bedding, fertilizer, electricity, waste heat, tipping fees, etc.)

Do these co-products represent a portion of income to the system without which the system would become financially insolvent? In other words, is the income from the production of co-products essential for the system to remain above water financially?

***If not*, are there any you would like to produce or have heard about, but are not producing?**

Are there any co-products you wish to know more about in terms of how they are made or what uses or benefits could be associated?

Is there equipment on-site that is necessary to store, transport, refine, or otherwise improve the quality of the system's co-products in addition to equipment that refines, stores, or transports the biogas?

Biogas Policy

Is there local community or political opposition to the use of biogas? What partnerships have you developed to garner local support for your operation?

What are the current water and air permit requirements for your facility? Do you have any concerns about current or future permitting or regulatory requirements for air emissions?

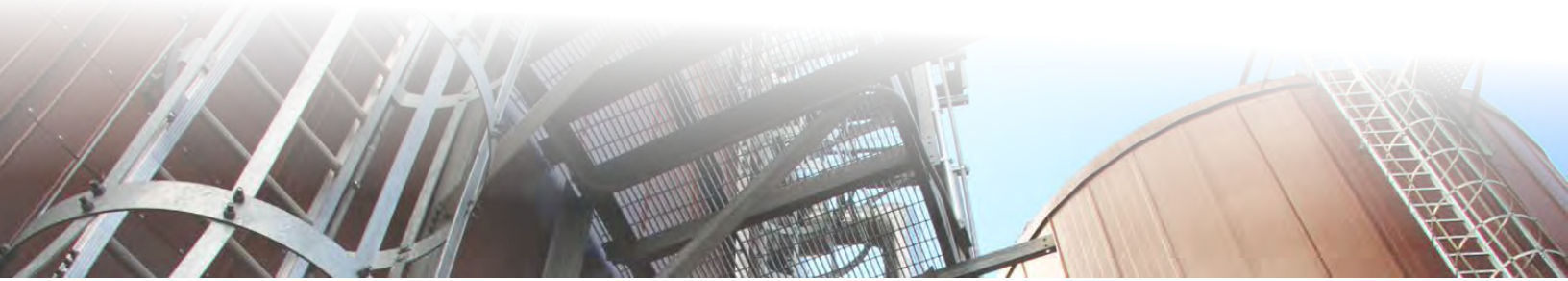
What value do you believe AD systems bring to the State of Wisconsin?

If there was government or local support for your industry, how could they help you with your project as it matures? How would you characterize your role in promoting biogas in Wisconsin? Is there a wish list of things that need to be done to help the biogas industry develop successfully in Wisconsin? What should the State legislature consider when developing policy that supports biogas?

When speaking of biogas development in Wisconsin, what kind of business environment would foster biogas development from your perspective? Are we missing any key industries in Wisconsin from our conversation?

For failed, cancelled, or otherwise shutdown dairy farm AD facilities:

Would you be willing to speak with AgSTAR, part of the US EPA, about the barriers to project implementation/operation?



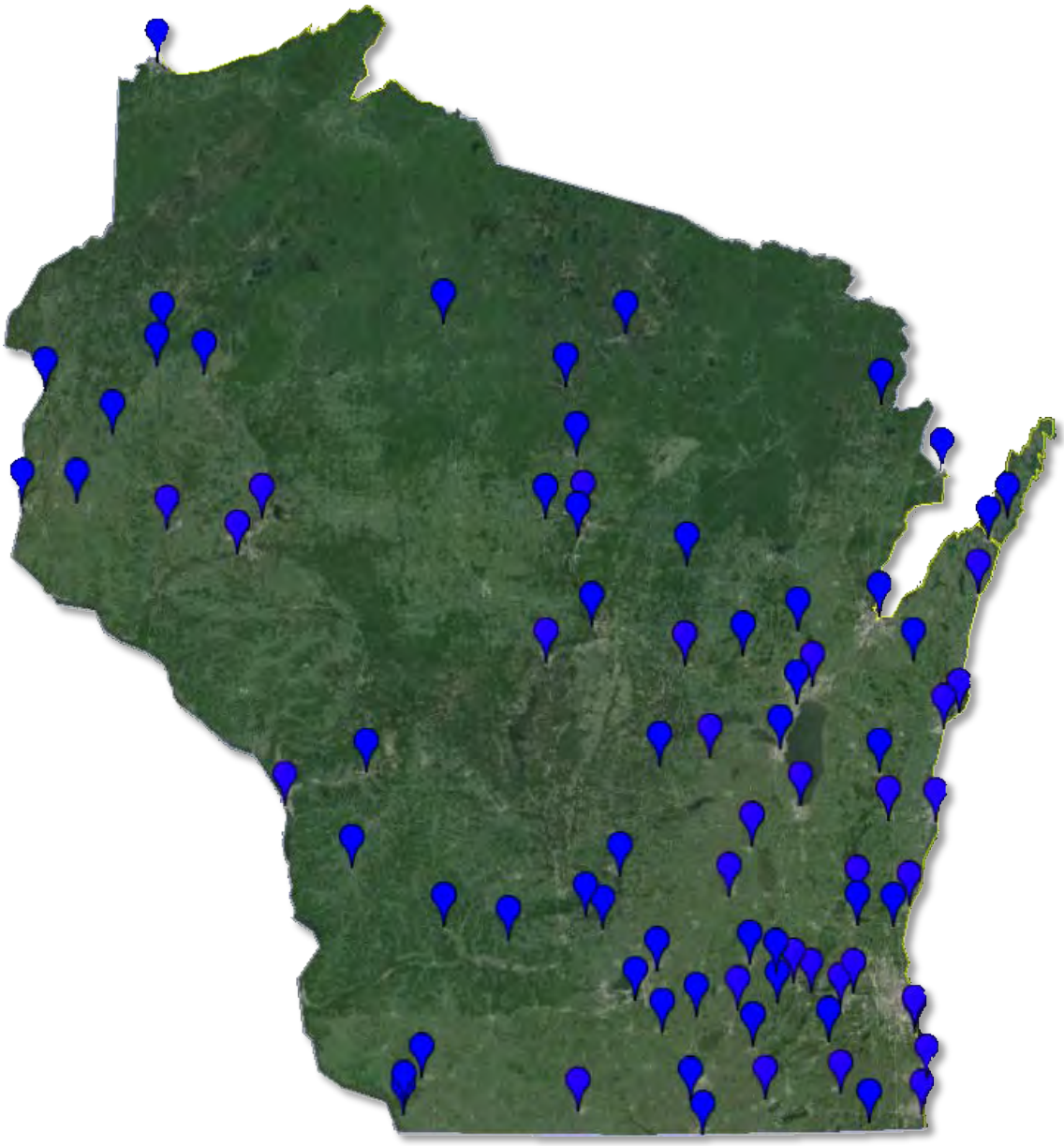
Appendix B – Biogas Industry Overview

As previously mentioned, the vast majority of AD systems are situated in the south-central, south-eastern, and central-eastern portions of Wisconsin, predominantly around the population centers of Madison, Milwaukee, and the Fox River area including Green Bay.

Municipal Wastewater Treatment Plants

AD systems operating at municipal wastewater treatment plants vary dramatically in size from facilities that process as little as 20,000 gallons of municipal waste per day to over 105,000,000 gallons per day. These facilities are located predominantly in populated areas or just outside the city limits. Figure 8 below shows the distribution of municipal wastewater treatment plants that operate AD systems:

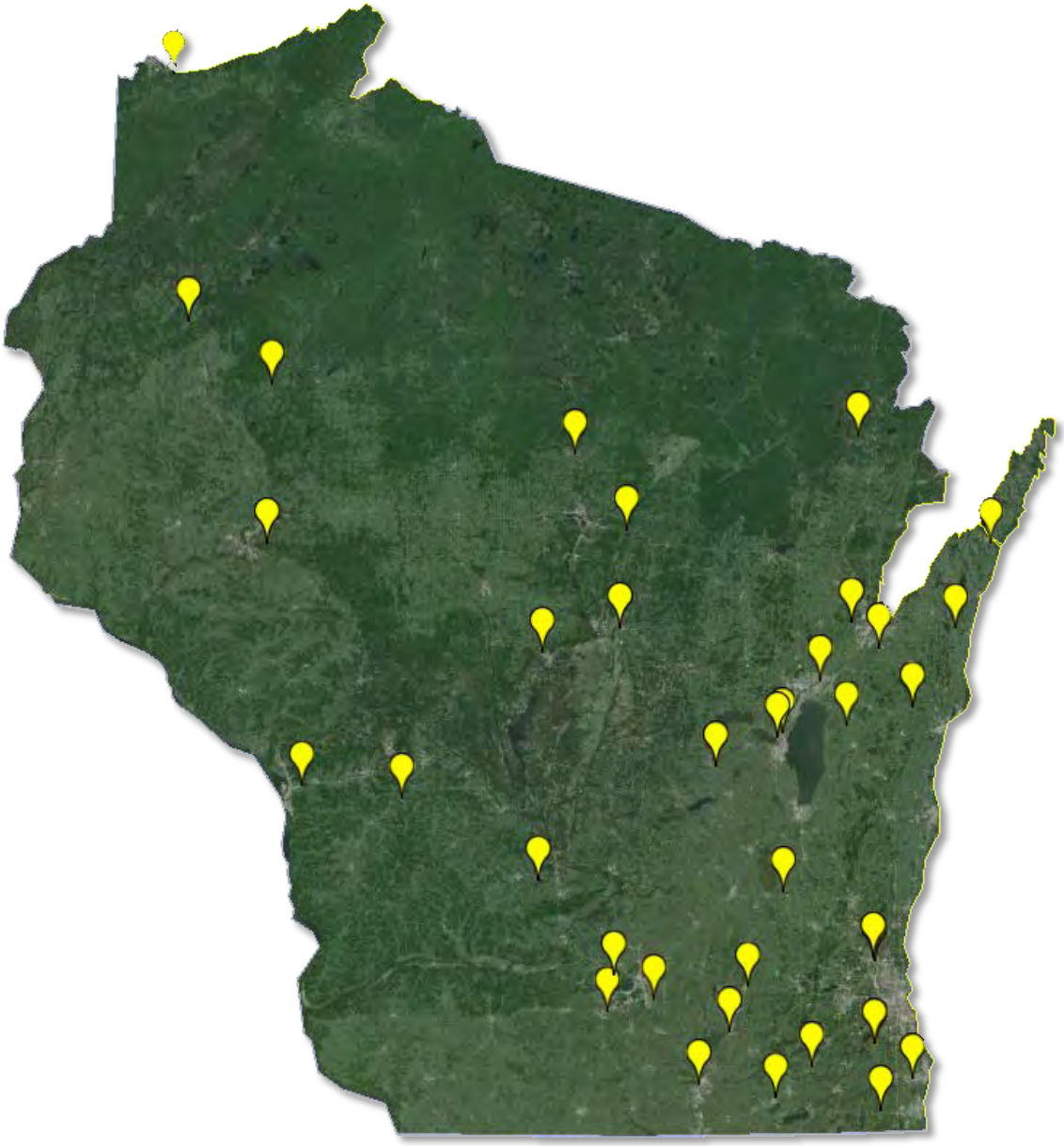
Figure 9 - Geographic Distribution of Municipal Treatment Plants

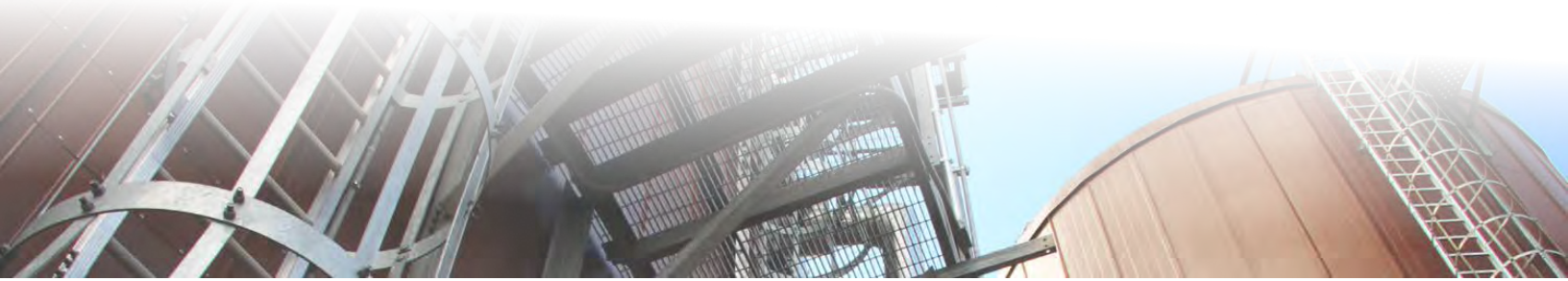


Landfill Biogas Capture Programs

The geographic orientation of landfill biogas capture facilities is similar to that of wastewater treatment plants in that they are often situated near populated areas, but there are fewer sites, and they are more often located outside of urban areas. In some cases, these sites are more isolated and rural, which can make utilization of the biogas in conjunction with neighboring entities more difficult. Figure 9 below shows the distribution of landfill biogas capture programs in operation:

Figure 10 - Geographic Distribution of Landfill Biogas Capture Facilities





Industrial Food and Fuel Producers

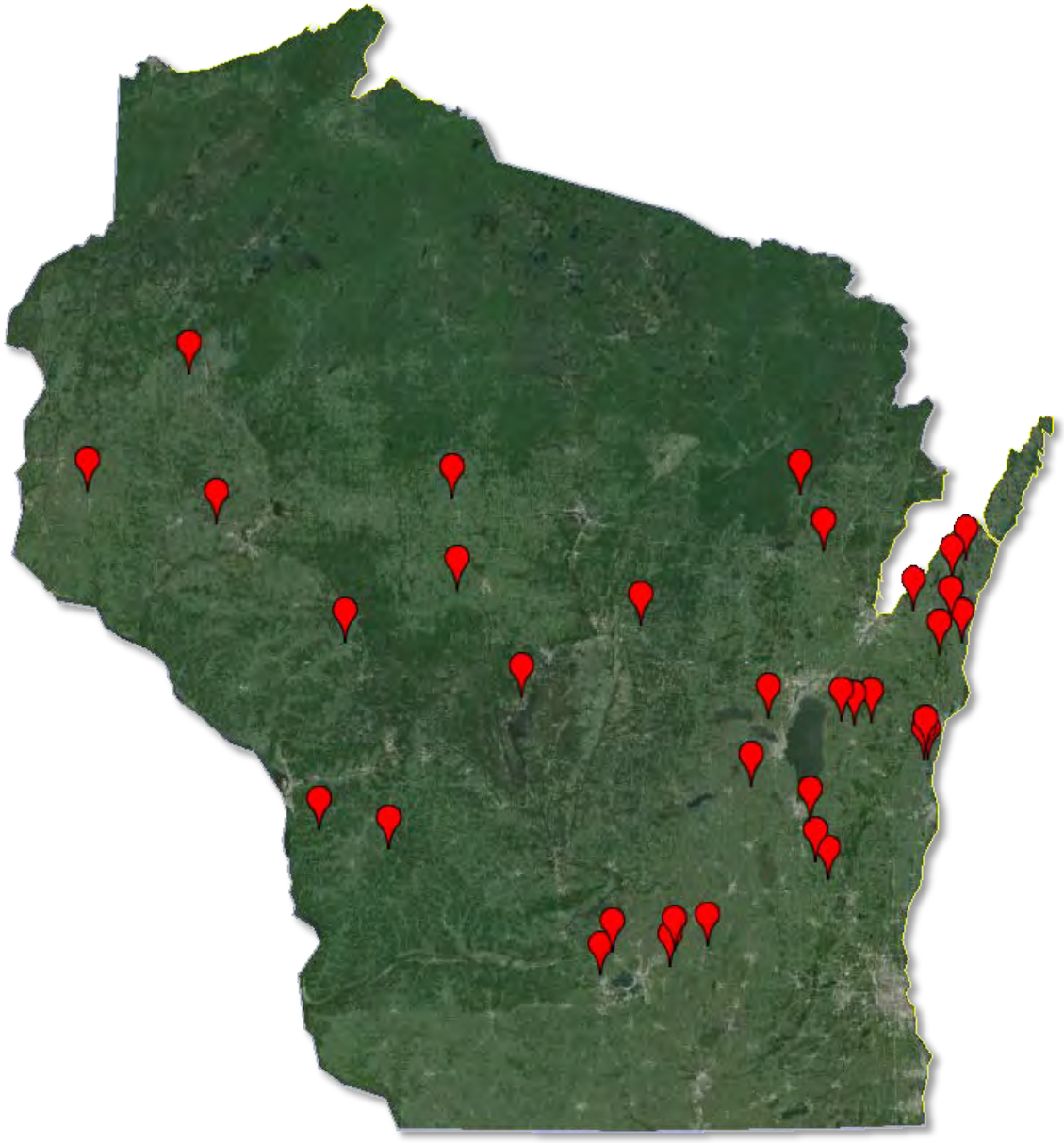
With few exceptions, industrial facilities that operate AD systems are found in, or very near, larger population centers. This geographic orientation allows them access to the transportation and power distribution infrastructures. Further, closely located systems could allow for more robust regional interaction with facilities interested in more efficient biogas operations; Regional Resource Recovery Centers (RRRC) will be outlined in a following section of this report. Figure 10 below shows the distribution of industrial food and fuel producers with AD systems in operation:

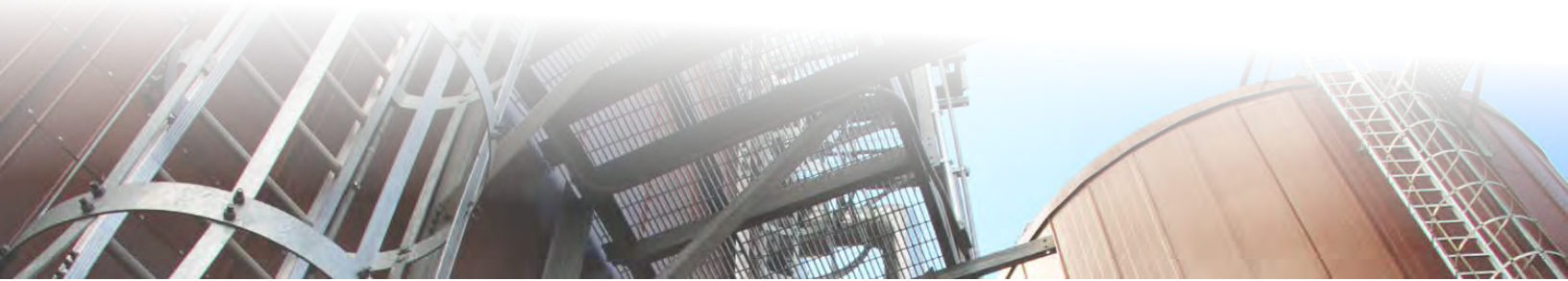
Figure 11 - Geographic Distribution of Industrial Food and Fuel Biogas Systems

Agriculture Operations

Standing apart from the other biogas industry sectors, agriculture AD operations are predominantly rural. They are still, however, mostly oriented in the south-central and central-eastern parts of the state with several other facilities spread out over the central and central-western regions of Wisconsin. Figure 11 shows the distribution of agriculture operations with currently operating AD systems:

Figure 12 - Geographic Distribution of Agricultural Biogas Systems



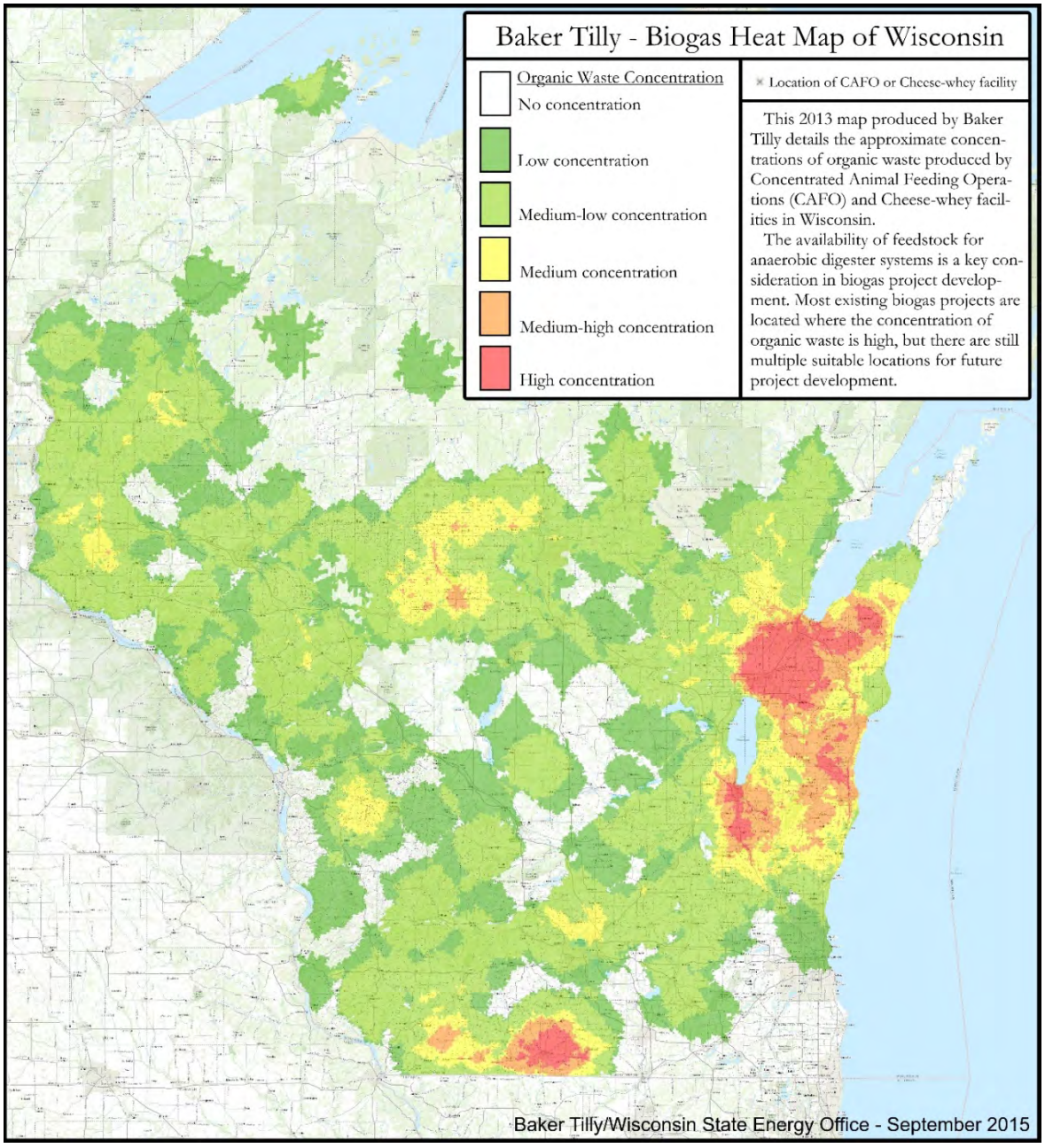


The Geographic Distribution of Selected Digester Feedstocks

One of the first and most important considerations when planning an AD project is the availability of consistent, in quantity and quality, organic waste to fuel the system. Without consistent feedstock, operational challenges related to feeding the digester including but not limited to foaming, pH imbalance, and microbial health are often substantial and can contribute to project failure. As a result, it is important to know where your feedstock is coming from before developing an AD system.

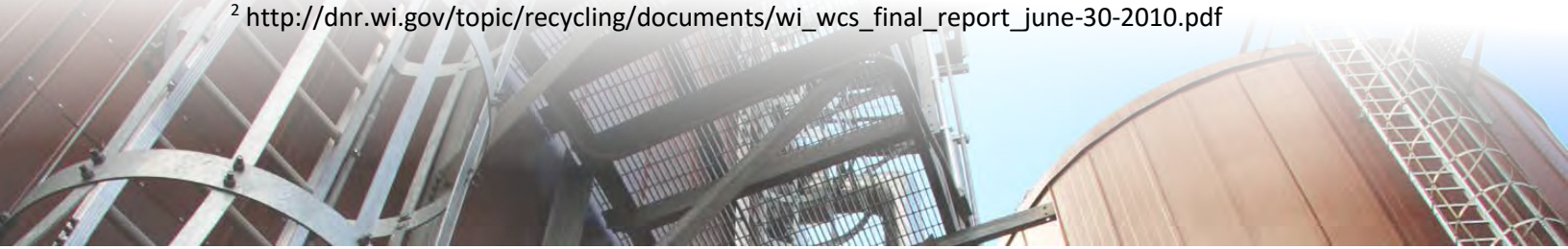
Recent studies highlight the geographic availability of certain organic waste streams, and they have been shown to accurately predict the current siting of AD systems across the state. A recent study by Baker Tilly evaluated "the opportunities and challenges in the area of biogas energy applications from dairy and cheese manufacturing waste" in Wisconsin and produced several resources, including a detailed heat map (Figure 12) showing the location of concentrated animal feeding operations (CAFO) as well as cheese processing facilities across the state. This, and other efforts like it, such as assessments of landfill and municipal wastewater treatment plant proximity to the natural gas 'grid,' for example, should be combined to further refine information available to AD project developers. Further, these maps and resources should include information about undeveloped feedstock resources like food waste and be made widely available.

Figure 13 - Heat Map of Biogas Feedstocks



Even while Wisconsin has established itself as an industrial food processing leader in the United States, there are still organic waste streams in the state that have not been fully utilized as a feedstock for AD systems. One of these opportunities lies in food waste diversion from human consumption. More than 455,000 tons of food waste[2] finds its way from dinner tables to landfills every year without much consideration for the energy potential of that material. Some facilities have begun to exploit this nearly untapped resource with very promising results, but they are still

[2] http://dnr.wi.gov/topic/recycling/documents/wi_wcs_final_report_june-30-2010.pdf



few in number. A robust review of food waste resources from Wisconsin institutional campuses and universities, grocery stores, urban residential food waste and others could expand the present understanding of AD system potential in Wisconsin and allow for further growth in the state's biogas industry and associated economic development. The potential of developing this abundant AD feedstock will be discussed in a later section.

Total Energy Produced by Anaerobic Digesters in Wisconsin:

Energy production from AD systems in Wisconsin can be broken down into four primary products: electricity, heat, CNG, and pipeline-quality renewable natural gas (RNG). Electricity production involves the production of electricity on-site at an AD facility for direct consumption or as an export to the utility grid for consumption by other utility customers. Heat production is accomplished through the use of a boiler or captured from power production exhaust and is usually consumed on-site at an AD facility for heating the digester itself, space or building heating, or for industrial processes. CNG production involves extreme compression of refined renewable natural gas to be consumed as vehicle fuel. And pipeline-quality renewable natural gas (RNG) is produced by removing moisture and other non-methane components of biogas to most often be injected into the existing natural gas pipeline infrastructure or grid near the AD facility. Since each biogas industry sector achieves energy production in a somewhat different way, it is helpful to group each product by sector as in the tables and paragraphs below.

Electricity Production. Electricity production is the predominant pathway for system operators to generate revenue for their AD project and improve their ROI. Most often, this is accomplished through a PPA with their local utility as mentioned earlier, but can also be done through on-site consumption of the electricity they produce. Altogether, Wisconsin's biogas industry produces more than 140MW of electricity. Table 6 below shows the installed capacity and number of facilities using biogas for electric generation.

Table 6 - Electricity Production at Biogas Facilities

Sector	Installed Capacity (MW)	Number of Facilities Producing Electricity/Total
Municipal Wastewater Treatment Plants	14.48	17/81
Landfills	92.1	19/35
Industries	10.04	7/21
Agriculture	23.87	33/34

Heat Production. Heat production was not quantified as many facilities experience significant variability between winter and summer months, and still other facilities rely on natural gas or propane to make up the difference between biogas supply and system demand. Some facilities are producing enough heat to sustain a suitable temperature for the digester to remain operational for much of the year. Still other facilities, particularly agricultural and industrial applications, produce enough heat to also offset their on-site heat demand, which allows for significant cost savings.

Combined Heat & Power (CHP). Many AD systems in Wisconsin produce both heat and electricity, a process often referred to as Combined Heat and Power (CHP). This is the case with nearly every agricultural facility that was surveyed. In one such case, a farm with 1,600 head of cattle that also brings in outside substrates consistently maintains production of around 600 kW of electricity and roughly 6,000,000 Btu/hour of heat energy. It can be estimated that for every 100 kW in generator capacity, approximately 1,000,000 Btu/hour in heat energy is produced.

Table 7 below shows the number of facilities in each sector that extract heat from the biogas produced by their systems and the manner in which it is produced:

Table 7 - Biogas Heat and CHP Systems

Sector	Heat produced with electricity (CHP)	Heat Only
Municipal Wastewater Treatment Plants	7	43
Landfills	12	N/A
Industry	5	7
Agriculture	33	1

Compressed Natural Gas Production. At present, two facilities in Wisconsin are engaged in CNG production. Both of these facilities produce CNG for their local government-owned vehicle fleets (one is a city-owned wastewater treatment plant and the other a county-owned landfill). The potential across biogas industry sectors is significant, as dozens of surveyed facilities responded positively to considering CNG production in the near-future if ideal circumstances were presented, such as grants or low-interest loans for capital investments or an increase in demand for CNG from the commercial trucking companies they regularly interact with. It is shown to be economically sustainable at both municipal wastewater treatment plants and at landfill facilities with biogas systems in Wisconsin and could see similar success at industrial and agricultural AD operations under the right conditions.

Although Wisconsin already has 48 compressed natural gas (CNG) fueling stations, survey respondents noted that their primary concern remains the lack of infrastructure. Municipal facilities, in particular, noted that without an existing CNG network, investment in CNG infrastructure and production was too financially risky. Even as these biogas system managers are unsure about producing CNG at their facilities, CNG consumption in Wisconsin is expected to grow in the coming years. This may influence some facilities to launch CNG production operations and contribute in the development of a robust CNG fueling network in Wisconsin.

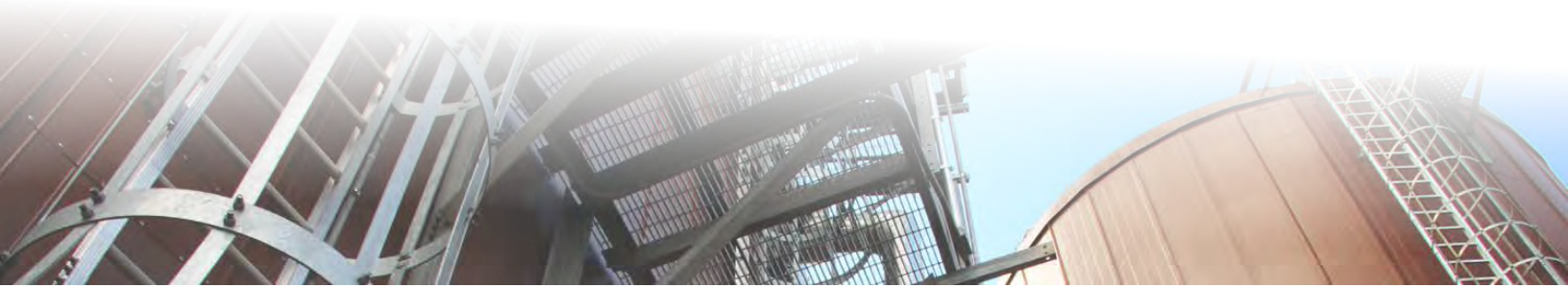


Table 8 below shows CNG production, availability, and development interest by biogas industry sector:

Table 8 - CNG Infrastructure and Interest

Sector	CNG for Municipal/Internal Fleet	CNG for Public Use	Interest in CNG Development
Municipal Wastewater Treatment Plants	1	0	5
Landfills	1	0	6
Industry	0	0	4
Agriculture	0	0	7

Pipeline Natural Gas Production. Production of pipeline quality RNG by AD systems in Wisconsin is primarily restricted by the low market price of natural gas. This means that margins for investing in components necessary to make the pipeline quality RNG and meeting the regulations and requirements for RNG quality are slim and difficult to justify economically. Some facilities have engaged in pipeline RNG production in recent years, but no facility is currently engaged in this activity. If the price of natural gas were to increase, regulations or requirements for access to natural gas pipelines were eased, or if new incentives were offered for pipeline RNG gas production, then more facilities may express interest in this use of the biogas they produce.

For now, the extent to which biogas is used at facilities as a natural gas substitute or alongside it is almost exclusively for heat production. This is the case for a significant share of municipal wastewater treatment plants and some industrial facilities (see heat production section). This allows facilities to offset some of the cost of using natural gas to satisfy their facility's heating needs.

Appendix C – Detailed Issues Discussion

Following is a more-detailed discussion of the issues and potential solutions identified by survey respondents and analysis by OEI staff as a result of survey outreach. Some issues were mentioned more frequently by respondents while others were deemed more important, and many concerns were sector- or feedstock-specific. Within each issue category are a number of problems paired with potential solutions. The noted problems ranged from project financing and economics to environmental regulations to education and outreach. One theme rang true for all survey respondents -- there is no single, easy answer to the challenges confronting this industry. However, there are certain "apex" issues, such as increasing the value of biogas-based energy that could moderate the effect of many other issues. Further economic and technical analysis is necessary to identify additional ways to promote development of Wisconsin's biogas industry.

Weak Wisconsin Market for Biogas-based Energy

There are many benefits to operating a biogas system, but they are different for each sector. Wastewater treatment facilities tend to use AD systems if they make economic sense for treating their high strength waste streams and tend to not rely heavily on income from energy sales. Landfill sites have access to a steady, predictable, renewable fuel stream and will use it if there is a willing buyer for the energy or fuel produced.

Agricultural biogas systems, on the other hand, tend to provide mostly non-monetized benefits[3], making sales of electricity an important revenue stream for the overall economics of the system. Electricity sales provides a distinct revenue stream that has helped many existing biogas projects obtain financing and be economically viable. The fact that nearly all farm biogas systems in Wisconsin generate electricity emphasizes the importance of this income stream.

There are 73 biogas facilities in Wisconsin that generate electricity and sell it to a utility for resale to utility customers. This arrangement requires substantial interaction and negotiation with utilities. System representatives identified some utility interactions as significant challenges for successful installation and operation of their AD systems.

Wisconsin utilities see shrinking value in renewable energy generated by customers. This is evident in lower offered buyback rates and few policy or procedural encouragements for customers to install systems.

One policy that elevated the value of renewable generation is the Wisconsin **renewable portfolio standard** (RPS).[4] This policy began, in 1998, with a requirement that power companies in the eastern portion of the state have 50MW of renewable electricity capacity on line by the end of

---

[3] They take the form of improved efficiencies or flexibility of operation, and, for farm systems, avoided costs for things such as fuel, fertilizer, or bedding.

[4] http://programs.dsireusa.org/system/program/detail/235

2000. As that date approached, lawmakers expanded the policy across the entire state and changed the requirement to 2.2% of electricity sales by 2012, establishing Wisconsin as the first U.S. state to institute an RPS. Since then, 34 other states and the District of Columbia have adopted their own version of the RPS.[5] In 2006 Wisconsin again modified the RPS to its current level of 10% renewable electricity generation by 2015. Utilities were generally in compliance with the RPS in 2014.

Problem: Decreased Revenue from Power Purchase Agreements

For most system owners, having a favorable power purchase agreement (PPA) with their utility is essential and was an important part of their business plan. Because Wisconsin utilities are in compliance with the RPS, the RPS has stopped influencing PPAs and utilities are now offering much lower buyback rates. This affects the economics of not only new and potential generators, but also existing system owners when PPAs come up for renewal. Many of those most dependent on electricity sales to keep their systems running (predominantly wastewater treatment plants and farms) predict that if buyback rates drop as predicted, they will shut down the energy generation and even the digesters because it will cost too much to keep them operational. Twenty-five representatives of facilities with AD systems said they were interested in using biogas to generate electricity, but low PPAs currently offered is a primary reason why they are instead just flaring the biogas.

The lack of favorable PPAs was also noted as a significant barrier to further biogas development in Wisconsin. Most survey respondents agreed that a rate of at least $0.08/kWh was necessary to justify the construction, operation, and maintenance costs for the life of the system. Adding to the frustration, many respondents explained that PPAs typically have a 10-15 year term, which is shorter than the system payback period. As many of these PPAs are approaching their final years, power companies have let facility operators know that the likely new rates will be considerably reduced, often to $0.04/kWh or less. This introduces a great deal of uncertainty about how existing electricity-producing AD operations will fare economically once their PPAs expire. Additionally, such a low rate all but eliminates the incentive for prospective operators, particularly in the agricultural sector, to construct new AD systems.

Solution: Increasing Wisconsin's Renewable Portfolio Standard

Having complied with the RPS requirements for 2015, many survey respondents felt that now was the appropriate time to update the state's RPS and renew the renewable electricity generation commitments of Wisconsin's power companies. From the survey, there was not a consensus on how much the RPS should be increased or in what timeframe, but they favored an evaluation of the effectiveness of the current standard and an investigation into what increase would be

[5] Hawaii adopted the most aggressive RPS targeting 100% renewables by 2045. Some states, like Virginia, opted for voluntary standards.

necessary to sustain offers of attractive PPAs from power companies across Wisconsin to preserve growth in the biogas industry and renewable energy development in general.

Indeed, one of the founding concepts of the RPS was to revisit the state's goals for renewable energy generation and update the standards in a way that is cost-effective for electric utilities and promotes economic growth in Wisconsin's fledgling renewable energy industries. From its inception in 1998 to the first and second updates in 2000 and 2006, the RPS has required modifications from lawmakers as citizens and businesses expect more renewables in Wisconsin's energy mix, and as compliance with the standard is achieved. Additionally, consistent early compliance with the RPS in Wisconsin may signal that lawmakers have been establishing modest goals for renewable energy generation and can offer expansions in the policy without fear of outstripping electric utilities' ability to comply. Other possible solutions include a mandate for power companies to value renewable energy generation at a specified rate, such as $0.08/kWh for biogas, for example.

Solution: Onsite Electricity Generation and Consumption

Other examples from the survey yielded a different approach to electricity generation with biogas that ensured a reasonable per kWh rate equivalent called behind-the-meter generation. To use one example, a system operator generates almost as much electricity as their facility demands for immediate consumption onsite and purchases the remainder from their local power provider. This allows them to offset a significant portion of their load at retail prices, though it requires more accurate monitoring of the facility's load from moment to moment and the ability of power generation equipment to safely rise and fall in output with the changes in electric load. Even with the extra costs of load monitoring and generator operation and maintenance, behind-the-meter generation may still provide compelling opportunities for facilities looking to generate electricity with the biogas they produce.

Problem: Uneven Access to Grid Infrastructure for Interconnection

This particular lesson is more a circumstance of geography and utility service provider than any other driving forces. The primary concern deals with the allocation of electricity distribution lines over the landscape, but also the interconnection requirements established by different power companies can vary dramatically leading to difficulties with biogas project development in certain utility service territories.

The uneven landscape of grid development across Wisconsin is particularly irregular in rural areas of the state where on-farm AD systems are most likely to be located. A proposed system is going to be confronted with a variety of different potential challenges given its distance and orientation to existing electric grid infrastructure, such as distribution sub-stations, distribution lines, transformers, and other relevant grid system components. Utility companies are generally concerned with recent or upcoming grid infrastructure upgrades, the capacity proposed by a project and the impact it will have on a particular distribution line. Proximity to distribution sub-stations is a key driver of the cost of a particular piece of infrastructure. There are also different costs involved with operating distributed generation (DG) in rural power grid settings as servicing

the grid is more complex with generators that are feeding power back onto the grid. Electricity generation is somewhat disruptive to grid operators' planning for upgrades and operations, but it is manageable and highlights the need for greater interaction between potential DG system operators and their power company. In one case, a survey respondent abandoned a planned AD system with electricity generation because they were positioned far from other distribution lines. This would have required them to pay for additional distribution line connections that would have impaired the project's economic viability. While proximity to grid infrastructure is an important consideration for developing an AD project, it is not the only issue to resolve.

Solution: Establish Standardized Interconnection Requirements across Wisconsin's Power Companies

In circumstances where there is a power interruption, a fallen tree on power lines for example, it is of great importance that DG systems are in communication with grid operators to ensure reliable and safe electricity service. Even though we have interconnection standards that ensure this inter-system communication, the implementation of communications systems are different from utility to utility. Current regulations only set a minimum standard to be upheld for these systems, but utilities can go above and beyond. Many survey respondents highlighted a central challenge with one particular utility; Alliant Energy requires that DG systems be connected to nearby substations via advanced fiber optics to ensure fast and complete communication with the grid in times when the grid is compromised. Often during power outages, there are a multitude of automated responses that the system conducts in order to keep power flowing. Additionally, these automated responses address safety concerns and trip a disconnection if necessary. If a distribution line is disconnected from a sub-station but a DG system on that line continues to operate, there are many safety-related problems that can surface very quickly. However, there are multiple technologies in addition to fiber optics, such as microwave and radio communication, that are much more economical and have proven to provide sufficient communication time when the grid is compromised. It is important to note that a number of other power companies around Wisconsin have not required fiber optic interconnection and have been able to manage outage scenarios involving DG systems with satisfactory results. More interconnection flexibility by power companies could reduce the overall investment burden for a proposed AD system and still maintain the safety features of Wisconsin's grid, one of the most reliable in the United States.

Regulatory Compliance and Policy Support

Biogas system operators require policy support on a wide range of issues, such as environmental regulation and the setting of standards to secure a fair price for the goods they produce. Fundamentally, nearly all survey respondents spoke about the importance of regulations that protect the environment in Wisconsin and indicated that part of the reason for developing a biogas project reflected that same goal for their organization or business. While acknowledging the importance of these regulations, many respondents highlighted several areas for improvement that could preserve the intention of the policies without causing undue harm to Wisconsin's biogas industry.

Problem: Inconsistent Application of Formaldehyde Regulations

The combustion of natural gas or methane, renewable or otherwise, emits formaldehyde into the atmosphere and can be a significant human health concern in high enough concentrations. Several survey respondents noted that air permitting rules are inconsistently imposed on natural gas and biogas combustion operations. More than a dozen survey respondents, particularly landfill gas operations and others that are currently flaring most of the biogas they produce, expressed frustration that air emissions rules were inconsistently applied. Formaldehyde emissions occur whether burning natural gas or biogas as it is a product of methane combustion. However, formaldehyde regulations only apply to biogas facilities. This inconsistency has placed biogas operations at a disadvantage to conventional natural gas combustion operations in Wisconsin, like those at natural gas-fired power plants or in many large boiler systems, even when there is a great deal of potential in many cases of combining renewable natural gas (RNG) with the natural gas pipeline network.

Solution: Create Consistent Rules for Methane-Fired Equipment

Clearly, regulators that are interested in reducing and controlling potentially harmful emissions should target all emitters equally to avoid harming environmental or public health. Therefore, regulations for controlling formaldehyde emissions should apply to all facilities combusting methane gas. In addition, studies should be conducted on the amount of formaldehyde emissions by facilities that process various volumes of biogas or natural gas as many may be small enough not to warrant strict emissions controls. In any case, establishing consistent rules for all methane-fired systems should be a goal for regulators.

Problem: Formaldehyde Regulations Incent Flaring of Biogas over Energy Production

This more stringent regulatory environment for formaldehyde emissions has also influenced many biogas facilities, particularly very rural landfill gas capture operations, to flare the biogas produced instead of producing heat, electricity, or other biogas products because of increased costs brought on by formaldehyde regulations. The extra cost of monitoring and requirements for flare systems often makes energy production systems uneconomical.

Solution: Create Funding Resources for Facilities to Avoid Flaring Biogas

Many survey respondents from landfills expressed frustration that the biogas resource they produce is being wasted because of the increased costs of controlling formaldehyde emissions. They felt that it would make more economic sense to run the biogas through a generator engine or produce CNG vehicle fuel, which would still combust the gas in a safe way to avoid problems with formaldehyde. Additional funding opportunities would make upgrading facilities possible and give these businesses and organizations an opportunity to generate revenue rather than sending the biogas they produce to a flare.

Problem: CAFO Regulations Prohibit Full Utilization of Outside Substrates

The current perception among some dairy farm digester operators is that the Wisconsin Department of Natural Resources (DNR) currently limits CAFO AD systems to a 10% mix of outside substrates in the feedstock used to fuel the digester. 8 farm digester operators expressed this concern, indicating that they would be willing and able to process more organic waste than they are now. With all of these possible advantages in mind, respondents were puzzled about this 10% outside feedstock limit and wished to have regulators justify this limitation. CAFO AD operators in Wisconsin acknowledge the political opposition they encounter from many groups in the state and want to do more to improve the environmental impact of their operations, and an easy way to do this would be to allow operators to take in more organic waste for processing in their digesters.

Solution: Allow CAFOs with Digesters to Process more than 10% Outside Waste Mix

Processing more organic waste would mean more revenue for farmers through additional tipping fees and biogas production, more processing of industrial organic waste instead of landfilling or direct land application, and could improve system operation for many under-performing AD facilities. One survey respondent added that the addition of outside substrates could reduce hydrogen sulfide (H2S) production in the biogas, a costly operational hazard for many on-farm digester operations as it is a corrosive element in electricity generator components. Additionally, this would increase the biogas production of these facilities further guaranteeing a return on their investment and increasing renewable energy production in the state.

As highlighted previously in the report (Regulatory compliance and policy support section), regulators are open to a greater share (up to 30%) of outside substrates after an evaluation of a particular farm's waste handling capability.

Problem: Environmental Regulations are Complicated and Facilities Often Lack Expertise to Comply Efficiently

One of the final questions in the survey addressed the permitting and regulatory requirements for biogas facilities and asked if these rules present challenges now or in the future. Most respondents described routine permitting for facilities of their type, particularly for air emissions. Respondents spoke of the importance of tracking and ultimately reducing greenhouse gas (GHG) emissions as a facet of their facility's mission. Also, while air emissions restrictions and reporting were at times burdensome, respondents were sensitive to the need to limit GHG emissions and felt that AD systems were a vital part of efforts to maintain clean air in our communities. Many also felt that regulators were providing too many disincentives to utilizing biogas, as expressed by landfill operators above, and that they should be doing just the opposite. However, many of them felt that they held little sway over regulators and felt that a resolution was not possible from their efforts alone.

Solution: Achieve Compliance through Third-Party Expertise

Survey respondents suggested addressing these concerns by establishing compliance through third-party handlers. Seven respondents, mostly in the agriculture sector, used outside firms and sometimes biogas system developers to handle permitting and regulatory compliance. As regulatory compliance is often a difficult matter for facilities that may not be experts in managing and operating AD systems, having skilled advocates administer regulatory compliance was useful. If these advocates were to be more active with other biogas industry sectors, they may be effective partners to have at the table to address regulators and decide which path to take in formulating phosphorus, formaldehyde, or even GHG emissions reduction strategies in a more fair and cost-effective manner.

Problem: Lacking Energy Policy Support

Apart from compliance with environmental regulations, the Wisconsin biogas industry is in need of policy support from other actors. Past Wisconsin policymakers promoted the production of renewable energy by introducing policies, like net metering and the RPS. However, since 2006, there have been few new policies introduced to directly incentivize the construction and operation of biogas systems in Wisconsin outside of the property tax exemption for biogas system put in place in 2013[6]. Survey respondents were also concerned that Wisconsin-- and the United States at-large-- still lacks a formal and robust energy policy that clearly outlines renewable energy generation goals and how biogas fits within the nation's energy mix. This creates uncertainty about investing in renewable energy systems and technologies and hinders the focus on energy-related challenges in Wisconsin and the United States.

Solution: Formation of Biogas Industry Advocate

AD system operators are frustrated that the Wisconsin state government has recently done little to create a favorable environment for AD system operation which in turn provide economic, environmental, and waste management benefits. As previously mentioned, many respondents called for an increase of the state's RPS, which would provide AD system operators with more resources to bolster compliance with environmental regulations, for example. This disconnect between the biogas industry and policymakers may be addressed by the formation of an organization that actively engages with state government officials on behalf of Wisconsin's AD owners and operators. Much like the American Biogas Council[7] does on the national level, an organization could be set up to educate policymakers on matters most important to the biogas industry in Wisconsin, ensure that biogas is included in considerations about rural economic development, and generally promote the production and utilization of biogas in the state. It may also be possible to modify existing organizations like the Wisconsin Wastewater Operators

[6] 2013 Wisconsin Act 20 and AB709

[7] Information on the American Biogas Council

Association or Wisconsin Rural Water Association to incorporate biogas advocacy with state government and industries associated with biogas.

Problem: Resources for Biogas Research are Lacking

Twelve survey respondents from every biogas industry sector spoke about the joint research projects they conduct with local universities, from biogas and digestate analysis to co-product feasibility studies. Still others, mostly from the municipal wastewater treatment and landfill sectors, wished to foster more robust relations with universities and other biogas experts to conduct research that could economically and technically strengthen the biogas industry. However, all of these respondents spoke about the limited resources available to universities and private research organizations to investigate the full potential of biogas.

Solution: Strengthen Funding Opportunities for more Biogas Research

These interactions, or want of them, indicate an opportunity for Wisconsin's public and private institutions to play a greater role in biogas research. Additional research into ways to make AD systems less costly and more efficient should be a top priority for policymakers, universities, and interested private organizations. Innovations in AD facility construction; biogas production, refining, and utilization; energy production; and system maintenance and operation could dramatically reduce the risks and highlight the benefits associated with AD system development. Additional research into the benefits of AD may include improved water quality as a boon to tourism in the state, ecological sustainability, and economic development related to a cleaner and healthier environment, all of which allow more organic waste producers and processors to improve economic development around Wisconsin and create jobs.

Capital for Project Implementation and System Upgrades

Yet another concern of project developers is a general lack of access to project capital as well as operational funding that they feel has limited the growth of the Wisconsin biogas industry. Recent projects have incorporated complex public/private agreements that further complicate the finances of a proposed project and have required the expertise of experienced contracting specialists to properly evaluate and position the financial assets of a proposal. These complications, often common attributes of proposed biogas projects, may raise perceived risks of potential project failure.

Problem: Financial Institutions are Unwilling to Provide Project Capital

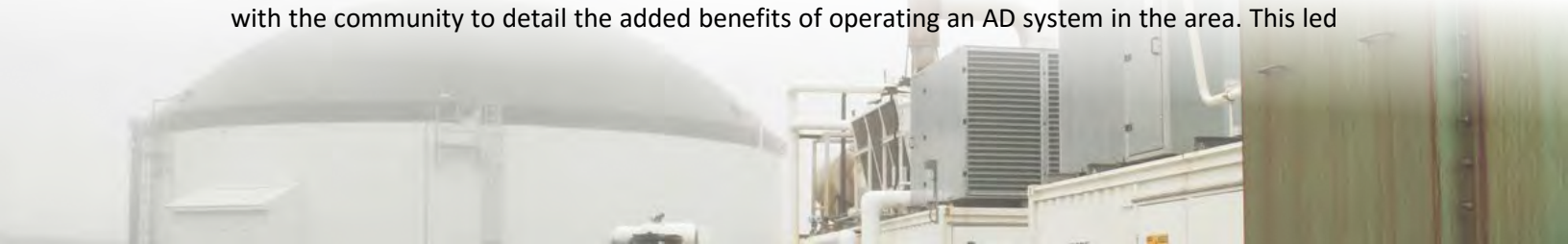
Project developers have expressed concern that banks are unwilling to provide favorable loans for new projects, and that the current limited incentive structure is insufficient to spur strong biogas system development. Recent funding programs for AD systems have been limited by overall program caps or problematic eligibility requirements. These limitations have left many prospective project developers discouraged and quick to abandon plans for new AD systems, unlikely to re-engage at a later date. Indeed, of the 29 proposed farm digester projects in Wisconsin, only eight expressed interest in moving forward, with many citing a lack of available funding as the primary barrier to implementation.

Solution: Increase the Availability of Grants and Low-Interest Loans, and Reform Eligibility Requirements

One of the most unified responses in all of the questions of the survey had to do with access to financial assistance from local, state, and federal governments. Sixty-three respondents, 43 of which were municipal wastewater treatment plant operators, felt that more grants, loans, and other financial aid should be offered to facilities to build, maintain, and upgrade their AD facilities. Many municipal wastewater operators suggested that an effort similar in size and scope to the funds mandated by the Clean Water Act of 1972 was needed to give that sector the resources it needed to operate most efficiently and realize the cost savings that those facilities are unable to capture without financial assistance. They widely felt that it was problematic that no significant effort in infrastructure spending for municipal facilities had been undertaken since the 1970s, and most thought that, given the maturation of technologies such as AD, a new program was needed to develop the biogas industry around Wisconsin and the United States. It is also important that these offerings be made to specifically support AD with modifications made to the eligibility requirements. In some cases, the timeline requirements for new renewable energy project assistance funding excluded AD projects because bringing a biogas project to completion is more demanding than for the construction of other renewable energy systems, and could not finalize construction in the allowed timeframe. Twenty-two survey respondents explicitly suggested that state lawmakers reform the regulatory framework to more fairly assign environmental quality requirements on AD systems and industries with similar environmental impact. Several other facilities generally supported such reforms without giving specific explanations as to how certain changes could affect them.

There is a comprehensive database whereby potential project developers can search for funding opportunities from across the United States and from multiple funding sources. This database is known as the Database of State Incentives for Renewables and Efficiency or simply DSIRE. In addition to these grants and low-interest loans, OEI is committed to providing project development and operational assistance through programs such as the US Department of Agriculture's Renewable Energy Development Assistance (REDA) program, part of a greater package of USDA programs known as the Rural Energy for America Program or REAP. REDA provides some technical assistance to proposed or existing renewable energy projects, including biogas, to increase efficiency and address design and operational challenges. OEI's current efforts with this program run through June of 2016.

State and federal governments were not the only targets for respondents' concerns. Particularly, private industry and farm digester operators felt there is a lack of involvement with local government and called for improved public-private cooperation. Twenty respondents in all, including five municipal wastewater treatment plants and two landfill gas project operators, made calls for greater interaction between system operators and their local governments. They felt that greater partnership could reduce concerns about biogas among local interests, from environmental impacts to a project's economic viability. In some cases, local governments had granted permitting approval for construction and operation of a plant, but did not further engage with the community to detail the added benefits of operating an AD system in the area. This led



to local groups and individuals expressing skepticism about the value of having such a facility operating in their community.

Problem: Some Farms and Small Businesses Lack Scale to Justify a System of their own

The cost of installing an AD system remains a concern even after several years of project development in Wisconsin, particularly for small farms and businesses. However, many survey respondents, most notably on-farm digester operators, said that the benefits of operating an AD system offset these costs and were willing to break even since the benefits were often far-reaching to other aspects of operating the farm. In some cases, this was also true for small businesses, but similar sentiments were couched in greater scrutiny of project costs and ROI compared to farm respondents. In the course of the survey, many respondents from the agricultural sector had contemplated the question about rather or not there was a hard limit in farm size below which an AD system was not economically possible. Many of these perceived limits are challenged by the operation of AD systems at farms with as few as 200 head of cattle.

While acknowledging the benefits of operating a digester, many respondents highlighted the persistent challenges and costs of system operation alongside day-to-day activities of the farm or factory. AD system operation commonly consumed labor time that had previously been dedicated to routine operations. This often resulted in lost productivity that had not been accounted for in the planning stages of AD system development.

Solution: Community Digesters and Shared Costs

Wisconsin boasts one of the most developed biogas industries in the United States. Yet, there is enormous potential for expansion across each of the biogas industry sectors. While this potential is apparent, the economic and technical barriers are equally so, particularly for small businesses and farms. As this remains a primary concern among many of the survey respondents, they were also enthusiastic about potential solutions. One such suggestion is in a relatively undeveloped organizational structure loosely referred to as the Regional Resource Recovery Center (RRRC). An RRRC is a facility that centralizes: the processing of separately generated organic waste streams; AD system operation; and refining of biogas and effluent end products. There are some examples of these types of facility arrangements in municipal wastewater treatment and agriculture operations, but operators of those systems contend that there are significant ways to improve the model and expand AD access to organic waste producers like farms and industry across the state, regardless of size.

The construction and operation of shared, cooperative, hub-and-spoke-type AD systems would more broadly distribute financial risk, concentrate operational resources and reduce maintenance responsibilities on some facilities, ease competition for organic waste, and heighten the energy production potential of many organic waste streams, among other benefits.

AD project developers often begin exploring the viability of a proposed system by evaluating the availability of organic waste needed to fuel it. These organic waste resources are frequently geographically clustered in areas where a central RRRC can be situated to easily service each producer. In recognition of the shared need to process this organic waste responsibly and cost-

effectively, multiple facilities could share costs of construction and operation rather than develop individual projects and sustain maintenance and operations staff separate from other facilities. A significant barrier to new facility construction or major component additions, like electricity generators or RNG production, is the high capital cost of these systems. A shared ownership arrangement would allow several facilities, in any combination of biogas industry sectors, to distribute the financial risk of these investments and take advantage of the energy produced by the organic waste products their operations create, all this instead of bearing a cost for external disposal.

Regional AD system collaboration can reduce costs to operators and reduce the risks associated with these large investments. In some cases, the construction costs of new AD facilities might be avoided through a better understanding of the organic waste resources available and the existing AD capacity in a given region. This aspect of regional collaboration can curtail the number of plants constructed that are too small to overcome obstacles inherent to scale and increase the number and viability of large plants that are able to utilize biogas in a sophisticated manner. Banks and other financial institutions may then see investment in AD systems as a less risky venture and reduce the cost of financing. Competition for organic waste may also be reduced since fewer facilities will be in search of feedstock to fuel a digester that may otherwise not be needed.

Market Barriers for Non-electricity Biogas System Products

Anaerobic digesters provide a multitude of product outputs that present opportunities from energy production to nutrient management. Still, barriers exist for the full utilization of these products and survey respondents were eager to share stories about proposals that could make a biogas project successful, but were nonetheless just out of reach. These schemes most often involved the development of renewable natural gas (RNG) for injection into local natural gas pipelines, compressed natural gas (CNG) for vehicle fuel, and the struggle to manage AD system effluent. Each of these is detailed in turn in the problems and suggested solutions below.

Problem: Utility Requirements for Renewable Natural Gas are Excessive and not Cost-Effective

An alternative to electricity production at AD facilities is making RNG for injection into the natural gas pipeline network for general use or for special use on-site or nearby to generate heat in buildings and for industrial thermal load processes. Converting biogas into RNG, also known as biomethane, involves removing nearly all contaminants so that it closely resembles the molecular makeup of traditional, fossil fuel-derived natural gas. The requirements that natural gas utilities place on the quality of RNG, however, including purity and injection schedule, are often excessive and cost-prohibitive. In one case, a survey respondent talked about requirements to keep a routinely-collected sample of RNG available for lab testing at all times in case contaminants were detected later within the distribution system, which consumed lab time and space even though no problems were ever detected with the gas being injected into the pipeline. Another obstacle to expanded use of RNG follows many of the typical concerns with the cost of system components. Systems for producing RNG and monitoring the quality of the gas are very costly, leading some facilities to discontinue RNG production or sideline proposed projects until the price of components and compliance is reduced and/or the market price of natural gas increases.

As an aside, as part of the Public Utility Regulatory Policies Act of 1978 (PURPA), electric utilities are forced to buy power from distributed, privately-owned facilities at a minimum of the avoided-cost rate for that power[8]. This provision has proven to be controversial for many utility companies across the United States, but has stood against litigation. In terms of distributed generation of RNG, there exist no such rules or mandates on natural gas utilities. This has become a considerable frustration for AD system operators in the state as there are opportunities for them to receive credits outside of Wisconsin for the RNG they could produce as long as they have access to the natural gas transmission and distribution systems.

Solution: Build Closer Relationships with Natural Gas Utilities

Some survey respondents felt that a closer relationship with the natural gas utilities could surmount some of the challenges with RNG injection into the natural gas pipeline network. Respondents talked about several instances where they felt natural gas utilities were simply unaware of the particular characteristics of RNG and were imposing impractical and burdensome requirements to avoid formulating guidelines for RNG producers. This includes 13 survey respondents, some of which indicated that robust plans for RNG production had already been developed and could be implemented as soon as these issues were resolved. Another operator had previously engaged in RNG production but discontinued the project citing issues with requirements from the utility, but was sure to add that he was open to doing it again in the future if changes were made to the requirements.

Solution: Allow Biogas Facilities to Access Specified Pipeline Locations where Quality Concerns are Reduced

Many locations where RNG injection has been proposed are found to be problematic by natural gas utilities because of an increased risk of contamination and RNG over-concentration. These locations, often at or near the end of major pipelines, are not seen as suitable for RNG injection, but utilities are eager to point out that other sections along pipeline routes may be ideal for RNG injection as high volume will dilute any potentially troublesome components of a biogas facility's RNG product. These sections are ideal for many existing facilities in Wisconsin's biogas industry as they are between population centers in rural areas, precisely where many dairy AD systems are located. Information sharing with natural gas utilities to identify these less problematic locations for RNG pipeline injection may also be useful for future biogas project development.

Solution: Establish Uniform Guidelines for Gas Quality across Wisconsin's Natural Gas Utilities

A logical step, much like the previous discussion about environmental regulations, is for natural gas utilities or their regulators to establish uniform guidelines for RNG quality and monitoring. This would provide RNG producers more certainty about gas quality expectations they would

[8] https://www.gpo.gov/fdsys/pkg/STATUTE-92/pdf/STATUTE-92-Pg3117.pdf

need to meet in order to inject into the pipeline and would give natural gas utilities certainty that RNG injected at any point in the pipeline is meeting high standards.

Solution: Provide Funding for the Development of RNG Infrastructure and Establish Cost Share Programs with Interested Local Communities Seeking Fossil Fuel Offsets

As with other uses of biogas, the components necessary to convert the gas into RNG are often very costly upfront or have high operating costs. There remain few funding incentives in Wisconsin for assisting AD operators in managing the costs of gas refining equipment. Even if making grants and low-interest loans is not possible, there are other ways in which state and local governments can ease the financial difficulty of upgrading biogas to RNG. Local governments, in recognizing the environmental benefits to the community of AD and the use of biogas as an offset to using fossil fuels to generate energy, could engage with project developers to share some of the risk of a proposed system. This could come in the form of sharing municipal facilities already in place to establish guarantees for gas quality through use of a lab or offer maintenance assistance for RNG equipment to allay natural gas utility concerns about impurities in the gas, as a few examples. Assisting AD system operators to have more cost-effective operations by utilizing RNG will not only impact the local community in terms of environmental benefits, but could also improve economic development and facilitate job creation for the local community.

Problem: State Policymakers do not Recognize RNG as a Viable Energy Source

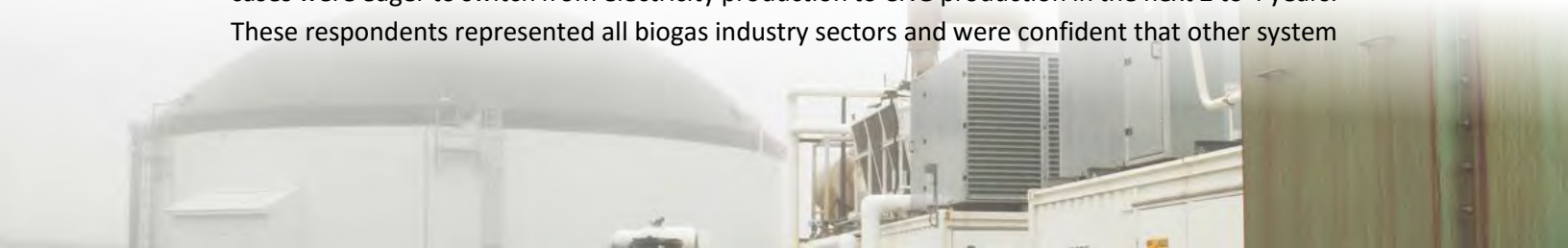
Furthermore, energy regulators and policymakers in Wisconsin have not yet recognized RNG as an energy source, particularly since Wisconsin has no fossil fuel reserves, such as natural gas. This lack of institutional and political support has left many AD system operators withholding plans for RNG development until questions about gas quality and regulation can be resolved.

Solution: Include RNG in Biogas Industry Advocacy

To date, RNG has not been a significant priority when it comes to advocacy for biogas in Wisconsin. Combined with efforts in the formation of a biogas industry advocacy organization previously mentioned, the production, distribution, and use of RNG could be encouraged as a home-grown resource in a state with no naturally-occurring fossil fuel resources.

Problem: Undeveloped Compressed Natural Gas Infrastructure

Another frequently discussed biogas product in the survey was CNG and how the lack of investment and development of CNG infrastructure has inhibited robust development in Wisconsin. CNG production involves removing nearly all contaminants and moisture from the gas and compressing it to less than 1% of its standard volume to around 3,000 psi. CNG can then be used as a substitute for gasoline and other conventional vehicle fuels after some vehicle modifications. Similar to some of the concerns with RNG for pipeline use, prospective CNG producers are wary of the cost for CNG-producing components as an add-on to their AD operation. Even so, 20 survey respondents expressed interest in producing CNG, and in many cases were eager to switch from electricity production to CNG production in the next 2 to 4 years. These respondents represented all biogas industry sectors and were confident that other system



operators would approach CNG production with more enthusiasm if the market were more developed. Conversely, AD operators, particularly farm operators, do not want to undertake significant risk of prematurely entering the CNG market. The market price of CNG remains low compared to gasoline, but a recent decline in petroleum prices has closed this gap and influenced some prospective producers to wait until the price of gasoline rises again. Having acknowledged the risk of being an early adopter of a relatively new technology, many respondents were excited at the prospect of expanded use of CNG in Wisconsin and felt it was an enormous opportunity.

Currently, there are only 2 facilities in Wisconsin's biogas industry that supply CNG, a landfill and a municipal wastewater treatment plant, but interest is growing and the expiration of PPAs in the coming years will likely push many AD facilities toward studies and economic analysis for producing CNG. The most frequently offered explanation for the lack of CNG projects to-date was the lacking development of the refueling infrastructure for the use of the gas in Wisconsin, particularly in rural areas. AD operators were not willing to enter into production until there were positive and robust signals from the market in Wisconsin that indicated it was a safe investment.

Solution: Allocate Resources to Construction and Operation of CNG Fueling Stations, Including at Existing Biogas Facilities

Creating dedicated funds for the construction and operation of CNG fueling stations is an opportunity not only for local and state governments to promote alternative, Wisconsin-grown fuels, but also for commercial trucking fleets in Wisconsin and neighboring states to participate in the build-out of a CNG refueling network that can reduce fuel costs and strengthen renewable energy industries in the Midwest. Other states like California have invested heavily in alternative transportation fuels, including CNG, and have experienced significant fuel cost savings in recent years. Similar efforts can be undertaken in Wisconsin, and it is an especially attractive opportunity given the existing biogas infrastructure that produces an under-utilized biogas resource.

Problem: Lacking Commitments from Commercial Trucking Fleets to Convert to CNG

Paradoxically, the use of alternative fuel vehicles by the general public is often stymied by the lack of refueling infrastructure, as mentioned above. Thus, there is reluctance to develop demand for CNG until there is adequate supply. In other words, a reluctance to purchase CNG-fueled vehicles until there is adequate amount of refueling infrastructure in place.

Solution: Establish Funding for Conversion of Commercial Trucking Fleets

To break this self-reinforcing, negative feedback loop, local and state government should consider taking an active role by offering assistance to businesses and consumers to convert their vehicles to CNG or buy CNG vehicles. It could be done in such a way as to promote a product made in Wisconsin by the state's most well-recognized industries: agriculture and food production. Providing these funds to increase the demand for CNG could spur further development of refueling infrastructure, including at existing biogas facilities.

Solution: Biogas Facilities Establish Agreements with Associated Commercial Trucking Fleets to Supply CNG

Existing biogas facilities may be in the best position to disrupt this negative cycle by entering into agreements with the commercial trucking fleets they are affiliated with to supply CNG fuel. If both groups are wary of investments in CNG technology because they fear a lack of customers or a lack of supply, extended agreements to buy and provide the fuel will help to ensure each group is able to recoup their respective investments. As an example, a farm digester could enter into an agreement with their milk hauler to supply CNG when the trucks stop by to pick up the farm's milk to be taken to market. A more tangible example is demonstrated by the 2 municipalities mentioned earlier that have successfully administered CNG programs at their biogas facilities. In these cases, municipalities have existing trucking fleets available to convert to use CNG creating a closed loop fueling system for the benefit of local taxpayers.

Problem: Many Facilities Flare off Excess Biogas

As mentioned in previous sections, many biogas facilities in Wisconsin are flaring all or most of the biogas they produce. In some cases, this represents an enormous loss of potential revenue and stimulates a discussion about potential uses for the gas. Most facilities are simply complying with air emissions regulations that require them to destroy or burn any biogas produced by the facility instead of allowing it to be vented into the atmosphere. This presents an opportunity to supply some low-cost uses for the gas rather than sending it to a flare.

Solution: Heat the Digester

The thermal value of biogas is high; roughly the same, with impurities removed, as traditional natural gas. With few modifications, natural gas-fired boilers fueled with biogas can generate impressive thermal resources and are often able to offset the thermal loads of entire facilities across biogas industry sectors year-round, even in Wisconsin. The heat generated from biogas is used for several different purposes at AD facilities. Most often, it is used to keep the temperature of the digester at mesophilic temperatures at minimum (around 98 degrees Fahrenheit) and thermophilic temperatures at maximum (around 122 degrees Fahrenheit), as is the case for many municipal wastewater treatment facilities.

Solution: Heat nearby Buildings

Another use of biogas is for generating space heat for nearby buildings, which is a very common and cost-effective use of the gas in Wisconsin. Many facilities are able to provide space and water heating using biogas, an enormous cost savings particularly in rural, northern regions of the state. Some facilities have also entered into agreements with businesses and organizations nearby to supply the gas to be used for heating. This provides revenue for the biogas facility and cost savings for associated organizations.

Solution: Heat Water for Agricultural or Industrial Processes

Additionally, when part of or near industrial and agricultural facilities, the biogas can be utilized to produce process heat for industrial operations and hot water, offsetting what would otherwise likely be accomplished, again, using natural gas. This is particularly common at food processing industrial operations and at dairy farms for using warm wash water. Each of these three uses of biogas are practiced in Wisconsin and can be further examined to formulate best practices for heat production in more cost-effective applications.

Problem: Effluent from some Sectors is Difficult to Manage, Particularly at Municipal Wastewater Treatment Plants

Many municipal wastewater treatment plants have seen in recent years more difficulty in finding enough available, nearby land to apply the digested sludge. In most cases, the only alternatives to land applying the sludge are storage, which is often very restricted and cannot be done for more than four to six months, and landfilling the material, which is usually frowned upon by members of the community as unsustainable, not environmentally friendly, and can be costly. While almost all wastewater treatment plants (53) explained that they give the effluent to local farmers for free, they are still paying for the transport of the effluent using their own hauling equipment or contracting the work to outside parties. Many facilities recognize that the material does have a nutrient value for land application and could be further refined to make more marketable products.

Solution: Produce Dried or Pressed Product (Class-A Sludge, Milorganite) or Secure Land near the Facility

With some larger facilities, driers and presses have been installed to process the material to produce a biologically stable, class-A sludge that has a smaller liquid component and can be sold to the general public in bulk. In a famous example, the Milwaukee Metropolitan Sewage District developed their own brand of fertilizer from their digester solids and market the product with big-name, local retailers. Many in southeastern Wisconsin now use Milorganite on their personal gardens and lawns as a powerful fertilizer with impressive results. Other, smaller municipalities have opted to purchase small parcels of land near their wastewater treatment plant for the purpose of land applying the effluent from the AD system at the cost of transport. It is important to note that these facilities have made these investments as long-term cost saving measures and not necessarily as a prospective revenue positive segment of their operations.

Solution: Produce Compost

Some facilities have entered into agreements with local composting companies that accept effluent from digesters and aggregate the material in their composting process. This has been an effective and safe way for facilities to properly dispose of the effluent and uphold recycling and environmental resource management goals and priorities.

Solution: Farmers use Biosolids as Bedding for Animals

A possible revenue generating option for on-farm digester operators is to use the fibrous biosolid effluent from the digester as a source of bedding for animals on the farm. For some, this is a more cost-effective alternative to using crop residues or sand, which can complicate digester operation by adding steps like intensive grit removal. Not only would this offset the cost of bringing in other bedding like sand or crop residues, but biosolids could also be a marketable product that other farms may wish to purchase, companies could use as a soil amendment, or researchers would use for projects involving commercial algae growth and other applications. Some farms in Wisconsin have put biosolids on the market to see what value they might be to nearby facilities to some success, but further development of the market is needed.

Problem: Use of Biosolids Increases Occurrence of Mastitis in Milking Herd

The use of digester biosolids for animal bedding has been observed to increase somatic cell counts in milk and occurrences of mastitis, but there are several strategies that survey respondents detailed to combat these challenges.

Solution: More Aggressive Stall Management

Seven survey respondents emphasized more rigorous stall management practices in an effort to keep the bedding dry to preclude the growth of bacteria that thrive in moist materials. This may be improved by more frequently changing out old material or installing driers to further reduce the amount of moisture in the solids after it has exited the digester.

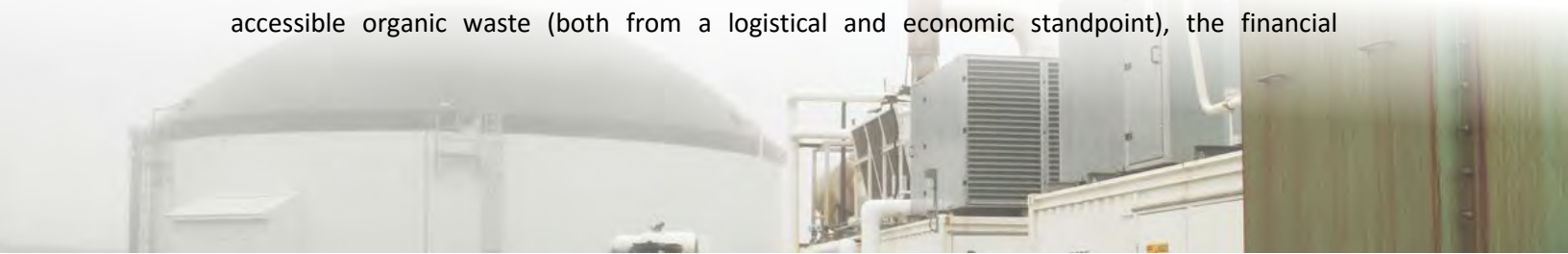
Solution: Mix Wood Shavings with Biosolids to Reduce Moisture

Another interesting solution was discussed by 2 survey respondents who had experimented with mixing the biosolids with wood shavings to reduce moisture levels. A mixture of 1 part shavings and 2 parts biosolids appeared to be the right recipe for reducing moisture and maintaining low somatic cell counts in the milk and guarding the health of the animals on the farm.

Costs of Construction, Operation, and Maintenance

As the biogas industry in Wisconsin develops, there become ever more opportunities for facilities to collaborate with one another in ways that can reduce operational risks and lower costs. Regions around the state with sizeable urban populations or a dense concentration of industrial food processors and large agricultural operations stand to gain the most from partnerships with neighboring facilities. Beyond working together on issues with feedstock acquisition or environmental regulation, organized project developers can realize cost savings by entering into agreements with nearby organic waste producers, coordinating maintenance procedures, and form joint physical or logistical connections for biogas and effluent resources to establish shared refinery facilities for revenue generation.

Before operational decisions are to be made, considerations about the construction of a new AD system introduces many complex and interacting elements. Among these are the availability of accessible organic waste (both from a logistical and economic standpoint), the financial



instruments at hand, the appropriate size of a system while also accounting for future growth, the manner in which the biogas produced will be utilized, and more. These considerations are essential to developing a successful and sustainable project. A number of system operators felt that the development stage of their projects could be improved in several key ways.

Problem: Project Development Proposals are Limited

There are a limited number of AD system developers active in Wisconsin; however, they represent divergent strategies for overcoming organic waste challenges and producing bioenergy. Despite this, many project managers still sought development estimates from only one developer and made decisions based on the recommendations presented. This narrows the scope of proposed projects and may lead to difficulties down the road if the nature of the project is altered by, for example, halting electricity production in favor of other uses of the biogas.

Solution: Project Developers should illicit more than one Proposal from AD System Developers

Some respondents suggested that, when possible, getting more than one developer to propose a system would allow project managers to more effectively choose the AD system that is best for their unique considerations. System operators would benefit from having "second opinions" for an AD system application and design. Allowing for a second or even third opinion may present a more economical means to accomplish the goals of a proposed project by introducing competition. Furthermore, additional opinions may allow for more transparency in system design and operational flaws. More eyes on the plan in the development stage can help to ensure that no aspects of the project are being overlooked.

Problem: System Operations Staff Face a Learning Curve for New Systems

Many respondents spoke at length about the difficulties they experienced when first bringing a new system online. Some described months-long and sometimes years-long struggles to optimize their operations. This can involve initial misunderstandings or lacking knowledge about the particular feedstocks they would be bringing onsite, as well as the complex interactions of the many components that make up an AD system. In one case, an ethanol plant invested in an AD system and had a very low tolerance for error in terms of their project budget. After 18 months of sub-optimal performance, they were forced to shutter the AD system and have yet to bring the system back online. In another example, operators came onsite to manage a system without receiving training or consultation about certain components at the facility. This lead to inefficient decisions about how feedstocks were to be processed or, in an extreme case, meant that certain unfamiliar components went without maintenance or replacement for extended periods resulting in catastrophic failures.

Solution: Have Operations Staff Present during Development and Construction when Possible

Wastewater treatment plant operators, in particular, noted that having system operators present and involved in the construction of the AD system was very beneficial. With recent wastewater treatment plant upgrades, the lead facility operators were also the principal project manager and had a say in what components or system design elements would be included. This gave operators

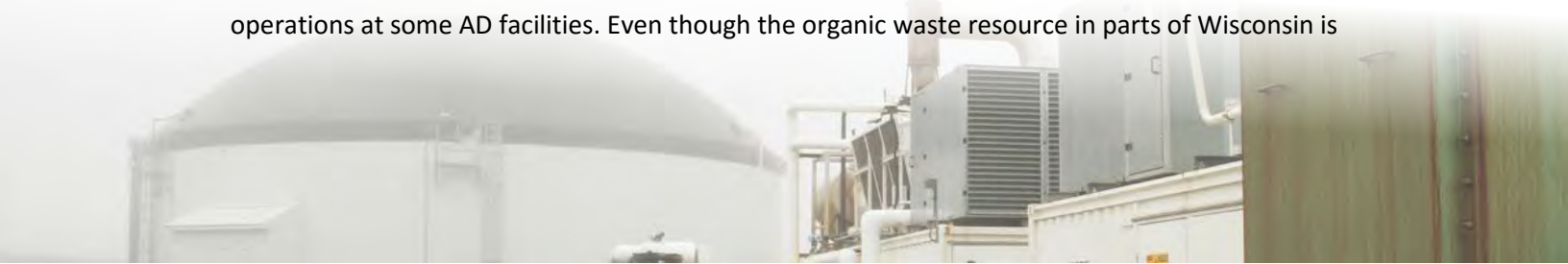
unique insight into challenges that surfaced during operation and allows a more informed approach to finding solutions to that problem. This is in contrast to many on-farm systems in that the day-to-day operators had little to no involvement in project development. Along these lines, many respondents commented that teaming up with other system operators or biogas industry consultants could allow for better project development, along with access to experienced system operators who have a unique understanding about how choices made during development and construction can affect system operations. The added costs of development consultants in the planning stages may be offset by the avoided costs of troubled operations due to design errors or other missteps during project development.

Through the survey, there were other suggestions about formally linking entities to create design/build companies that have a hand in both project planning and physical construction as a way to streamline the development process. Other ideas included a more regional focus on planning and project development to ensure that organic waste challenges of particular communities and regions are addressed without damaging the system fueling prospects for facilities that already exist, as mentioned in a previous section. Additionally, when new system managers are brought onsite long after the completion of construction, developers and those involved in the project's construction could step in to guide the new operator through the ways that construction and component selections could affect operations. As with many other aspects already discussed, greater biogas industry collaboration, cooperation, and transparency can go a long way to neutralizing or at least blunting significant concerns across the industry, particularly in project development.

Problem: Non-Regional Project Development Creates Competition for Organic Waste

As the biogas industry in Wisconsin continues to develop, competition for organic waste has increased. This introduces an opportunity for multiple facilities that produce organic waste to pool waste management resources in a cooperative effort rather than maintaining or constructing separate facilities. This could lead to a reduction in the cost of waste processing for each facility compared to a scheme in which they built and operated an AD facility on their own. As long as the development of organic waste-producing industries in Wisconsin remains steady, the availability of organic waste is likely to follow in a steady quantity. There are, however, still many opportunities to smooth and improve the organic waste landscape in Wisconsin as there will still likely be locations in the state that experience higher-than-normal competition for organic waste, particularly in communities along Lake Michigan and in rural areas with limited transportation corridors and access.

The lack of biogas industry coordination when approaching project development has dramatically increased feedstock competition. While there is an abundant organic waste resource in regions of the state like the Lake Michigan shoreline from the numerous food processing plants and other facilities, feedstock resource allocation schemes for a select number of new facilities were often developed without coordination with existing AD system operators, which has led to very competitive- and often unreasonable- tipping fee structures and termination of co-digestion operations at some AD facilities. Even though the organic waste resource in parts of Wisconsin is



robust, there is still an upper limit to the number of facilities that can be adequately fueled to carry out resource management obligations and produce biogas in sufficient quantities.

Solution: Build Trust by Encouraging Collaboration and Information Sharing in the Biogas Industry to Improve System Siting and Operation

Twenty-eight survey respondents felt that greater collaboration and cooperation within and between biogas industry sectors was necessary to improve the industry's overall efficiency and remove specific barriers that plague certain operations in the state. At the top of these facilities' concerns was the competition for feedstock. To address these concerns, project developers should weigh the cost-effectiveness of building new systems against simply transporting organic waste to an existing nearby facility for processing. To touch on a previous section about the Regional Resource Recovery Centers (RRRC), it may not be necessary for some facilities to build a new system, but instead feed into the AD network already in place. This could avoid the significant upfront costs involved in new facility construction and also lower the risk burden on nearby facilities by giving them more materials to process and potentially ensure more sustainable operation.

Given the lack of robust biogas industry interaction indicated by many survey respondents, OEI staff are committed to hosting an annual Wisconsin Biogas Industry conference where AD system operators can come together to learn more about other AD facilities in the state and establish new conduits for collaboration with nearby facilities. Such a conference was recently held in November of 2015 with plans for another conference in the summer of 2016. This inter-industry collaboration could take the form of sharing training resources; sharing standby components with similar systems; sharing information about overcoming operational challenges; forming a coalition of AD facilities to lobby policymakers or exercise organizational weight for a variety of industry needs, like interacting with local utilities or regulatory agencies; among others. Communication between Biogas Industry sectors will become even more important as facilities become more comfortable with co-digesting diverse feedstocks. Given the complexity of co-digestion, lessons learned with early experiments will prove vital to future operational efficiency for many facilities.

Solution: Establish Guidelines for Determining Tipping Fees or Explore Pipeline Infrastructure Development

Tipping fees are simply a charge assessed on organic waste producers to offload materials to be processed at an AD facility. As there are different features of organic waste that could impact specific systems at an AD system, it is appropriate for tipping fees to vary given the kind of waste that is being brought in. Survey respondents also calculated unit charges in different ways, from per thousand gallons to per ton. Based on the type of waste, tipping fees established by survey respondents varied from no charge to $70 per ton and from $12.50 to more than $70 per thousand gallons. One of the smaller systems surveyed explained that they have been able to bring in between $30,000 to $40,000 per year in tipping fees alone, which can account for a sizeable reduction in the amount of time it takes for a project to payback financial obligations or offset other operational costs. As these represent wide ranges for tipping fees that are often

dramatically different from one biogas industry sector to another, establishment of a more equitable fee appropriate for organic waste of a particular type may be beneficial.

Improvements can be made to arrangements between facilities also by constructing a direct pipeline between an organic waste producer and the AD facility that will eventually process the material. While there is an upfront cost to constructing such pipelines, the ease of operation and lacking need for hauling trucks and other equipment may increase the value of the transaction for all parties involved. Of course, these direct pipeline arrangements are very sensitive to siting and cost since the facilities often need to be in very close proximity. There also may be difficulties as to the kinds of materials to be transported in the pipeline and what lies between the two facilities. Local governments will generally be cautious about permitting the construction of such infrastructure through or near residential zones, for example.

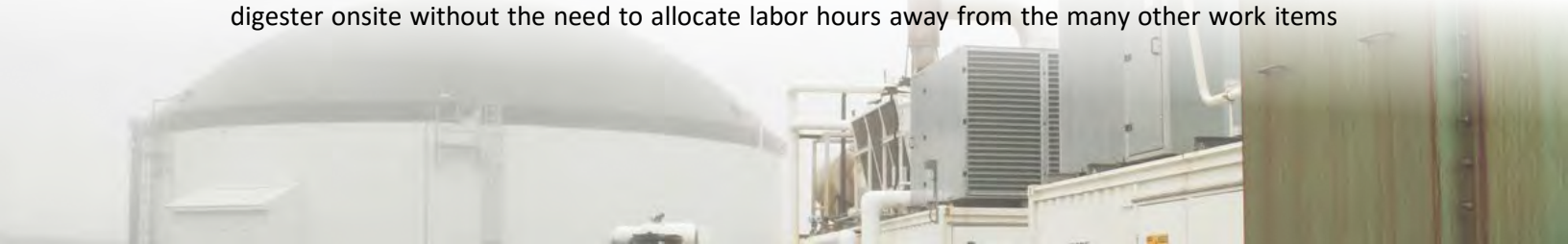
Problem: The Financial Burden and Technical Requirements of System Operation and Maintenance

One of the primary concerns among survey respondents was that operating an AD system required labor hours to be redirected away from normal operations, on the farm or in the factory, to monitoring, operating and occasionally maintaining the AD system. Additionally, many facilities do not have staff that are trained or that have extensive experience with AD systems, leading to sometimes prolonged periods of sub-optimal operations while they become more familiar with how the AD system will react with the available organic waste feedstock, among other things. Also, a lack of redundancy or spare parts were frequent concerns among survey respondents.

Solution: Community Digesters, Third-Party System Operation, and Shared Costs

Most facilities that responded to the survey were operated by the owner, but a small number of facilities were operated by outside staff and there were some particular advantages to this scheme depending on the biogas industry sector. In many cases, respondents were very comfortable with outside operators coming to their facility to operate the AD system. Also, as in a community ownership model, an arrangement between multiple facilities may allow them to justify bringing on dedicated staff to operate and maintain the AD system and leave their other staff to concentrate on conventional operations of the farm or factory, for example. There are a number of different companies and organizations that operate systems on behalf of a system owner, and while this may increase operating costs up front, having skilled and experienced biogas system operators can produce several cost advantages in the long-run. Specialized AD staff are better equipped to address potential operational concerns and administer the project more efficiently. Joint facilities could together build a more robust maintenance account to ensure that the facility benefits from greater uptime. With the shared resources of more system owners, stand-by parts and a more proactive maintenance regime are more attainable than individual operations where labor hours and/or maintenance dollars may be more restricted.

For many farmers, incorporating the additional tasks necessary to operate an AD system is a significant burden, but outside operators allow farm owners to benefit from the operation of a digester onsite without the need to allocate labor hours away from the many other work items



on the farm. In some cases, outside operators also manage the permitting and regulatory requirements for the system as compliance can become complicated for unexperienced AD system project developers as mentioned in a previous section. At least 6 survey respondents had outside firms coming in to operate the AD system and some felt that this could be an enormous opportunity for Wisconsin's biogas industry in the future. In short, system owners in a region or community could share a system operator who would regularly visit the sites under their care and ensure high quality system performance. In this way, multiple system owners could share the costs of an operator, which could also be a way for operators to gain more knowledge and experience in best practices and specific needs of agricultural AD systems.

Some of the same advantages might also be realized by industrial facilities. Many industrial system owners allocate non-specialized staff to work with the digester, pulling them away from other essential daily tasks. A third-party operator would allow an industrial AD system owner to go about doing what they do best and leave the AD system operation to a specialized team that could be shared with other nearby facilities. In some cases, industrial facilities are located near landfill gas capturing projects that are flaring or otherwise under-utilizing the biogas produced. These situations could be ideal for an outside operator to coordinate multiple facilities in a community in order to manage the biogas energy resources being produced. A lone facility may not be able to justify investments in biogas utilization systems like electricity generation or CNG production or have the onsite expertise to efficiently operate them, but multiple facilities may benefit from sharing the costs and benefitting from the improved scale of combined projects.

Solution: Convert to System Components that are Fueled by Biogas

Another design modification involves converting components around the facility, like fans, blowers, motors, and engines, which normally draw electricity to be powered directly with biogas. There are several examples of this strategy in the state, particularly at municipal wastewater treatment plants. This approach is particularly useful in situations where electricity production using biogas is difficult and can be thought of as an energy efficiency improvement project. There is, however, risk involved as well in that there will need to be greater component redundancy or backup systems that run on electricity to avoid system failure during unexpected outages of certain components, but the benefits during normal operation could make such an approach worthwhile.

Equipment and Training for Stable Biogas System Operation

Many survey respondents had strong opinions about the usefulness and effectiveness of certain AD systems and components over others. The most notable responses were in response to challenges encountered by mixing systems, electricity generators, and feeding components and techniques. Combined, these three items were a top-three concern for 103 responses of 227 in total; just slightly under half of the total of all significant operational challenges reported.

It is important to note that these three concerns were not always evenly distributed across Wisconsin's biogas industry sectors. All but 5 complaints about mixing came from municipal wastewater treatment plant operators; about 75% of complaints about electricity generator maintenance and operation came from on-farm digester operators; and of the 46 feeding system

complaints, half (23) were from wastewater treatment plant operators and the rest from on-farm digester (12) and industrial system operators (11). This is encouraging because it may indicate that inter-sector information sharing may prove useful as a process improvement strategy, which will be addressed in the next section.

Also in this section, concerns about training and ways it can be improved will be discussed. As with some of the primary challenges to operation outlined above, many training-related challenges also appear to be biogas-sector specific. Even though there are many training resources available across the state of Wisconsin, along with multiple research institutions and university programs, mainly one of the four biogas industry sectors, that of municipal wastewater treatment, appears to be taking full advantage. But let us begin with the survey's findings on equipment choices.

Problem: Foaming and Unstable Digestate Chemistry

Digester systems can experience foaming as result of a variety of operational missteps, primarily inconsistent feeding either temporally or in terms of feedstock composition. Foaming reduces biogas production and creates mechanical issues with the system which can lead to increased maintenance costs and extended periods of downtime. Foaming can clog biogas recovery systems and even lead to overflowing tanks where material escapes the digester and requires extensive contaminant mitigation and cleanup efforts. This is of particular concern to survey respondents from municipal wastewater treatment plants and some industrial facilities as they are often located within urban areas close to important infrastructure and homes. In the case of wastewater treatment plants, operators were especially cautious about bringing in feedstocks from outside sources to produce more biogas as a measure to keep digestate chemistry stable. Many respondents cited foaming and other smaller related challenges as the primary motivation to resist bringing in additional waste streams for processing at their facility.

Solution: Feedstock Storage Tanks

As mentioned above, a number of the survey's respondents described feeding a digester in inconsistent time intervals as a practice that resulted in system upsets. At times, this inconsistent interval was a product of lacking infrastructure like a waste receiving dock which made it difficult to keep up with a consistent feeding schedule, a common discussion point with municipal respondents, or the periodic unavailability of certain co-digestion feedstocks, a much wider challenge across biogas industry sectors. As an example, one respondent talked about how the industry that supplies an additional feedstock was not in operation on weekends or some holidays, which meant there were periods when the timeliness of the feedstock going into the digester was irregular. In response, the survey respondent spoke about the inclusion of a feedstock storage tank that allowed their operation to continue consistently feeding the digester even on days when the nearby industry was not in operation, as long as they were able to bring in a surplus of material during the industry's normal operational periods.

Solution: Pre-Mixing Tanks and Improved Lab Testing

As previously mentioned, survey respondents who have experienced periods of operational instability indicated that conveying feedstock in regular intervals and ensuring that the feedstock does not introduce dramatically different material to the digester biology is essential for smooth operation. To address the second part of the inconsistency they spoke about, a number of respondents from across the biogas industry advocated for the use of pre-mixing tanks where incoming feedstocks are fully homogenized before entering the digester tank. This allows for a more consistent influent in terms of content and mitigates shocks to the system that may result from various unmixed or non-processed feedstocks. This also gives operators a chance to treat or prep the feedstock, such as by adding compounds to assist the anaerobic bacteria in breaking down the material or bringing the feedstock up to a suitable temperature. Twenty-seven survey respondents from across the biogas industry described difficulties maintaining the temperature of the digestate, particularly in the winter months. The ability to bring the pre-mixed materials up to an appropriate temperature before entering the digester tank may resolve some temperature management issues.

Pre-mixing tanks could also make waste pre-treatment and sampling procedures easier by allowing operators to sample and test the influent before it enters the digester to make more informed decisions about how to modify the influent if an upset is present in the digester tank. Facilities that employed pre-mixing tanks indicated fewer incidents of foaming and other complications due to problematic feedstock characteristics. Having a feedstock pre-staging area also allows operators to ensure no contaminants will damage the digestate biology. Contaminants can then be discarded or treated before flowing into the digester. More generally, survey respondents that experienced fewer operational upsets were engaged in more frequent and comprehensive lab testing of incoming waste materials and the digestate, giving them more information to make quick, better informed decisions if signs of an upset appear.

Problem: Insufficient Mixing

Significant concerns among respondents included the effectiveness of the mixing that occurs within the digester tanks themselves. Mixing within the digester tanks assists the anaerobic bacteria in accessing the available food in the digestate. Mixing also maintains consistency of the digestate temperature throughout the tank and reduces portions of the tank where sediments and other materials gather, known as “dead spots” where the bacteria are not productive.

There are several kinds of mixing systems available. Some employ the biogas produced by the bacteria by recirculating it to the bottom of the digester tank to bubble up to the surface, agitating the digestate as it goes. Others function alongside heating components where digestate is constantly pumped out of the digester tank, heated, and moved back into the tank creating a circulation pattern in the digestate. The final type, and perhaps the most simple, are mechanical agitators that physically move the digestate with fans or blades. Each of these systems exhibit advantages and disadvantages in cost and mixing effectiveness and are ideal in varying circumstances dependent upon feedstock composition, total solids content, and other environmental characteristics.

Solution: Use of Mechanical Mixing instead of Compressed Gas Mixers

Twenty-four municipal wastewater treatment respondents, for example, spoke about problematic mixing technology in use within the digester tanks and expressed interest in moving away from compressed gas mixers and toward mechanical mixing. Mechanical digestate mixing is important to avoid aforementioned dead spots. Nearly every wastewater treatment plant operator that had upgraded their mixing system mentioned that moving away from the compressed gas mixing resulted in better digestate consistency, fewer dead spots in the digester tank, and less downtime from removing clogs in the digestate pumps and pipes. Altogether, it would appear that even though the compressed gas mixing systems require the smallest upfront cost, they create the most headaches with operation and maintenance and may not be cost-effective over an extended timeframe.

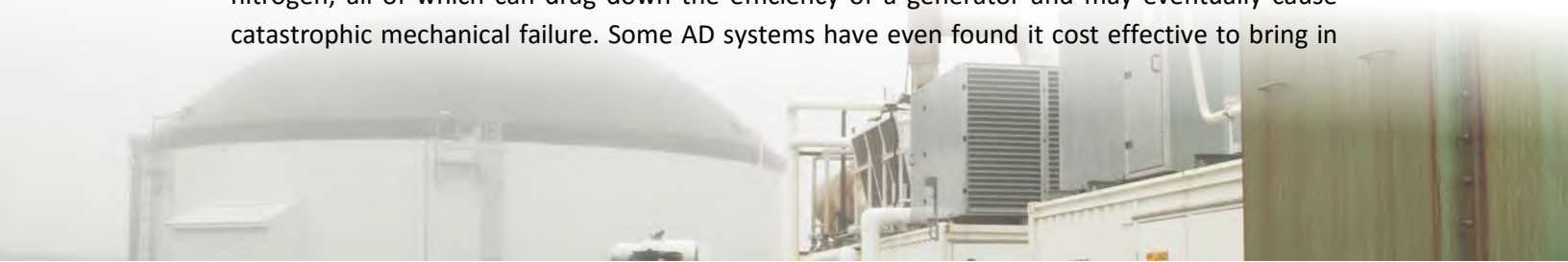
Problem: Genset Operation and Maintenance is Complicated by Dirty Biogas

Beyond the fight for digestate consistency, a principal concern among survey respondents was the maintenance and operation of electricity generators at AD facilities. Many of these generator engines have experienced catastrophic failures rendering them inoperable for up to several months leading to significant lost revenues and complicating system economics. In most cases, PPAs were ongoing even though no power was being generated, severely limiting the overall cost-effectiveness of electricity generation investments. This is especially important in an environment where favorable PPA renewal is uncertain. Challenges confronting operators with electricity generators varied, but were primarily a function of biogas characteristics or quality, time and resources required for maintenance, and availability or reliability of service and support technicians.

Solution: Implement One or More Biogas Scrubbing Systems

There is a wide variety of biogas scrubbing technologies commercially available that are tailored to contaminants that are common in particular feedstocks. As a general rule, many survey respondents mentioned that project developers and owners should be considering biogas scrubbing systems more often to ensure that the gas is adequately refined in proportion to the generator's capacity. Without adequate biogas scrubbing components as part of the AD system, operators will need to allocate more labor hours and parts replacement cost to maintenance for the generators, as well as account for more downtime that can diminish the value of a hard-won PPA.

In many cases, operators have opted for a more aggressive maintenance schedule to protect generator functionality, which may cost less than a sophisticated biogas scrubbing technology. In other cases, operators have brought in systems to extract biogas contaminants to preclude the need for an intense maintenance regime. Contaminants include siloxanes (a product of soaps and beauty supplies, prevalent at wastewater treatment plants and landfills), hydrogen sulfide (H_2S, most common at on-farm AD systems), and other combustion inhibitors like carbon dioxide and nitrogen; all of which can drag down the efficiency of a generator and may eventually cause catastrophic mechanical failure. Some AD systems have even found it cost effective to bring in



more than one biogas scrubbing system as certain contaminants are removed by some techniques and not by others or are simply more effective in concert. For each scrubbing system, there are variations in upfront cost, operational cost, and effectiveness in removing contaminants. AD system developers and other biogas quality consultants can provide additional information regarding the costs and benefits of specific systems.

During the development of an AD project, when considering biogas scrubbing systems, decision makers are often confronted by a choice between high upfront cost and high operational cost. As a simplified example, a power system that has just a genset without scrubbing technology will involve less upfront cost, but the cost of maintenance and operation will increase. In comparison, a power system that has a genset and biogas scrubbing technology will involve more upfront cost, but the cost of maintenance and operation will be relatively reduced. This isn't to say that there are no maintenance or operational costs associated with biogas scrubbing technologies as many require replacement of scrubbing media or a steady input of chemical or biological additives, which means that the same considerations about upfront cost versus operational cost still apply.

Through the responses from the survey, it is clear that there are opportunities for AD system developers and consultants to inform their clients about the role biogas scrubbing systems can play in smoother AD system operation. In addition to greater education about biogas scrubbing for AD system owners, many survey respondents felt that more research should be conducted to find more economical solutions for biogas scrubbing, particularly for H_2S removal as this was a primary factor in on-farm AD genset failure.

Solution: More Aggressive/Pro-Active Maintenance for Generators

For each strategy, there are advantages and disadvantages, but municipal wastewater treatment plant operators have valuable information regarding more aggressive maintenance regimes. Nine municipal AD system operators had adopted a more proactive maintenance regime for their system and 14 moved to automated maintenance systems. This strategy requires more generator downtime, but may be more cost-effective than bringing in additional components, like biogas scrubbing, in some circumstances. Compared to other biogas industry sectors, municipal wastewater facility operators more often had staff with advanced training in generator maintenance and other system maintenance specific to the needs on site. As previously mentioned, farm and industry system operators are subject to allocating labor hours to many daily activities other than AD system maintenance, complicating the decision to employ a more robust maintenance regime. Still, it may be a more cost-effective solution compared to biogas scrubbing systems.

Solution: Third-Party Operations and Maintenance Staff for Generators

An important consideration highlighted by a number of agricultural AD system operators was bringing in a third-party to conduct generator service support, which was often lacking and varied widely depending on equipment vendors and service providers. On-farm system operators generally lacked knowledgeable in-house staff who could effectively perform generator maintenance, as well as a burdensome workload with too few hands available and problematic

system design. A handful of survey respondents commented on the advantages of having offsite personnel operating the digester and generators as it allowed farm staff to go about the business of running the farm and allowed specialized digester operators to handle maintenance and operation of the AD system, and similar comments were made by industrial system operators. Indeed, this was a primary concern of one would-be on-farm AD system owner who was unwilling to commit to installing a system unless he could find an experienced outside operator. In fact, survey respondents who were currently engaged in this type of a relationship with a third-party operator voiced the fewest concerns about system operations and felt that they were getting the most worthwhile service for what they had invested. In all, there were 18 survey respondents who maintained a close relationship to their system's developer for maintenance and operational support and 16 other respondents who relied on third-party operators for complete or partial system operation.

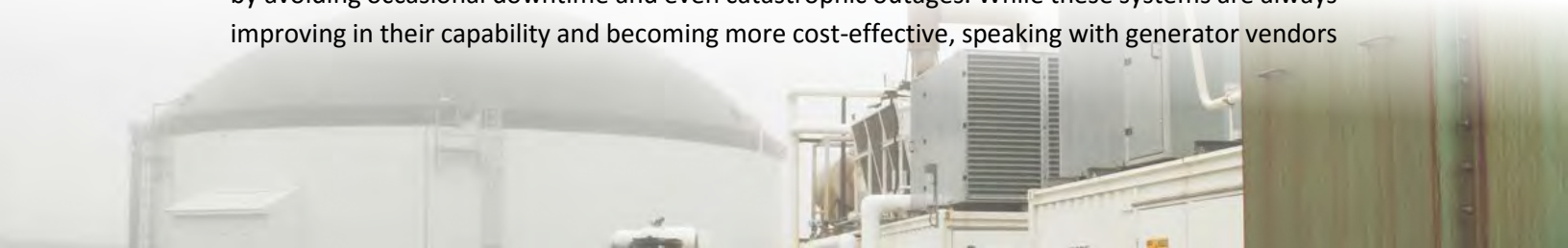
Problem: Complex System Maintenance Requirements

Survey respondents repeatedly described AD systems as simple machines surrounded by complex, supporting components that require concerted daily interaction to maintain a high level of operational efficiency. Sixty-one survey respondents, almost exclusively municipal wastewater treatment plant operators, mentioned replacement and maintenance of these supporting components as a top concern. While not strongly correlated, respondents that spoke about proactive maintenance regimes seemed to experience fewer unexpected system outages and saw overall higher uptime.

Solution: Automated Maintenance System

Thirty-four respondents, wastewater treatment plants in particular, had mentioned that a reactive maintenance regime was adequate to address the inevitable breakdowns and setbacks that come with AD systems. However, 33 system operators, evenly distributed across biogas industry sectors, explained how they had, over recent months and years, moved to a more proactive maintenance regime to limit downtime and introduce more predictability to system outages. An additional 16 respondents spoke about how the move to an automated maintenance system had further improved their system's uptime and stabilized the often uneven schedule of costs involving the ordering and installation of replacement parts. Even with these advancements in maintenance techniques, generator maintenance remains a difficult obstacle, particularly when specialized service and support is lacking as mentioned in the previous section.

In any case, it seems that one of the more successful tactics in system maintenance is to shift to a more proactive maintenance regime. And if operational budgets allow, the incorporation of automated maintenance systems are also valuable to ensure greater uptime. In the case of electricity generation, improved software has recently given generator system operators better insight into how the generator is functioning and provides more detailed readings about a machine's output and where potential problems are likely to surface. These monitoring add-ons may carry a larger cost upfront, but they appear effective in lowering long-term costs of operation by avoiding occasional downtime and even catastrophic outages. While these systems are always improving in their capability and becoming more cost-effective, speaking with generator vendors



and other consultants can point system owners and operators in the direction that best suits a particular facility's needs.

Problem: Lacking Co-Digestion and Equipment Maintenance Training

Many survey respondents explained that training was not specifically designed to address challenges regarding co-digestion of multiple feedstocks and relied on established procedures that had not been recently updated. Survey respondents even mentioned that training was not a significant concern for their operations, though many facilities relied heavily on learn-as-you-go training, and this was very sector-specific. For example, 51 of 63 municipal wastewater treatment operators mentioned that their operators had formal AD training through a variety of resources, but only 3 of 25 farm digester operators indicated having received such training. Conversely, 15 farm digester operators relied heavily on learn-as-you-go training and 12 municipal wastewater facilities did the same. There are often structural reasons for this in that municipal wastewater treatment operators are often in specialized positions, while many farm digester operators are conducting AD system operations alongside a multitude of other farm-related tasks with fewer colleagues to organize AD-related tasks. In sum, greater outreach to facilities to identify training opportunities may help to avoid certain operational challenges and allow the biogas industry to function more effectively.

Solution: A Re-Working of Standard Conventions for AD Operation

Regarding these established procedures, one survey respondent in the municipal wastewater treatment sector explained that these guidelines were out of date and were in need of significant revision. They went on to say that they had been engaged in co-digestion of multiple different feedstocks for several years and had experienced great success in biogas production and system performance despite established industry norms.

Solution: Allocation of additional Time and Resources to Operator Training

This success, they explained, was at least in part due to advanced training in AD co-digestion and heightened diligence in monitoring system stability. Most of the operators on staff, as well as lead operators, were graduates of the University of Wisconsin system with technical training in waste treatment and natural resource management, and had participated in multiple training courses through the Wisconsin Wastewater Operators Association (WWOA), the Wisconsin Rural Water Association (WRWA), and the Central States Waster Environment Association, a branch of the Water Environment Federation (WEF).

To address concerns about degradation of components when co-digesting feedstocks, another primary reason many respondents gave to avoid co-digestion, the respondent described a robust program where each digester tank was taken down for cleaning and inspection every three years, making it one of the most extensive maintenance programs in that biogas industry sector. Altogether, the operators of this facility showed a great deal of confidence in advanced training being a central aspect in their successes in handling multiple waste streams and bringing biogas production to a high level.

Additionally, many survey respondents spoke about the creation of a Wisconsin biogas forum where system operators, organic waste producers and other stakeholders could exchange information to increase the overall efficiency of the biogas industry. System operators often suffer from a lack of information regarding nearby resource needs and capacity. Similar to earlier mention of a need for greater openness and collaboration concerning organic waste resources, Wisconsin's biogas industry would also benefit from more information about energy needs in the surrounding community. While many landfills and industrial facilities currently flare most or all of their biogas, surely a missed revenue generating opportunity, there may be facilities nearby that AD system managers could enter into an agreement with to provide biogas to offset heat and/or electricity costs that would benefit both facilities.

Biogas Industry Collaboration and Cooperation

As mentioned in other sections, many of these challenges can be addressed through collaboration with other stakeholders in the biogas industry. Particularly in the case of agricultural and industrial systems, dedicated staff with a strong technical understanding of genset operation and maintenance are not always on hand and such facilities would benefit from shared maintenance staff that can be regularly rotated between a group of collaborating facilities, for example. In a more intensive interaction, nearby facilities could pipe biogas to a centralized hub for scrubbing and power generation, foregoing the need for such staff to be available at an AD facility.

In a broader sense, Wisconsin's biogas industry suffers from a lack of leadership when taking on policy challenges and barriers erected at the local level. Also, facility operators, even within the same biogas industry sector, are unwilling to share their success stories for fear of losing a competitive advantage. These are difficult barriers to overcome, but should be set aside in pursuit of solutions to shared challenges.

Among the actions to be taken from the findings in this report, OEI staff are committed to bringing Wisconsin biogas industry stakeholders together for annual meetings to share the challenges they have faced and the lessons they have learned by operating their AD systems. As it will be apparent from the following discussion, OEI and many of the survey's respondents are confident that greater transparency and information sharing between AD system operators would allow for more efficient biogas industry operation and allow positive aspects of these systems to be even more impactful.

Problem: Lacking Biogas Knowledge among the General Public

Awareness among the general public about Wisconsin's biogas industry is relatively limited. Many survey respondents shared a number of anecdotes about how their operations had touched the lives of people living in the same community, and in some cases people were completely unaware. When asked if there was organized opposition to AD operations, 26 survey respondents mainly highlighted the opposite, but also 12 respondents indicated that neighbors were likely not aware of the AD system at all. A handful of other respondents commented that opposition was limited to normal industrial-type nuisances, such as mechanical noise, project siting, emissions or visible steam, increased traffic, and odors.

Solution: Targeted Education and Outreach for Communities

In communities where AD project developers took an active role in reaching out to members of their communities, there was a notable increase in support for the project. Often, there were comments about why this type of activity isn't more prevalent in Wisconsin. The few instances where opposition grew with outreach mostly stemmed from project siting as some in various communities did not want to be next door to an AD facility. Primarily, any mention of community interaction with an AD system, particularly regarding farm digesters, came in the form of not experiencing something unpleasant because of the digesters operation. For example, one farmer talked about how switching over to land applying fertilizers that have gone through an AD system instead of raw manure allowed him to land apply fertilizer even on the day of the big football game right next to where the game would take place and heard no complaints about manure odor. In general, survey respondents agreed that more outreach efforts to the general public about the biogas industry would be of some benefit for the biogas industry.

Problem: Lacking Biogas Knowledge among State Policymakers

Of greater focus for survey respondents, more than outreach to the general public, was outreach and education for state and local policymakers. Many respondents had had some interaction with their local elected officials in some capacity to support AD operations and were at times met with lacking knowledge of how these systems work or what would be the best ways that support can be provided. Twenty-two survey respondents suggested that odor and pathogen reduction were of the more significant benefits of AD, and 34 respondents indicated the positive impact of nutrient management through AD on local waterways, all of which are very localized environmental benefits. Nine other respondents commented on the cost-effectiveness and economic development potential of AD, which can have a dramatic impact on smaller, more rural communities in terms of job creation. Additionally, representatives in the Wisconsin Senate and Assembly are often unfamiliar with the positive benefits of AD as a tool to promote essential Wisconsin industries, improve environmental quality, and create jobs. Even so, local city or municipal leaders are often unaware of the positive impacts of AD systems.

Solution: Establish Regular Outreach Events with Policymakers

Twenty-seven survey respondents suggested that targeting state-level policymakers for outreach and education about AD would benefit the industry and create more opportunities for the industry's development. Eight other respondents suggested specific policy items that state lawmakers should be more supportive of, including increasing Wisconsin's RPS, offering additional financial assistance, and facilitating more interaction with power companies. They went on to mention the potential effectiveness of regular outreach to policymakers both in their local communities and in Madison. Through regular interactions, policymakers may become more familiar with the challenges to the biogas industry in Wisconsin and with the potential that the industry has for economic development and meeting the state's energy goals.

Problem: Unfavorable Press

In many conversations with survey respondents, concerns were expressed about the way in which journalists have covered issues concerning the biogas industry in Wisconsin. With few exceptions, AD system operators felt that local and state media had unfairly portrayed AD as an environmental hazard, a dangerous and unproven technology, an ally to some of the most controversial agricultural operations in the state (CAFOs), and a financial boondoggle thrust upon struggling businesses and farmers. They were concerned that articles mostly focused on failures and missteps in the biogas industry rather than positive stories about economic development, environmental stewardship, and improved relations with neighbors that AD systems have made possible. In particular, system failures and incidents that have occurred at one or few AD operations in Wisconsin have been used to paint the entire biogas industry as a troubled organization with deep flaws that are in desperate need of being addressed.

Solution: Open Up Facilities to the General Public and Share Success Stories

In response to criticism for the industry as a whole, many facilities, particularly on-farm systems, have opened their doors to the public to provide an in-person look at how AD systems fit in with agricultural operations and provide unique benefits. Given the 12 survey respondents who mentioned that neighbors were likely unaware of the presence of their AD system, this may be an opportunity for businesses, farms, and local municipalities to open up to the local community and encourage meaningful exchange to counteract the view that AD systems are ill-managed operations. Through the survey, it was clear that there are a number of success stories for facility owners and operators to share that could improve the biogas industry's image. It is incumbent upon them to approach the media with these stories rather than wait for the next operational miscue.