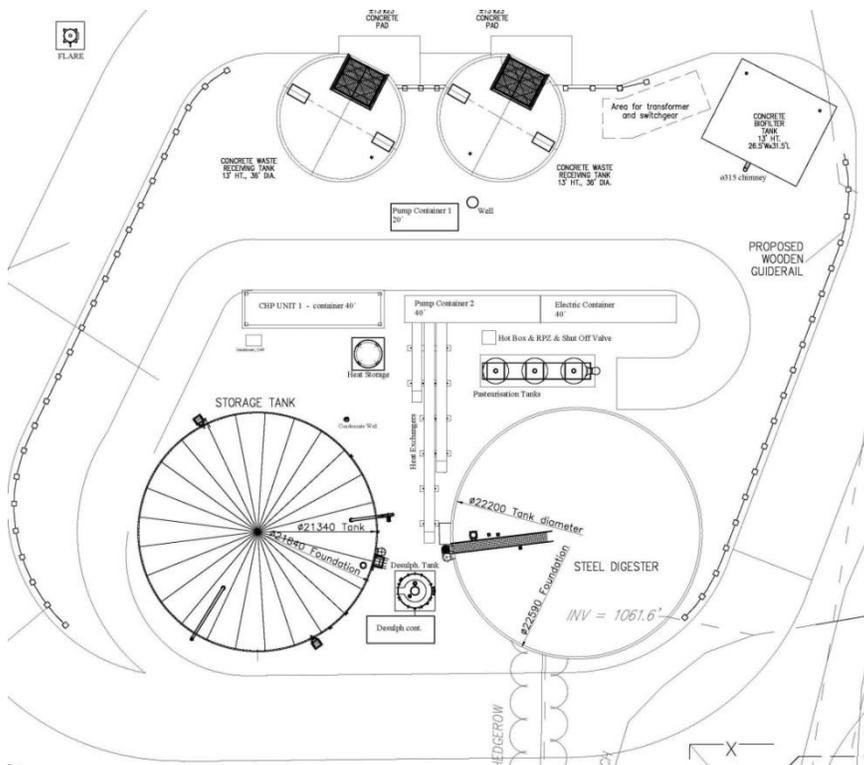




Cornell University

2012

Practical Considerations and Implementation of Anaerobic Digester Systems



Written by: Jennifer Pronto,
Curt Gooch, P.E., and Nellie
Brown, M.S. C.I.H

Cornell University PRO-DAIRY Program
and Workplace Health and Safety

Program

6/20/2012

A guide to educate participants on farm-based anaerobic digesters from planning and design to construction

NOTICE

This report was prepared by Jennifer Pronto and Curt Gooch, P.E. in the course of performing work contracted for and sponsored by the New York State Energy Research and Development Authority (hereafter NYSERDA). The opinions expressed in this report do not necessarily reflect those of NYSERDA or the State of New York, and reference to any specific product, service, process, or method does not constitute an implied or expressed recommendation or endorsement of it. Further, NYSERDA, the State of New York, and the contractor make no warranties or representations, expressed or implied, as to the fitness for particular purpose or merchantability of any product, apparatus, or service, or the usefulness, completeness, or accuracy of any processes, methods, or other information contained, described, disclosed, or referred to in this report. NYSERDA, the State of New York, and the contractor make no representation that the use of any product, apparatus, process, method, or other information will not infringe privately owned rights and will assume no liability for any loss, injury, or damage resulting from, or occurring in connection with, the use of information contained, described, disclosed, or referred to in this report.

Notes:

Course Outline

1. Introduction and course objectives
 - 1.1. Course description
 - 1.2. Audience
 - 1.3. Approach
 - 1.4. Objectives
2. Practical Considerations
 - 2.1. Farm needs, goals, objectives, and plans
 - 2.2. Utility interfacing
 - 2.3. Nutrient management
 - 2.3.1. Nutrient transformations
 - 2.3.2. Assessment of additional waste inputs
 - 2.4. Neighbor relations and community education
 - 2.5. Management of pathogens
 - 2.5.1. Effect of anaerobic digestion on pathogen levels
3. Design Considerations: What producers should know
 - 3.1. Selecting the digester designer
 - 3.2. Digester type and AD system components
 - 3.2.1. Plug-flow AD
 - 3.2.2. Mixed AD
 - 3.3. Codes and laws
 - 3.3.1. Animal by-product regulations
 - 3.3.2. Nutrient management and land application guidelines
 - 3.3.3. Zoning codes
 - 3.3.4. Regulations on biogas plants and biogas handling
 - 3.3.5. Net metering
 - 3.3.6. Air quality regulations of distributed generation sources

Notes:

- 3.3.7. USDA AD standards
- 3.4. Characteristics of manure and other inputs
- 3.5. Identify potential safety hazards
 - 3.5.1. Designing out confined spaces
- 3.6. Monitoring and instrumentation
 - 3.6.1. Performance evaluations
- 3.7. Manure collection, handling, influent storage
- 3.8. Effluent and separated solids handling
- 3.9. Subsystem components and design
 - 3.9.1. Biogas handling and transport
 - 3.9.2. Combined Heat and Power Systems (CHP)
 - 3.9.3. Parasitic load
 - 3.9.4. Flare
 - 3.9.5. Boiler
- 4. Safety
- 5. Construction/Contracting Management
 - 5.1. Contract documents
 - 5.2. Contract management, the Big Three: scope, schedule, costs
 - 5.2.1. Scope
 - 5.2.2. Schedule
 - 5.2.3. Cost
 - 5.3. Construction management options
 - 5.4. Pre-Construction: Project bidding
 - 5.5. Pre-Construction: Construction contracting
 - 5.6. Construction
 - 5.7. Post-construction
 - 5.8. Suggestions for prudent construction management
- 6. Considerations of AD process performance

Notes:

7. Value added ventures

7.1. Excess heat usage

7.2. Excess biogas uses

7.3. Post-digested separated solids

7.4. Long term contracts

7.4.1. Power purchasing

7.4.2. Food waste

7.5. Food waste inputs

7.5.1. Quantity and type of waste

7.5.2. Effect on quantity of biogas and subsystem sizing requirements

7.5.3. Land base requirements

7.5.4. Regulations of food waste handling and processing

8. Additional resources

Appendix 1: Glossary for New York State manure-based AD

Appendix 2: PSC role for Distributed Energy Generation Systems

Notes:

Acknowledgements

Thanks to Rodrigo Labatut, PhD for his written contributions to this document.

Notes:

Course content

1. Introduction and course objectives

1.1. Course description

This course prepares learners to implement and run an AD system from the planning and design phase to operation and maintenance. It focuses on the design of AD systems; how to successfully interact with a designer so that the farm's needs are met; and basic operation and maintenance.

1.2. Audience

This course is aimed at dairy producers who have made the decision to pursue anaerobic digestion on their farms, engineering companies, dairy advisors, university personnel in animal agriculture, extension staff, professionals seeking continuing education units, agricultural professionals, environmental management planners, manufacturers and suppliers of subsystem parts, contractors and service providers.

1.3. Approach

This is a two day short course. A course workbook is provided.

1.4. Objectives

- Describe the differences in available AD system designs, and identify designs suited for particular farm characteristics
- Recognize and explain the fundamental components of the AD and their functions
- Recognize and explain the fundamental components of the entire AD system and their functions
- Understand construction management options and the benefits/shortcomings of each
- List and describe laws, agreements, permits, and codes that are relevant to anaerobic digester development and operation
- Produce an implementation time table for the development of an AD system
- Produce and maintain documents tracking project scope, schedule, and costs.
- Recognize and understand important issues regarding utilities, such as interconnection and the NYS Net Metering Law
- Operate equipment to measure gas quality, and be aware of equipment used to measure gas quantity and measure gas flow.
- Describe safety considerations in regards to AD design in order to minimize operational safety hazards.

Notes:

- Learn the options for, and importance of, removing confined spaces from an AD design
- Learn the options for, and importance of, installing sensors and control devices to ensure operational safety
- Operate equipment to measure gas quality, and be aware of equipment used to measure gas quantity and measure gas flow.

Notes:

2. Practical Considerations

2.1. Farm needs, goals, objectives, and plans

A clear definition of the goals and objectives of the farm is necessary to proceed in making the decision to incorporate an anaerobic digester to the farmstead. An initial step is to assess these goals and objectives and to have open discussions between the design team and the farm. Experience has shown that common goals and objectives that producers have include:

- Reduction of odor
- Reduction of manure application costs (tangible and non-tangible)
- Generation of electricity
- Production of bedding material from separated manure solids
- Assistance in complying with nutrient management plans
- Exportation of nutrients off-farm
- Reduce greenhouse gas emissions

The proper viewpoint on anaerobic digestion is one that recognizes that anaerobic digestion is a viable component of an overall manure treatment and handling system for many, but not all, dairy farms. A systems-based perspective of anaerobic digestion is one that not only looks at the advantages and disadvantages of anaerobic digestion itself but also how anaerobic digestion affects the farm from all pertinent perspectives. This approach is imperative in today's dairy industry and environmental regulatory climate as each are dynamic and change is driven by forces outside of the dairy producer's control.

There are many timely items in the process of planning and constructing an on-farm anaerobic digester system. Below are some important items of business to keep in mind, not necessarily in the order they may occur:

- Determine farm goals and needs
- Perform an energy audit
- Perform a feasibility study
- Interview designers and consultants
- Contact utility with intent to net-meter
- Source feedstock(s) (if applicable)
- Sign long-term contracts (if applicable)
- Source energy end-user (if applicable)
- Sign energy purchase agreement (if applicable)
- Obtain proper permits (i.e., building permit, land application permit, etc.)
- Choose AD designer
- Apply for appropriate grants

Notes:

2.2. Utility interfacing

In order to develop uniform interconnection requirements across all New York State utility companies, the Public Service Commission (PSC) developed the “Standardized Interconnection Requirements” (SIR) guidelines. This is an important document for producers to review and understand before beginning the process of installing an AD system to generate power. A summary of the guidelines presented in the SIR document are outlined in Appendix 2.

2.3. Nutrient management

2.3.1. Nutrient transformations

Dairy cattle manure naturally contains nitrogen (organic-nitrogen and ammonia-nitrogen), phosphorous (in solid and dissolved forms), and potassium. These nutrients are needed by crops such as corn and alfalfa grown on dairy farms to feed the cows.

Anaerobic digestion of dairy cow manure has been shown to conserve the basic elements N, P, and K. However, some of the organically bound N and P are converted to soluble form during the digestion process; the soluble form is readily available for plant uptake and utilization. Cornell University research has shown that ammonia-N ($\text{NH}_3\text{-N}$) and ortho phosphorus (OP) increased on average 23.4% and 15%, respectively, as a result of the anaerobic digestion process at five farms, as shown in Figure 1.

Timely application of stored digester effluent on a growing crop results in a higher percentage of the manure nutrient being used by the crop and thus less available for further transformation to oxidized nitrogen (nitrite-N and nitrate-N).

From a phosphorus standpoint, anaerobic digestion increases the fraction of total phosphorus in a dissolved state, which is the form more available for plant utilization.

Overall, high plant utilization of manure nutrients lessens the impact on water quality from both human health and environmental conservation standpoints.

Notes:

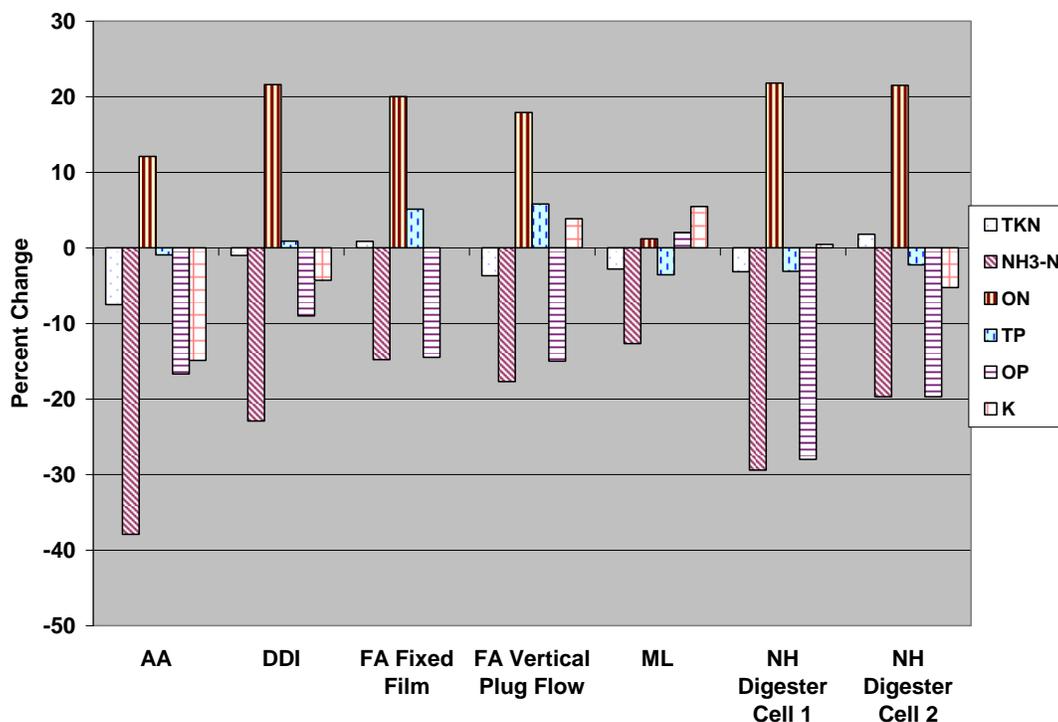


Figure 1. Percent change in constituent concentration during anaerobic digestion for each farm. Negative values represent an increase in the constituent concentration

2.3.2. Assessment of additional waste inputs

It is likely that the most difficulty farms will have with importing substrates for anaerobic digester is difficulty in maintaining mass nutrient balance. Substrates contain nutrients N, P, and K and therefore add to the nutrients coming on-farm. The concentration, generally expressed at the farm level in the units of lbs/1,000 gallons, varies by substrate. The NYS farm with the longest history of importing food waste for co-digestion in the U.S. has sourced substrates from multiple sources since 2004. Digester substrate sampling from January 2004 to May 2005 showed that overall a tanker load of imported food waste had the same nutrient content of a tanker load of that farm's dairy manure.

2.4. Neighbor relations and community education

In preparing to incorporate an anaerobic digester to a dairy farm, it is important to keep in mind the effects on neighbors and the wider community. Despite the fact that anaerobic digesters offer several benefits to the immediate farming operation and the wider community, the technology and/or the motivations for using it may be misunderstood.

Notes:

The main effort at this point in the digester planning process, is community education. Effectively educating a lay audience is foremost in increasing the knowledgebase the public has with regards to this technology. Additionally, presenting information in a manner that is engaging will attract attention and enhance education efforts. These efforts are important in order to reach an audience that includes potential neighbors and those to be affected by the change in manure management strategy. It may also be important to educate local municipalities to highlight funding needs.

In order to increase awareness of AD, a group must first have the knowledgebase to understand the topic and related issues. The first step in educating the public on AD technology, is to synthesize the information to be concise, jargon-free, easy to understand, and easy to relate to. Making information concise, jargon-free and easy to understand are common methods of translating technical information to make it easier for a lay audience to understand. However, it is also important to create an aspect of audience-specific content that will make the audience able to relate to the information. Several parties involved with the implementation of on-farm AD have the responsibility to disseminate information to the public, including: extension educators and producers.

In addition, local media outlets have an interest in serving their audiences and presenting information in a way that is meaningful and useful to their viewers/readers. Although it may be contrary to commonly-held public perception, reporters are looking for positive stories to tell; with increased interest in both how food is produced and the generation of renewable energy; AD makes a well-suited candidate. Local reporters can be effective at educating local readership audiences about a technology or project.

There are various materials that can be designed to effectively provide information at a basic level, including: case studies, websites, posters, articles and videos, among many other visual formats.

Another way to directly present introductory material on the topic of on-farm AD is being pursued by the PRO-DAIRY Dairy Environmental Systems group at Cornell University, who are currently offering one-day workshops that target a lay audience and local media outlets. The workshop begins with a classroom-based instruction session in the morning and concludes with a tour of an existing on-farm anaerobic digestion operation in the afternoon. This format exposes participants to information in a lecture-style format for half a day, presented in both printed and visual formats (i.e., use of a workbook and slide presentation) and also exposes participants to a hands-on learning experience by viewing an actual operation, the second half of the day. Please contact the authors for more information on scheduling this type of workshop for your farm project.

Extension educators can provide tools to producers in order for them to be able to reach the public and when they do have a public audience present on the farm, to be able to distribute

Notes:

concise information in a positive light. Simply equipping producers with materials for a lay audience can greatly improve the education of a public group when visiting a farm. In addition, workshops can be designed to teach producers, first, the complete set of benefits AD technology has to offer the farm and the community, and second, how to effectively present farm visitors with this information.

2.5. Management of pathogens

2.5.1. Effect of anaerobic digestion on pathogen levels

Dairy cow manure is known to contain multiple pathogens (i.e. fecal coliform, *E. coli*, *Cryptosporidium parvum*, *Giardia*, *Salmonella spp.*) that can adversely affect water quality. Cornell University research has shown that anaerobic digestion of dairy manure significantly reduced the viable concentration of fecal coliform. The percent change in fecal coliform concentration (cfu/mg) for five farms extensively monitored was 99.9, 99.7, 96.3, 98.4, and 99.5 percent as shown in Figure 2. Although the destruction of other pathogens present in manure was not studied, the significant fecal coliform reductions can be used to suggest equally high reductions of other pathogens present in dairy manure. This study also showed that the plug-flow design had more effective pathogen kill rates than the mixed designs.

Notes:

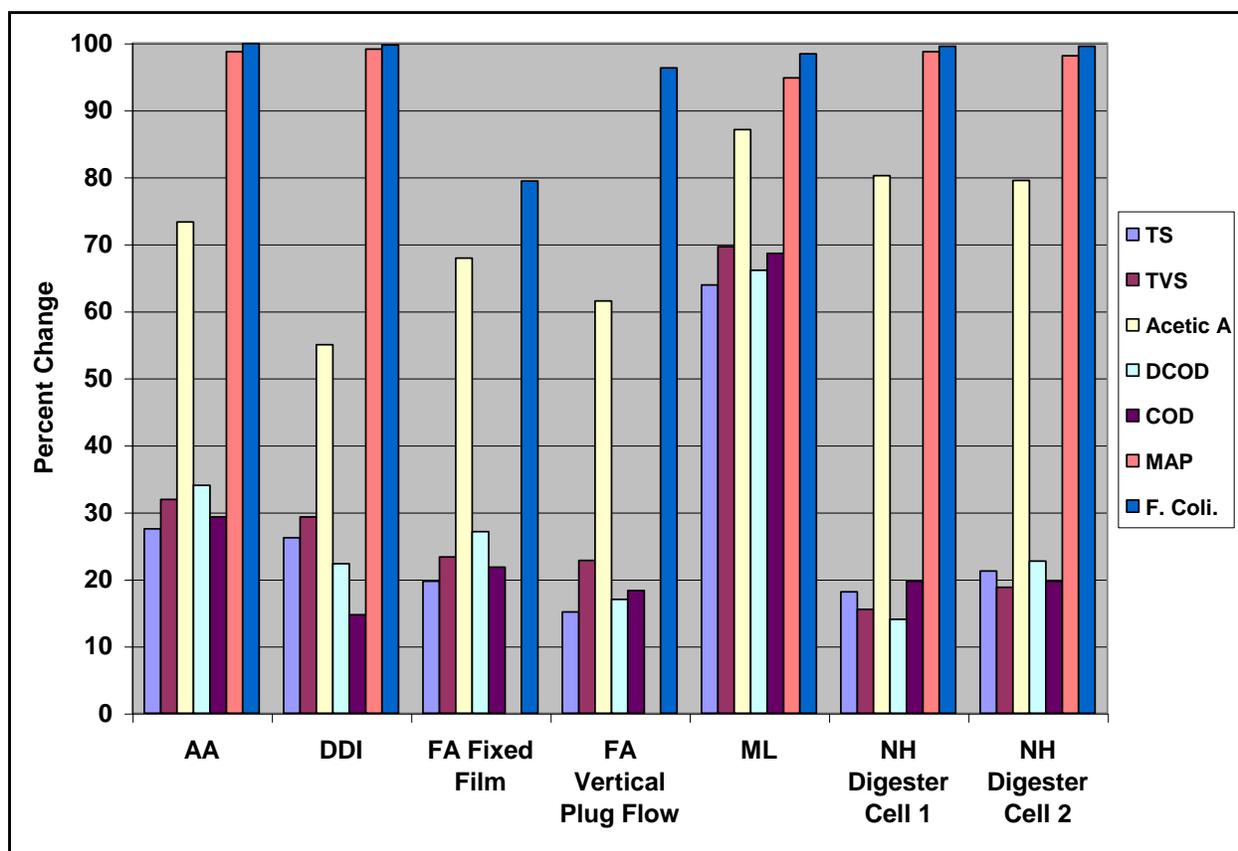


Figure 2. Percent change (reduction) in constituent concentration during anaerobic digestion for each farm. (Source: Gooch et al., 2007)

Digester systems can operate in either mesophilic or thermophilic temperature ranges, however mesophilic is more often used at this time in the New York State. Thermophilic methanogens grow in an optimum temperature of about 130°F. The higher operating temperature also increases pathogen reduction, and allows for shorter retention times thus reducing the capital cost of the digester vessel (Labatut, 2012).

An option to manage pathogen levels is to incorporate pasteurization of either the influent or effluent. Pasteurization subjects the material to high temperatures for a specified period of time. There is currently one farm-based AD in NYS using pasteurization; in this system, the influent blend of manure and substrates is heated to 158°F and this temperature is maintained for one hour. There are currently no regulations in New York State that require the pasteurization of digested material, however, several other countries require that any waste containing animal by-products be subjected to pasteurization, which is normally pursued prior to the digestion process since it also provides the benefit of breaking down solids.

Notes:

3. Design Considerations: What producers should know

3.1. Selecting the digester designer

There are several factors to consider when choosing a design company to work with through the process of building an on-farm AD system. A discussion of these factors follows here:

System design: One of the first things to consider is what type of system(s) a design company offers. Ideally, the farm has had a feasibility study performed and knows beforehand the type of system best suited for their needs. Knowing this information will narrow the options and streamline the decision making process.

Track record: Knowing how many systems a company has previously built and how they have performed can be the most compelling of reasons to choose one company over another. In 2007 the Association of State Energy Research and Technology Transfer Institutions (ASERTTI) developed a national performance monitoring protocol, which has been implemented on several farm-based digesters in NYS. Results from this monitoring research can be assessed with the goal of comparing system performance (please visit www.manuremanagement.com for project reports).

Location: How far a company's headquarters are from the project site can impact the overall cost of project construction, and can come into play later when problems arise and a support person needs to be sent to the site. Also, if the company is located in a region with significantly different climate or market trends, their systems may be better suited to that specific region or use, and this should be investigated.

Customer support: Depending on how many systems a company has in a given region, they may or may not have a representative stationed nearby, and may or may not be able to send someone on demand. Having someone readily able to attend the project site in the event of a system disruption, can have an impact on the timeliness of resolving the problem, which in the end affects the total cost of the system being down.

Price: The ultimate capital cost of the system will be affected by system design and various components included in the design, however, it is also a factor that needs to be weighed, depending on the needs and goals of the farm.

Guarantees: Depending on the business arrangement, there may be certain performance guarantees available or necessary, and these should be assessed. Some designers complete feasibility studies to submit for grant money on behalf of a farm; subsequent awarding of grant money ensures the project for that specific design company. This type of arrangement may be attractive for some farms.

Notes:

3.2. Digester type and AD system components

3.2.1 Plug-flow

The first anaerobic digesters constructed on dairy farms in the U.S. were plug-flow digesters, and subsequently many similar systems have been built and are operational in New York State, all basically like the one shown in Figure 3. The primary reason for their historically wide-span adoption is that plug-flow digesters are low in equipment and operating costs (not necessarily overall costs) relative to mixed digesters. A basic longitudinal cross-sectional diagram of a plug-flow digester is shown in Figure 4.

Plug-flow digesters are generally below-grade vessels in which manure additions theoretically flow as a “plug” from the digester inlet to the outlet. Digested manure generally exits the digester at the end opposite the inlet at a point of time in the future that equals the digester’s hydraulic retention time (HRT). The design HRT in most plug-flow digesters is about 21 days; HRT is calculated by dividing the digester treatment volume by the average daily influent volume. In contrast to mixed digesters, plug-flow digesters operate most effectively with influent having a total solids concentration greater than 10% but below 15%, which is close to manure’s natural consistency (13% total solids). An advantage of plug-flow digesters is that they do not have the mechanical complexity associated with mixed digesters.



Figure 3. A horizontal plug-flow digester with a flexible top membrane located on a Cortland County, NY dairy farm

Notes:

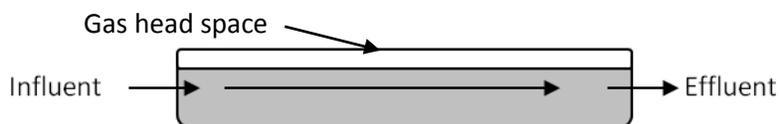


Figure 4. Basic cross-sectional view of a plug-flow AD

Plug-flow digester vessels are generally constructed using reinforced poured-in-place concrete. Insulation is added to the exterior walls of the vessel before backfilling to reduce the system's parasitic heat load. The tops are either concrete (pre-cast or poured-in-place) or flexible membrane (as shown in Figure 3).

3.2.2. Mixed digester

Mixed digesters (see Figure 5) periodically or continuously mix dairy manure and potentially other feedstock(s) by mechanical means. One advantage of a mixed digester is the ability to handle wastes with higher water content, including imported food wastes. When manure is too liquid, separation of solid and liquid fractions occurs. Periodic mixing is needed to achieve the goal of maintaining homogeneity of digester contents and to prevent significant solids accumulation.

One disadvantage of mixed digestion is that the mixing components add mechanical complexity and parasitic load, thus increasing total operational costs. In addition, AD influent is mixed with contents already undergoing digestion, and as a result, mixed digester effluent contains AD contents which have been in the tank for various lengths of time. Therefore, there is the possibility that undigested manure may exit the digester prematurely and that well-digested manure may remain in the tank in excess of the design hydraulic retention time (HRT).

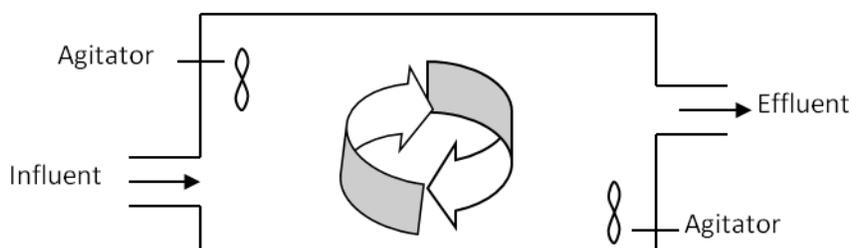


Figure 5. Basic plan view of a horizontal mixed AD

Mixed AD systems are mainly utilized in scenarios that involve feedstock(s) having total solid concentrations greater than 12 percent (not common with dairy manure) or less than 10

Notes:

percent. Digester influent concentrations less than 10 percent total solids are common when co-digesting manure with imported food waste(s).

In New York State, many farmers are interested in mixing food wastes with manure due to:

- The increased biogas production potential the mixture has, and/or
- The associated tipping fees for allowing food waste generators to unload their byproduct(s) on the farm.

Horizontal mixed digesters incorporate agitation systems in a plug-flow style digester vessel. Vertical mixed digester tanks can be either below-grade (atypical) or above-grade (typical) as shown in Figure 6. Cast-in-place concrete, welded steel, bolted stainless steel, and glass-lined steel panels are all options for vertical tank construction. Vertical tank digesters in the U.S. are predominately used when dilute digester influent (TS less than 10 percent) is involved.



Figure 6. Above-grade vertical mixed digester on a Wisconsin dairy farm

The mixing process is achieved by various methods; one method employs an external electrical motor (about 20-Hp) that turns a vertical shaft, concentric with the digester tank, that has multiple large paddles attached; the shaft would rotate at low speeds. Another method uses submersed impeller agitators each driven by either an electrical motor or hydraulic motor powered by a centrally located hydraulic pump. These types of impellers (as shown in Figure 7) are usually small diameter and would spin at higher speeds as compared

Notes:

with the larger paddles. Yet another method of mixing is an external pump that constantly pumps material out of and back into the digester vessel.



Figure 7. In-vessel mixing unit (impeller agitator driven by a hydraulic motor)

Vertical tanks are insulated during the construction process to minimize the maintenance heating requirement (heat to maintain digester operating temperature). Significant heat can be lost from vertical tank digesters if they are not properly insulated.

3.3. Codes and laws

A primary function of construction codes for structures, electrical systems, ventilation, and flammable gas equipment is to minimize or eliminate conditions that have led to past fatalities and losses. When planning for new construction, or reviewing an existing facility for safety, it is important for owners to insist that the applicable sections of codes be followed, even if doing so adds additional cost. Codes of interest that are likely to contain clauses pertaining to AD system construction are:

- National electric code
- National fire safety code
- National gas code
- New York State Building code

Notes:

This will likely require the services of a qualified engineer or other professional who is familiar with the specific application. The US Dept. of Labor's Occupational Health and Safety Administration maintains a comprehensive code of regulations that governs workplace environments. Owners and operators should be mindful of the Hazard Communication provisions that specify how worker training is to be carried out. While at present, there are provisions imposed by Congress exempting certain agricultural operations from specific enforcement actions, businesses should seek to comply with the law and regulations whether currently subject to enforcement or not.

3.3.1 Animal by-product regulations

The New York State Department of Environmental Conservation (DEC) has outlined the different permitting requirements based on the different types of waste that are accepted on farm for treatment in an anaerobic digester. Below are two scenarios of waste containing animal by-products and the permits that are required in each instance. For more information on both the CAFO permit and 360 permit mentioned, please refer to sections 8.2.1 and 8.2.2, respectively.

- Slaughter waste/mortalities/fats/oil/grease waste generated off farm mixed with farm waste
 - Under the CAFO permit – not allowed unless it can be shown that the material can be digested effectively
 - Under the 360 permit – Permit 1.9(b) – it must be demonstrated that the digester can handle the material
- Slaughter waste/mortalities waste generated on farm mixed with farm waste
 - Under the CAFO permit – not allowed unless it can be shown that the material can be digested effectively
 - Under the 360 permit – Exempt 1.7(b)(4)

In Europe, many countries have strict regulations requiring the pasteurization of material accepted for inclusion to an anaerobic digester which contains animal by-products, before it is land applied. In New York State, no such laws exist as of the printing of this document.

3.3.2 Nutrient management and land application guidelines

Concentrated Animal Feeding Operation (CAFO) Permit

Almost all New York State dairy farms with 200 to 699 cows are required to have a medium CAFO permit while those with 700 or more cows are required to have a large CAFO permit. Currently, there are about 450 medium permitted dairy CAFOs and 145 large permitted dairy CAFOs in New York State.

Notes:

While the CAFO permit itself does not specifically address farm importation of off-farm substrates for co-digestion, it does specifically require the farm have a Comprehensive Nutrient Management Plan (CNMP). The CNMP is essentially a tool to account for all of the nutrients coming on the farm and leaving the farm, and the CAFO permit stipulates that there needs to be a balance between inflows and outflows of the nutrients nitrogen, phosphorus and potassium (N, P, and K). The procedure for doing this is called a “Whole Farm Nutrient Mass Balance”. The CAFO permit requires each farm to have a third party planner certified by the state to develop each farm’s CNMP.

It is likely that the most difficulty farms will have with importing substrates for anaerobic digestion is in maintaining mass nutrient balance. Substrates contain the nutrients N, P, and K and therefore add to the nutrients coming on-farm. The concentration, generally expressed at the farm level in the units of lbs/1,000 gallons, varies by substrate.

Farms that are best positioned to import substrates for co-digestion are those that have access to cropland that exceeds that needed for forage crop production for their herd. Since this is generally not the case in NYS, wide-span adoption of co-digestion systems hinges on the economics associated with not only producing and utilizing the biogas but also with the equipment needed to condense excessive nutrients in digester effluent so they can be exported. Overall, the best substrates for co-digestion in many cases are those that produce the highest value biogas (a combination of quantity and quality) with the lowest associated nutrient loading; this can be expressed as mmBtu/lbs N, P, and K.

Food Waste Permit

Unlike some other states, NYS has an existing permitting process for farms to receive and land apply food waste, food processing waste, or other organic waste on agricultural land. As a result, a number of NYS farms have been paid a tipping fee to receive whey and other food processing by-products and directly land applying them for many years. The farm incurs costs to temporarily store and then to land apply the food waste. Co-digesting food waste has the potential to provide increased value to the farm.

There are three permits available from NYSDEC for farm importation of biomass wastes. They are an Exemption Permit, Registration Permit, and a Permitted site. The appropriate permit depends primarily on the type of waste but sometimes also on the quantity. An overview of each is provided below.

Exemption Permit

The Exemption Permit is the lowest level permit and is issued when there is a *low* potential for environmental harm from the imported biomass. Biomass must be visually *recognizable*. Examples are the following vegetable residues: corn husks and cobs, cabbage leaves, grapes and apple pomace, bean snips and carrot, tomato and potato skins.

Notes:

Registration Permit

The Registration Permit, similar to the Exemption Permit, is based on the determination there is *limited* potential for environmental harm from the imported biomass. However, this permit covers the case when the biomass is visually *non-recognizable*. Examples include: milk processing byproducts such as cheese whey, whey permeate and lactose, brewery and winery wastes, and byproducts from canned, frozen, or preserved fruit. The permit recognizes that biomasses imported under this permit are those generally in a liquid form, and it sets a limit on the importation amount of 10 percent of the manure storage volume.

The permit has specific requirements above that of the Exemption Permit. The biomass needs to be analyzed for its composition, and limits exist for when the biomass can be land applied based on field conditions and weather conditions.

Permitted Site

A Permitted Site permit is needed for facilities importing biomass that require greater DEC review and oversight or when the Exempt or Registered facilities are out of compliance. This is the highest level permit of the three-tiered permit system and has the most onerous requirements. A vicinity map and information about flood plains, wetlands and soil types need to be developed and maintained. Detailed operation records tracking the rates and methods of material application and incorporation along with hydraulic loading rates need to be maintained and kept current. Additionally, specific written permission is required from landowners of land where the food waste is land applied if it is not owned by the permit holder. Chain of custody forms need to be kept for all biomasses imported under this permit.

Based on the type of waste received at the farm, there are also implications for both the farm's CAFO and 360 permits. The NYSDEC has compiled a list (shown below) of various characteristics of wastes available for inclusion to an anaerobic digester, and each of their impacts to both the CAFO and the 360 permitting process.

- Manure, process waste water, other farm generated waste only (excludes farm generated sanitary waste)
 - CAFO – CNMP, NRCS 313
 - 360 – Exempt 1.7(b)(4)
- Recognizable food processing waste with farm waste
 - CAFO – CNMP, NRCS 313
 - 360 – Exempt 4.2(a)(2)
- Nonrecognizable food processing waste with farm waste
 - CAFO- CNMP, NRCS 313
 - 360 – Registration 4.2(b)(1)(vii) required up to 40% by volume, liner certification required if greater than 10% by volume, Permit if greater than 40% by volume
- Septage without farm waste
 - CAFO – not applicable (no WQV)

Notes:

- 360- Permit 1.9(b)
- Septage with farm waste
 - CAFO- not allowed
 - 360- Permit 1.9(b)
- Biosolids without farm waste
 - CAFO – not applicable (no WQV)
 - 360 – Permit 1.9(b)
- Biosolids with farm waste
 - CAFO – CNMP, NRCS 313
 - 360 – Permit 1.9(b)
- Slaughter waste/mortalities/fats/oil/grease waste generated off farm mixed with farm waste
 - CAFO – not allowed unless it can be shown that the material can be digested effectively
 - 360– Permit 1.9(b) – it must be demonstrated that the digester can handle the material
- Slaughter waste/mortalities waste generated on farm mixed with farm waste
 - CAFO – not allowed unless it can be shown that the material can be digested effectively
 - 360 – Exempt 1.7(b)(4)
- Other industrial/commercial waste generated off farm mixed with farm waste
 - CAFO – CNMP, NRCS 313
 - 360 – Permit 1.9(b) – must be able to be digested effectively

3.3.3 Zoning codes

There are minimal zoning codes that exist in New York State for farm-based anaerobic digesters, however for centralized digesters or digesters located on non-agriculturally zoned land, there are likely additional regulations. A farm use designation can be sought from the New York State Department of Agriculture and Markets to declare that the anaerobic digester exists on a property for farm use. The Agriculture and Markets Law (AML) 301 (11) includes “manure processing and handling facilities” as part of a “farm operation” for purposes of administering the Agricultural Districts Law. Regulations vary at the local level depending on the township and their agricultural designations and exemptions. Depending on the level of public opposition to a particular project, the local governing bodies may exempt a project from holding a public hearing or from having to complete a State Environmental Quality Report (SEQR). For centralized or industrially-zoned digesters, a SEQR and public hearing will likely be required.

Appropriate building codes and fire and safety codes must be adhered to, depending on the designation of a property (i.e., farm or industrial).

3.3.4 Regulations on biogas plants and gas handling

For New York State farm-based anaerobic digester operations, there are few enforceable regulations regarding the handling of biogas. There are however, several best management practices and important safety codes in place concerning the handling of flammable and

Notes:

otherwise hazardous gases. The methane-based biogas that is produced by an anaerobic digester is flammable and is heavier than oxygen and ambient air. Below are a few examples of places in the AD system where gas handling safety practices should be implemented:

- Electrical systems installed in and around the digester structure should be approved for use in an environment where hazardous gases are present.
- Flame arrestors should be present on the pipelines carrying biogas produced by the anaerobic digester.
- Confined spaces in and around the anaerobic digester should have adequate ventilation, and confined space entry safety should be practiced (i.e., multi-gas detector, self-contained breathing apparatus, etc.)
- Adequate signage describing dangers present should be posted and should be visible.
- Make sure the local fire department is aware of the flammable gases present on-site

Local town and county offices generally administer land use codes, and building and electrical codes are enforced by state agencies based on zoning classification.

Application-specific codes, standards, and requirements exist for such things as grid interconnection equipment, pressurized flammable gas equipment, electronic telecommunication equipment, and ventilation for toxic environments.

Organizations that may have codes or standards impacting certain technical areas include the Natural Resources Conservation Service (NRCS), professional societies, industry and trade associations, departments of labor, departments of environmental protection, private and public funding sources, and insurers.

There are several organizations where additional information on the codes for construction and operation involving flammable and hazardous gases, can be found:

- Compressed Gas Association
- Occupational Safety and Health Administration
- American Society of Agricultural and Biological Engineers

Owners and designers have the responsibility for determining what codes, standards, and regulations apply to a particular project. It should be noted that code compliance, both mandatory and voluntary, adds significant cost and complexity to a project proposal, therefore, these costs must be considered and incorporated into overall project feasibility determinations. Compliance will also increase assurance of quality, lower risk, and protect the lives and economic investment of all involved.

3.3.5 Net metering

Notes:

The original NYS Net Metering law was signed in to law on August 13, 1997. The current Net Metering law is outlined in Sections 66-j and 66-l of Article 4 of the Public Service Law, and includes net energy metering for farm waste systems. Net energy meter means, a meter that measures bi-directional flow of electricity between the electricity supplied by an electric corporation to a customer-generator and the electricity provided to the corporation by that same customer-generator. Farms can elect to deliver excess electrical power to the grid through the existing net metering program, or by alternative tariff provisions for selling power. For a list of necessary steps to interconnect with the utility in order to participate in Net Metering, see Appendix 2.

For farm waste customer-generators that qualify for net metering under current statutes, the current NYS Net Metering law mandates that:

- biogas-derived electricity sold back to the grid be generated at a maximum capacity of 1-MW
- if the generating capacity (kW) of the farm waste generating system surpasses 20% of the capacity of the local feeder line, the utility may require additional compliance to meet applicable safety standards for other customers on the line
- electricity sold back to the grid be fueled by a minimum of 90% biogas produced annually from the anaerobic digestion of agricultural waste
- biogas used to generate electricity sold back to the grid be produced from the anaerobic digestion of at least 50% livestock manure by weight (a farm is limited to importing 50% of its total digester influent weight in the form of off-farm substrates)
- the customer-generator pay the electric company's costs to install a transformer or other equipment to provide for the safety of the line, up to \$5,000 for a farm waste generator; the utility shall not impose any other fees for interconnecting to net meter a system
- net metering systems are limited to a customer of an electric corporation, who owns or operates farm waste electric generating equipment located and used at his or her "farm operation"

The Net Metering law also contains requirements for utility companies with regards to purchasing electricity from customer-generators. The electric utility company will provide for the interconnection of farm waste electric generation equipment, if that customer-generator enters into a net metering contract with the utility. The utility company must also "establish consistent and reasonable rates" for net metering customers, and must provide the net metering program until 1% of that utility's 2005 demand is reached by the generating capacity of farm

Notes:

digester and photovoltaic solar power generators in their system. Each utility must establish standards for net metering and farm waste generating system interconnection.

Net metering billing is determined using the following criteria:

- If the amount of electricity supplied by the utility is higher than that provided by the customer-generator to the utility during the billing period, the utility will bill them for the net electricity supplied at the same rate per kWh as other customers in the same service class that do not generate electricity on-site.
- If the amount of electricity provided by the customer-generator to the utility is more than the amount of electricity provided by the utility to the customer-generator during the billing period, the utility will apply a credit to the customer-generator's next bill for the net electricity provided, at the same rate per kWh as other customers in the same service class which do not generate electricity on-site.
- On an annual basis, the utility will pay the customer-generator for the value of any remaining credit for the excess electricity produced by the customer-generator and the rate will be the utility's avoided cost to the customer-generator.
- If the utility imposes charges based on kW demand for customers in the same service class as the customer-generator but which do not generate electricity on-site, the utility may impose the same charges at the same rates as for the customer-generator, but the kW demand must be determined by the maximum measured kW demand actually supplied by the utility to the customer-generator during that billing period.

3.3.6 Air-quality regulations of distributed generation sources

According to The Department of Environmental Conservation (DEC), current New York State regulations for distributed generation sources treat biogas fuel like natural gas, and the same thresholds apply for permitting. The size threshold for facilities to be considered exempt from enforceable regulations is 400 break horsepower. However, within each air pollutant category, a threshold is used to define major versus minor facilities. For the NO_x (nitric oxide and nitrogen dioxide) class of air pollutants, the threshold value is equal to 100 tons per year in the Upstate New York region (where the siting of anaerobic digester facilities is most likely). For the volatile organic compound (VOC) class of air pollutants, the threshold value is equal to 50 tons per year in the Upstate New York region. Most farm-based digester systems will be considered minor facilities, and therefore are only required to submit a registration form to register their system. This form can be found on the DEC website at the following web address: <http://www.dec.ny.gov/chemical/4754.html>.

Notes:

In the future, the DEC plans to implement regulations to enforce air pollutant limits for minor facilities as well as the major facilities that are now regulated.

3.3.7 USDA anaerobic digester standards

The Natural Resources Conservation Service (NRCS), an agency within the USDA, drafted the anaerobic digester practice standard (Code 366). This practice standard applies to:

- systems planning biogas recovery
- new construction or retrofits
- farms that have suitable material to digest
- operators that can monitor and manage an AD system.

The practice standard provides several criteria as well as general recommendations about on-farm anaerobic digester systems, including:

- food waste composition and treatment
- safety design and signage recommendations
- design criteria for different types of AD vessels
- design criteria for gas collection systems
- necessary system monitoring equipment
- design considerations
- requirements for plans and specifications
- proper operation and management procedures

The Association of State Energy Research and Technology Transfer Institutions (ASERTTI) anaerobic digester monitoring protocol was developed in 2007 with the goal of providing a standardized method to assess the performance of on-farm digester systems for comparison between different types of systems. The Cornell Dairy Environmental Systems program monitored seven on-farm systems in NYS; the seven individual reports and one final aggregated report can be found on the program's website (www.manuremanagement.cornell.edu).

3.4. Characteristics of manure and other inputs

The best predictor of manure volume produced by a dairy cow is dry matter intake. Milk production is the second best predictor. If dry matter intake or milk production information is not available, then standard values of manure production per lactating cow per day would be used in conjunction with the current and projected herd size, along with the volume of milking center waste water and any other substrates planned to be added, to determine the total volume of influent. The total volume of AD influent affects design values for the size and treatment volume of the digester vessel, as well as how much material is removed and added on a daily basis. The amount of material the digester vessel is able to contain directly impacts the hydraulic

Notes:

retention time (HRT) of the digester, which is the length of time material spends in the digester. Material must remain in the digester long enough to breakdown the organic material as completely as possible, in order to maximize biogas production. However, if material stays in the vessel too long then it no longer produces biogas, and is negatively impacting the economics of the system by occupying space that new material could be filling.

Accurately estimating manure and other on-farm waste volumes is important to determine the overall cost to construct the digester system.

Dairy farms are well positioned to be significant contributors to the State's renewable energy goals and beyond. There are significant opportunities for dairy farms to co-digest off-farm biomasses, commonly referred to as feedstocks, with dairy manure and other farm-generated biomasses.

Co-digestion provides the opportunity to significantly increase biogas production per unit volume of influent over that of manure only based systems. A few dairy farms in NYS have been co-digesting at their sites for several years and monitoring analysis shows biogas production on these farms is three times that of other monitored farms with manure only systems. Even greater production is possible with co-digestion of specifically selected substrates. A Wisconsin farm-based digester produces five times the biogas due to co-digestion. Biogas production is increased in two ways, by:

1. Conversion of the additional biochemical energy contained in the substrate itself
2. A symbiotic affect that results in more efficient utilization of the biochemical energy contained in manure

An increased number of partnerships between dairy farms and food processors, waste haulers, and communities (both private and public entities) are needed to significantly bolster the number of digesters in the state and subsequent biogas production.

Just as the volume of manure being digested is crucial to biogas production and cost estimates, so is the volume of off-farm substrates. The volume should be provided by the farm as background information, but based on the type of waste, the strength (biogas producing potential) will be estimated, if this information isn't otherwise available. Several characteristics of the waste can be used to determine the biogas producing capability. Substrates with high fat contents generally produce more biogas.

The amount of feedstock imported to the farm for digestion may be limited by the strength, and only able to be added in small quantities, or it may be limited by a regulation. In New York

Notes:

State, the Net Metering law only allows co-digestion substrates up to 50% (by weight) of livestock manure.

3.5. Identify potential safety hazards

Before we examine the biogas generation process to explore hazards and risks, first let us note the potential types of hazards we may encounter:

- Chemical: including fire, explosion, reactivity concerns; and adverse health effects upon acute (short-term) or chronic (long-term or repeated) exposure
- Biological: organisms or parts of organisms which could cause inflammation, allergy, or infection
- Ergonomic: strains, sprains, over-exertions (acute or cumulative)
- Occupational stress: including shiftwork and scheduling
- Physical: radiation, thermal (heat or cold stress), electromagnetic fields (EMF), vibration, noise
- Trauma: slips, falls, impact, compression, bruises, broken bones, cuts, amputation
- Violence: verbal harassment, threats, physical assaults, arson, vandalism

In the process of doing work, injury or illness may occur in a variety of ways in which we come into contact with objects, chemicals, or equipment:

- Struck-by
- Struck-against
- Caught-between
- Contact-with
- Contacted-by
- Caught-on
- Caught-in
- Fall same level
- Fall to below
- Overexertion
- Exposure

To reduce hazards or risks, we will try to stay as high up on the Hierarchy of Controls as we can. The following are some potential hazard reduction or elimination methods in the hierarchy:

Source elimination is the most powerful method:

- Hazard substitution such as using a safer chemical for a cleaning job
- Process change such as designing-out the need for confined space entry for a maintenance task on a manure pit pump

Notes:

If this is not possible, then we next consider Engineering Controls:

- Enclose process
- Mechanize process
- Barriers / isolate hazard
- Local exhaust ventilation
- General dilution ventilation

If these do not work or are not sufficient, then we next consider Administrative Controls:

- Housekeeping
- Work practices and procedures; work rules; policies
- Preventive maintenance
- Job rotation

If these do not work or are not sufficient, then we next consider personal protective equipment:

- Respirator
- Clothing
- Gloves
- Ear plugs or muffs
- Face shield

3.5.1. Designing out confined spaces

Confined space is one of the most important hazards we will need to address in biogas generation. Confined spaces include pits, tanks, vessels, and the digester itself.

A confined space by design:

- has limited openings for entry and exit
- has unfavorable natural ventilation which could contain or produce dangerous air contaminants
- is not intended for continuous employee occupancy

While the Occupational Safety and Health Administration (OSHA) does have a regulation on confined space entry (USDOL. OSHA. 29 CFR 1910.146 Permit-Required Confined Spaces) it does not apply to agriculture. However, OSHA could still cite an employer for a confined space problem under the general duty clause of the OSHAct because it is a well-known problem capable of causing death or serious physical harm.

Wherever there is manure, or even moisture or standing water, in a confined space, bacterial growth will deplete the oxygen levels and produce gases with serious hazards of fire/explosion and toxicity. The atmosphere in a confined space may include:

Notes:

- asphyxiating atmosphere, including oxygen deficiency due to:
 - displacement of air (by decay gases such as methane)
 - consumption of oxygen by decay (principal problem for manure storage)
- explosive atmosphere, from gases such as methane or hydrogen sulfide produced by decay
- toxic atmosphere (such as hydrogen sulfide or carbon dioxide produced by decay)

In addition to atmospheric hazards, a confined space may also have:

- mechanical hazard, needing lockout/tagout, line-breaking, or other procedures
- engulfment – such as drowning
- entrapment – such as sloping bottoms of pits or tanks

Confined space work has produced injury and fatality on farms, especially after entry into manure pits and wells. Often people do not realize that the hazardous conditions may not be seen or smelled or that equipment needs to be inactivated so it can't be started up while someone is in the space.

A confined space may simultaneously have multiple hazards from the above list. If designing a digester, consider maintenance tasks (not just operations tasks) and plan ways to avoid the necessity of confined space entry to accomplish the task. The safest systems are designed so that there is never any reason or need for confined space entry to perform maintenance.

A recent review¹ of fatalities and injuries associated with manure storage and handling found that:

- Over half involved dairy operations; 21% involved persons <16 years of age.
- 34% of deaths were the persons performing repair or maintenance on manure handling equipment
- 22% of deaths were would-be rescuers performing rescue of another person
- Most frequently-identified cause: asphyxiation; with elevated levels of sulfide in the blood noted in some cases
- Peak period of incidents was during hottest part of summer

While the recommendations below emphasize air testing, you may wish to consult the industry standard: ANSI/ASABE S607 Oct2010 Ventilating Manure Storages to Reduce Entry Risk, available at www.asabe.org

Before entry into a confined space, test the air with a calibrated direct-reading instrument for:

- Oxygen content (should be 19.5 – 23.5%)

¹ Summary of Documented Fatalities in Livestock Manure Storage and Handling Facilities -- 1975 – 2004. Beaver, R. L. and Field, W. E. 2007. *Journal of Agromedicine* 12(2): 3 – 23.

Notes:

- Flammable gases and vapors (should be <10% LEL)
- Potential toxic air contaminants (should be less than OSHA PEL: for hydrogen sulfide <20 ppm; for carbon monoxide <50 ppm)

These items must be tested in that order. Test from top to bottom of the space, so that gases that are lighter-than-air or heavier-than-air are found, if present.

Biogas composition and hazards (typical composition):

- Methane 50-60%
 - Asphyxiation can occur at 87% due to oxygen deficiency
 - Lower explosive limit (LEL) is 5%
 - Upper explosive limit (UEL) is 15%
- Carbon dioxide 38-48%
 - At concentrations of 11% or above, unconsciousness occurs in a minute. At 25-35%, convulsions occur. Immediately dangerous to life and health at 50,000 ppm or 5%.
- Hydrogen sulfide 580 ppm
 - Immediately dangerous to life and health at 100 ppm. At about 500 ppm, there can be pulmonary edema causing an imminent threat to life, and strong nervous system stimulation which can cause breathing to stop.
 - LEL @ 4.3% or 43,000 ppm.
 - UEL @ 46%
- Other minor constituents

If the atmosphere is unacceptable, then use forced air ventilation to bring the atmosphere to acceptable levels. Periodically re-test as necessary to ensure that continuous forced air ventilation is preventing the accumulation of a hazardous atmosphere. If a hazardous atmosphere is detected during entry, each employee shall leave the space immediately. Evaluate the space to determine how the hazardous atmosphere developed.

Some considerations for air testing:

- Use the test instrument in accordance with the manufacturer's specifications.
- When testing stratified atmospheres, test approximately 4 feet in the direction of travel and to each side; slow the entrant's travel to accommodate the instrument's sampling speed and detector response.
- a standby person should be in constant contact and ready to lift the worker to safety with mechanical lifting equipment (winch, hoist, or pulley), and anyone entering a manure pit should wear a safety belt or harness with a lifeline tied to the mechanical lifting device.

Notes:

3.6. Monitoring and instrumentation

Most digester design companies will by default incorporate many of the instrumentation suggestions found in this section, however some suggestions made here are not currently installed on many AD systems in NYS. It is apparent, that as co-digestion of substrates other than livestock manures is pursued, more advanced monitoring strategies need to be relied upon to further optimize performance.

Biomass flow meters: influent flow rate is an important measurement to determine the volume of material entering the AD system. This value often needs to be adjusted to account for variances in substrates, to achieve desired gas production levels, and to manage system effluent levels.

pH meter: internal AD pH levels are important to monitor to ensure they remain within the optimal range of operation (neutral pH) for maximizing process performance.

Temperature probes: internal AD temperature is important for the same reason pH levels are important – to ensure operating temperature remains consistent, at least within the optimal range for maximizing process performance.

Biogas flow meters: The volume of biogas used by different components (e.g. electricity generation system, boiler, gas flare, etc.) of the AD system is important to measure. It is also recommended to utilize a meter that is temperature and pressure compensated, or for some meters, that has an additional temperature and pressure compensating unit able to be installed. Installation of the gas flow meters should incorporate means for occasional removal from service for cleaning and calibrating purposes, based on manufacturer's recommendations or as needed.

Biogas quality testing: Frequent measurement of the major constituents of biogas (e.g. methane, carbon dioxide and hydrogen sulfide) is a standard way to monitor system performance. Equipment to perform gas testing can be integrated with the system for continuous monitoring or can be performed manually on a set schedule.

Data acquisition system: A Supervisory Control and Data Acquisition (SCADA) system, or similar, provides an interface to monitor and control several aspects of the system electronically.

Computer: A computer with internet access and an alarm system interface is necessary to control various aspects of an electronically-controlled system, and also provides a way for alerting operator(s) to failures in the system.

Diagnostic lab: It is becoming apparent that a diagnostic laboratory to perform organic waste utilization measurements (ex. total solids, volatile solids, volatile fatty acids, and alkalinity) is vital to ensuring continuous, optimized performance of the AD system. Daily monitoring and

Notes:

data collection allows the operator to develop and observe trends in the system which greatly helps in realizing “red flags” or impending system failures.

Electricity production/use meters: The utility normally provides a meter to measure electricity purchased/sold from/to the grid, and the engine-generator set set-up normally includes a total electrical energy production (kWh) meter and an instantaneous electrical power generated (kW) meter.

3.6.1. Performance evaluations

The Association of State Energy Research and Technology Transfer Institutions (ASERTTI) anaerobic digester monitoring protocol was developed in 2007 with the goal of providing a standardized method to assess the performance of on-farm digester systems for comparison between different types of systems. This protocol was developed to collect data from three main categories: biomass to biogas conversions, biogas utilization, and system economics, for a one-year monitoring effort. The protocol does include some monitoring parameters that would be appropriate to monitor on a continuous basis (e.g. heat flows, biogas quality, biogas production and electricity production and usage).

The 2007 protocol was updated in 2011 to reflect changes in the monitoring procedure, including the designation of different “levels” of monitoring intensity. There are four levels of monitoring starting with more basic parameters and increasing in the scope of data collection.

There is a significant value that exists to have a third party pursue this type of monitoring evaluation for a farm-based AD system to highlight the opportunities for improvements and optimizations in the system.

3.7. Manure collection, handling, influent storage

An anaerobic digester, just as a dairy cow, performs best when fed in a consistent and continuous manner. Manure is generally aggregated in one location where it can be homogenized prior to inclusion to the AD. Manure on most dairy farms in NYS is collected within the barn(s) using either alley scrapers, where manure is deposited in under-the-barn channels and aggregated as it flows to a main pit, or the use of a skid steer, where manure is manually collected and deposited in either a pit or a channel flowing to a main pit. Occasionally, a farm also conveys manure from other barns or heifer facilities off-site, and this can be done manually using a skid steer or by piping the manure, if feasible.

There is also the opportunity to incorporate other on-farm wastes (i.e., milking center wastewater or bunker silo leachate) however, doing this makes the system vulnerable to an upset since these flows are either easily contaminated or higher-strength. Waste water can occasionally be contaminated by cleaning agents or other chemicals that can severely disrupt microbial activity

Notes:

within the AD system. Leachate is a high-strength substrate and while inclusion to the AD can be beneficial, volumes incorporated should be controlled and effects observed. All efforts should be made to maintain a consistent supply of alternate wastes, to ensure system stability.

Influent pits are normally below-grade, covered concrete pits. Since they are generally open pits, freezing of manure in the colder climates can be an issue. Continuous or frequent mixing can prevent this problem. Frozen manure should never be put in an AD. There are a few systems in NYS that heat influent prior to inclusion to the AD, using a heat exchanger and heat from the effluent.

Odor control may be necessary from the influent storage; at least one farm in NYS has a bio-filter made of wood chips that filters air collected within a structure covering the influent pits. There are specific factors that are important to consider when designing bio-filters so that an effective result is achieved.

There are different types of pumps used to convey influent material from the storage pit into the AD vessel, the most common ones being piston pumps and centrifugal pumps (which may or may not be chopper pumps). Different pumps are used for different applications and can also depend on farm management.

3.8. Effluent and separated solids handling

There are several options for treatment of AD effluent that should be based on the goals and needs of the farm. Post-digested effluent can either be stored as is for eventual land-application, or can be separated into liquid and solid portions. A screw-press separator is the most common means of separating solids and liquids for farm-based AD systems. The solid portion is stored in a covered structure until needed for cow stall bedding material, or can be composted further and offered for sale as a compost amendment. The liquid portion that is separated is stored long-term in an earthen storage to await eventual land-application.

The flow diagram shown in Figure 8 incorporates some options for advanced treatment options of AD effluent.

Treatment options exist to customize the nutrient concentrations in the final effluent product, or to pasteurize the final effluent product. These management options are not currently pursued in the U.S., however, in Europe, regulations are in place that require some systems to employ on-farm pasteurization of AD effluent prior to land application. Other AD systems include nutrient treatment, such as phosphorus removal, for land application to sensitive areas, or where an excess is present.

Notes:

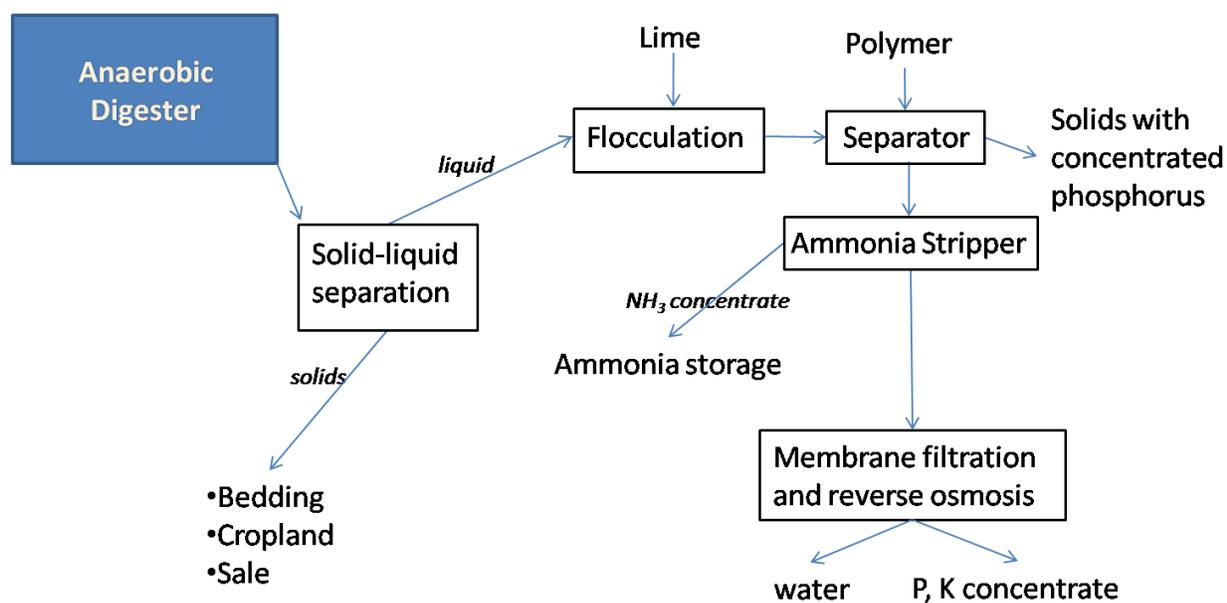


Figure 8. Select advanced treatment options for AD effluent

An alternate option for post-digested effluent is to transfer the material to a secondary vessel for additional gas collection. After the primary digestion phase, the digested material is still in the process of anaerobic decomposition and a significant portion of the biogas production can be realized at this point. This is not currently a common practice for farm-based AD systems in NYS, but is common in many European systems.

3.9. Subsystem components and design

3.9.1. Biogas handling and transport

Gas quality involves energy content, hydrogen sulfide content, moisture, and contaminants from the gas handling equipment. While not necessarily considered a gas quality issue, a related condition is that of contamination from digester foaming. Biogas is similar to natural gas, in that it is mainly composed of methane, however, since other constituents exist in the biogas, it has a lower heating value.

The proportion of methane in the biogas from the digester can vary due to a variety of conditions, some of which may be difficult to ascertain. Temperature, influent feed rate, feed ration changes, and non-manure substances introduced with the influent can all affect the productivity of the microorganisms within the digester and thus the quantity and concentration of methane.

The percentage of hydrogen sulfide found can range upwards to 0.4% with influencing factors being levels of sulfur in the cattle feed ration and water supply, and sulfur in non-manure

Notes:

components of the influent stream. It is possible to scrub hydrogen sulfide from the gas before utilization, using commercially available equipment. The cost of scrubbing will likely diminish the net return of the operation to an extent such that alternatives to scrubbing will be preferable.

The potential for introduced contaminants will vary with system designs and material composition of gas handling equipment selected. Iron components should be avoided in favor of aluminum or stainless steel. While PVC pipe has frequently been used, this pipe does not comply with applicable codes, and presents greater risk in the case of a fire. PVC should be used for biogas pipe below grade. Above grade, black iron pipe is required by most building codes because it offers better mechanical protection. Biogas will eventually corrode black iron pipe, which will need to be replaced over time. Copper tubing and galvanized pipe should never be used.

Water vapor is present in sufficient quantity to cause condensate trapping in low sections, and freezing during cold periods. The piping system should be designed so that condensate drains back to the digester to the greatest degree possible. Other preventative measures include installing water traps, insulating exposed sections of pipe, installing heat tape and routing the pipe with sufficient slope. Adequate pipe sizing is important and should take into account gas flow rates, slope, length of run, and exposure. An example of condensate trapping is shown in Figure 9.

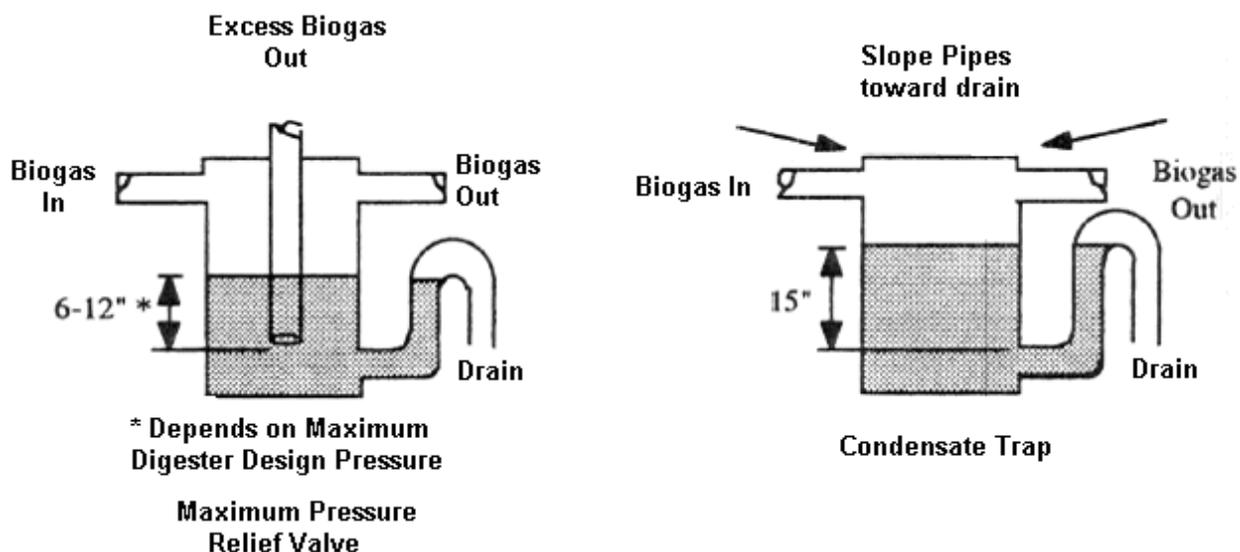


Figure 9. Simple devices for maximum pressure relief valve and condensate traps

With most digesters, conditions will eventually develop where an excess of foam will develop which may reach the biogas delivery piping. Changes in livestock feed rations and ingredients in non-manure feedstocks are likely the causative agents. Once foam enters the gas pipeline, the

Notes:

entire gas utilization system must be shut down and completely cleaned. Any residues not cleaned out will eventually reach the engine with negative effects. The design of the gas piping inside and outside the digester can affect how much the system will be affected by digester foaming.

3.9.2. Combined Heat and Power Systems (CHP)

Combined heat and power systems (CHP systems) are typically operated in conjunction with on-farm AD systems. The CHP system is fueled by biogas derived from the digestion of manure and possibly other organic wastes. Since the price to sell biogas-derived electricity is comparatively low, the most advantageous use is to first offset electricity used by the farm enterprise. Any heat recaptured from the CHP system is first used to satisfy parasitic thermal demands from the AD system. There is normally no critical need for heat on dairy farms, thus, the parasitic use of this by-product does not interfere with on-farm energy needs.

There are four major components of the CHP system (Figure 10): the engine, generator, controls, and heat recovery.

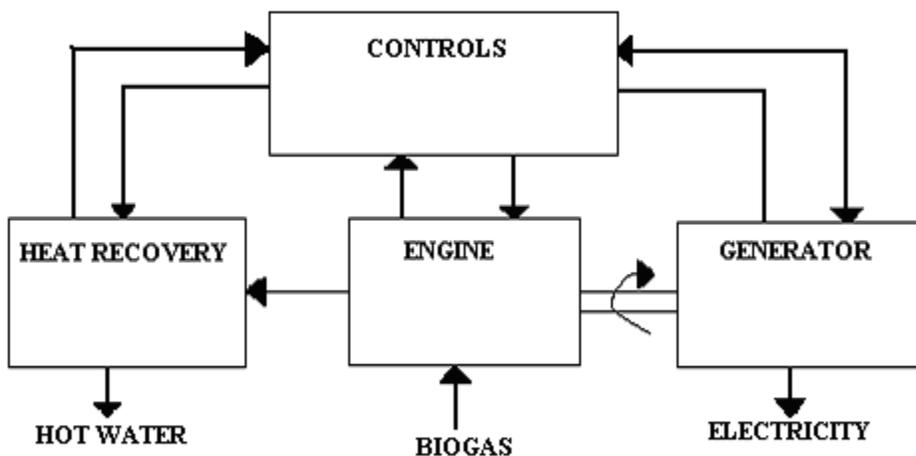


Figure 10. Four components of an engine-generator set

There is one component of biogas that presents problems for utilizing biogas in any energy-generating unit, and that is hydrogen sulfide. This is a corrosive gas that makes up less than 1% of biogas. It can however be significantly reduced using several different available technologies, to extend the life and improve performance of the energy generating unit.

Biogas can also be used to fuel a boiler to generate additional heat, if there is need for heat on the farm (e.g., a shop or calf barn) or if an opportunity for revenue can be realized (e.g., a complementary business such as grain drying or maple sugaring).

Notes:

For systems operating in parallel to the utility grid, engine-generator sizing is based upon the expected rate of fuel production. For isolated systems, sizing is based upon the maximum expected farm demand. This latter condition is rarely feasible because biogas output may not be sufficient to supply an engine-generator sized for maximum farm loads.

For the most common configuration, generating in parallel to the grid, the engine-generator should be sized so that the biogas supply will not be exceeded. It is preferable to size the unit slightly smaller than the gas supply will support so that the engine can be operated continuously and at full capacity. Over-sizing will result in greater initial cost to purchase equipment, lower operating efficiency in converting biogas to electricity, and higher maintenance costs.

For continuously operated co-generators in a manure-only system, one kilowatt of generator capacity per 4 lactating cows is a reasonable starting point. For example, a 250-cow dairy farm producing 4,500 gal of manure daily should expect to generate approximately 1,300 kWh of electricity per day, which requires a 50-kW engine-generator set.

Efficient conversion of biogas to electricity will affect the total annual cost of the system. Even small shortfalls from peak efficiency have economic implications for a continuously operated generator. To monitor operating efficiency, the system should include meters for gas consumption by the engine and electricity production by the generator. A comparison of these two measurements represents critical information for the management of the co-generation unit. In addition to low conversion efficiency, operation at less than 80% full load may create operational problems from accumulating exhaust gas condensation.

For the above reasons, it is difficult to size the generator for the future if there are possibilities for business expansion at a later date. In the event that gas supplies increased due to expanded operations or the addition of food waste, options could include adding other uses for biogas or replacing the generator with a larger unit. It is recommended to size the engine-generator set after digester start-up is complete but this is rarely possible.

3.9.3. Parasitic load

Parasitic load is the amount of energy (electric and thermal energy) the system needs to operate properly, which is deducted from the overall gross energy production. The parasitic loads depend on, 1) the size and type of the digester vessel, 2) the quantity of material being digested, and 3) the presence of mixing equipment. When determining the feasibility of an on-farm digester, the energy needs to operate the system must be taken into account in order to ensure the system will have a positive energy balance. While multiple pumps and mixing units may be necessary to achieve optimal performance, they each add parasitic load and any excessive units should be eliminated. A 20-Hp external mixer is shown in Figure 11 as an example of a source of parasitic electrical load.

Notes:



Figure 11. 20-Hp external mixing unit; this unit contributes to the parasitic load of the AD system

If biogas is used to generate electricity using a combined heat and power (CHP) system, heat can be reclaimed and used primarily to provide digester heating. There is normally no critical need for heat on dairy farms, thus, the parasitic use of this by-product does not interfere with on-farm energy needs. However, the potential exists to generate revenue from the sale of excess heat, if there is a seasonal business that could make use of the heat in the warmer summer months when the demand for digester heating is low.

3.9.4. Flare

Since biogas contains approximately 60% methane, raw biogas should never be vented to the atmosphere without being combusted. All AD vessels should include an emergency pressure relief system that connects to the biogas flare, and in the event pressure needs to be released, it is routed to the flare to be combusted before release to the atmosphere. Biogas can either flow by gravity to the flare, or a blower can actively move it through the system.

3.9.5. Boiler

Farm-based AD systems with the primary intention of reducing manure-related odors can simply be connected to a biogas-fired boiler, combusting all biogas produced in the boiler in order to heat the AD vessel, and utilize the excess heat available for other uses.

Notes:

4. Safety

The Occupational Safety and Health Act of 1970 which established the Occupational Safety and Health Administration (OSHA) sets forth the duty expected of an employer as follows...

“...Each employer --- shall furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing, or are likely to cause, death or serious physical harm to his employees.”

The OSHA regulations listed below which address emergency planning and fire response apply to General Industry, but not to Agriculture as an industry sector. Never the less, these regulations are useful guidance to deal with potential hazards. The recommendations made below were derived from these regulations. As discussed elsewhere in the safety and health section of this curriculum, digester/biogas systems involve working with explosive gases and possibly dusts, asphyxiating gases, toxic gases, flammable or combustible liquids, electrical equipment, confined spaces, engulfment/drowning, and other potential hazards. Regardless of the safety precautions in the digester/biogas system’s design and its standard job operating procedures, it is always important to consider what potential emergencies your system might encounter -- accidents, fire, tornadoes, blizzards, hurricanes, floods, earthquakes, and any emergencies unique to your particular geographical area.

- 29 CFR 1910.151 – medical services and first aid; in the absence of an infirmary, clinic, or hospital in near proximity to the workplace, an employee shall be adequately trained to render first aid; adequate first aid supplies shall be readily available
- 29 CFR 1910.36 – design and construction requirements for exit routes
- 29 CFR 1910.37 – maintenance, safeguards, and operational features for exit routes
- 29 CFR 1910.38 – employee emergency plans
- 29 CFR 1910.39 – fire prevention plans
- 29 CFR 1910.157 – portable fire extinguishers
- 29 CFR 1910.158 – standpipe and hose systems
- 29 CFR 1910.165 -- employee alarm systems

An emergency plan should be in writing and employees need to be trained on what they are expected to do in an emergency, including:

- how to report the emergency and how to raise a general alarm
- what employees are expected to do in the event of a fire or other emergency,
- who is expected to leave the area and who remains to perform critical functions (such as shutdown procedures), so it is important to have:
 - operating instructions in case of a malfunction of the digester/biogas system
 - operating instructions for shutdown of the digester/biogas system
- are employees expected to perform rescue and/or perform any first aid

Notes:

- if an evacuation is necessary -- where people should gather after evacuation; what is the refuge or safe area (parking lot, open field, or street), and how are they all to be accounted for

Fire Preparation

Before or soon after the digester system begins operating, the local fire department should be contacted and consulted so that, in the event of an emergency requiring their assistance, they will have already visited your facility, know its layout and potential problems. This enables the fire department to assess access roads and deployment and movement areas in the event of an emergency such as: a digester fire or explosion, failure of a building ventilation system to exhaust potentially explosive gas mixtures, or failure of a flash arrestor to address backdrafting. A local fire company may not be familiar with potential fire scenarios at digester facilities; so, consider that items of interest for your emergency response procedures may be of interest to them as well. Some examples could be: location of shutoffs, flash arrestor, or other isolation methods, or the use of the flare as a potential emergency response method for gas disposal.

To respond to a fire on site, either selected workers (or possibly all) workers should have access to water or other extinguishing methods and be trained how to use them. For a fire in a building, Class A portable fire extinguishers, which deal with wood and paper, should be located within 75 feet for rapid access. For a fire involving oils, fuels, etc., such as in the generator building, use a Class B portable fire extinguisher. In addition, it is a good idea to have emergency fire fighting equipment on site that contains the necessary equipment and materials such as a fire extinguisher, fire hose and couplings, instructions and keys to buildings.

Some considerations for having water systems available to suppress a fire in an emergency include having sufficient water reserved for short term fire fighting. This should be 3000 gallons, which is enough to supply 100 gallons per minute for 30 minutes (or 114 m³ at 380 liters per minute). To accommodate this flow rate, the soft hose should be at least 3 1/2 inches (90 mm) in diameter. For any enclosed structures associated with the digester and biogas system, local fire codes should be consulted to determine the requirements for building sprinkler systems. Note that an enclosed structure means a structure with a roof or ceiling and at least two walls.

Keep in mind that piles of dewatered digester solids may build up heat from bacterial growth, creating the potential for fire by self-heating (that is, spontaneous combustion). Be alert for smoke and steam emanating from hot spots in stored piles. If storage is likely to be prolonged, consider using a temperature probe (such as those used for compost piles, available in 4' or greater lengths) to check the temperature of piles. If serious hot spots develop or smoke is observed, open the pile to expose the hot spot and direct water to that specific area for rapid cool-down.

Notes:

In the building(s) housing the solids separation equipment and/or stored solids, it is important to use good housekeeping to keep down dust accumulations on all surfaces, including overhead beams and structures, to reduce the potential or severity of fire or dust explosions.

Means of exiting from a building

For any buildings which are part of the digester and biogas system, workers should be able to exit or escape during an emergency, such as a fire. At least two exits should be available – these should be free and unobstructed with no locks, chains, or fastenings to prevent free escape from the inside. Exit doors should swing outward and all the exit door hardware should be functional and operational. Exits need to be clearly visible and the exit routes clearly marked so that the direction of escape is obvious. Signs should be either internally illuminated or self-luminous with the word “EXIT” in letters at least 6 inches high. If the exit is not readily apparent, then clearly visible signs and arrows should be used. A sign reading “Not an exit.” should identify any door, passageway, or stairway that is not an exit or a path to an exit. Note that exits should discharge directly onto a road, yard, or other open space that gives safe access to a public way.

First Aid

First aid refers to medical attention that is usually administered immediately after the injury occurs and at the location where it occurred. It often consists of one-time, short-term treatment requiring little technology or training to provide. Some examples are cleaning minor cuts, scrapes, or scratches; treating a minor burn; applying bandages and dressings; use of non-prescription medicine; draining blisters; removing debris from the eyes; massage; and drinking fluids to relieve heat stress.

Proper first aid response would be to provide medical and first aid personnel and supplies appropriate to the hazards of the workplace. Even more important than the first aid kit itself is proper first aid training – certainly a first aid kit is useless if a person does not know how to use it.

The table below sets forth the minimally acceptable number and type of first-aid supplies for first-aid kits according to the OSHA standard. *Make sure your emergency kit contains personal medical information and supplies for those with special medical conditions.* For example, a sting to someone who's allergic to bee venom could be life-threatening, so appropriate anti-toxins must be included. The name and telephone number of a family doctor for everyone who might be involved in a medical emergency also should be included.

The contents of the first-aid kit listed should be adequate for small work sites, consisting of approximately two to three employees. For operations with more employees, the supply quantities should be increased or additional kits provided. Label the kit and place in a location that is easy to see and access. Consider having a first aid kit in all buildings and restock supplies as they are used.

Notes:

Eyewashes are important for rapid response to chemical exposures. The OSHA standard requires these where corrosive materials are present, but these are also useful for other chemicals, materials, or dusts in the eyes. It is also possible to install faucet adapters which enable a faucet to be used as an eyewash in an emergency. The table below provides some recommended features of eyewashes. Be sure to remove contact lenses and flush the eyes well. Although 15 minutes of flushing is typically recommended for chemical exposures, field studies of eye incidents indicate that at least 20 minutes are needed for chemicals which are alkaline/caustic in nature (some scientific literature suggests 30 minutes of rinsing). A small piece of pH test paper (or litmus paper) can be used to check eye moisture to determine when eye irrigation has been sufficient (pH will be 7 or neutral). In any case medical attention should be sought after any eye injury.

Recommended Contents for Workplace First Aid Kits

(Minimum Contents (per OSHA standard 29 CFR 1910.266 Appendix A))

- Gauze pads (at least 4 x 4 inches)
- Two large gauze pads (at least 8 x 10 inches)
- Box adhesive bandages (band-aids)
- One package gauze roller bandage at least 2 inches wide
- Two triangular bandages
- Wound cleaning agent such as sealed moistened towelettes
- Scissors (strong enough to cut through denim; e.g. stainless steel bandage scissors)
- At least one blanket
- Tweezers
- Adhesive tape
- Latex gloves
- Resuscitation equipment such as resuscitation bag, airway, or pocket mask
- Two elastic wraps
- Splint
- Directions for requesting emergency assistance

Recommended features for emergency eyewashes

- Aerated potable water
- Tempered water @ 70 F; mixing valve with “anti-scald” feature is desirable
- Copious and gentle flow; 3-7 minimum of 15 minutes of water flow
- Hands should not be required to maintain the water flow
- Test on a regular basis; keep a record of the testing; for plumbed installations, flush the lines once per week
- Locate eyewash units no more than 10 seconds in time or greater than 100 feet in distance from the hazard
- For a disabled persons’ use, the hand-held spray on a hose is the recommended unit
- Label the location

Notes:

References:

German Agricultural Occupational Health and Safety Agency. 2008. *Safety Rules for Biogas Systems*.

Brown, N. J. 2007. *Conducting a safety walk-through on a farm: hazards of the manure handling system, anaerobic digester, and biogas handling system – a self-assessment guideline for farmers*. Manure Management Program. Cornell Dept. of Biological and Environmental Engineering. <http://www.manuremanagement.cornell.edu/HTMLs/Safety.htm>

Brown, N. J. 2005. *Generic Protocol -- Conducting a safety walk-through on a farm: hazards of the manure handling system, anaerobic digester, and biogas handling system*. Manure Management Program. Cornell Dept. of Biological and Environmental Engineering. <http://www.manuremanagement.cornell.edu/HTMLs/Safety.htm>

Brown, N. J. "Composting safety and health" in: Rynk, R. et al. (Eds) (tentative fall 2012). *On-Farm Composting Handbook*. NRAES (Natural Resource, Agriculture, and Engineering Service). Cooperative Extension. Ithaca, NY. "Emergency Action Planning and Fire Response"

Notes:

5. Construction/Contracting Management

The planning, design, and construction of a new anaerobic digester system is an exciting time on the farm. It signifies the expansion of the producer's overall operation and a feeling of growth and achievement often accompanies the construction period. The key to this successful endeavor can be found through implementation of a prudent construction management plan; a prudent, comprehensive plan includes:

- Development and use of quality construction documents
- Clearly defined project scope, schedule, and cost
- Use of a construction manager
- Obtaining competitive bids
- Ensuring the project scope of work is executed completely, on time, and at cost

These and other related items are discussed in detail below.

5.1. Construction documents

There two construction documents used for large capital construction projects like anaerobic digester systems; they are a 1) complete set of plans and specifications, and 2) a signed construction contract (or contracts if the producer is going to be the general contractor).

The project must start with a well-defined project scope of work by the producer. This scope will be used as a basis for developing plans and specifications. The plans and specifications should be prepared by an engineer who is qualified and has expertise in designing anaerobic digester system projects. A bid package is composed of the prepared plans and specifications and may also be referenced as bid documents.

The goal is to provide bid documents that will be used to obtain competitive bids. The plans and specifications are the benchmark by which all construction is governed; therefore, these must clearly and concisely depict the producer's complete vision of the final product. The bid documents should include a baseline construction schedule, indicating tentative start and completion dates.

There are many sources of information available that detail preparation of plans and specifications and bid packages for construction projects. This paper does not provide a full explanation on this subject. The reader is referred to Brugger and Wille (1994) and Moore (1994) for a complete description of construction plans and specifications and bid document preparation, respectively.

5.2. Construction management, the Big Three: Scope, Schedule, and Cost

Notes:

5.2.1. Scope

The project scope of work is a written statement that provides the boundaries of the work and an overall description of the project. Many times the statement references the project plans and specifications. It is important that the scope of work is clearly stated as the financial cost of the project is based on this information.

5.2.2. Schedule

All projects need to have a schedule with a set starting date and a set completion date. These dates are established based on the time needed to accomplish all tasks associated with completing the project scope of work.

Project scheduling is a strategic process that is used to develop a written sequential list of tasks necessary to complete the overall project. For example, a project baseline schedule should be developed at the beginning of the project and should include a time frame for all major tasks. Development of a baseline schedule serves two purposes. First, it requires the developer (project manager, construction manager, producer, or other) to think about all the steps and their associated time frame for a particular project. Second, it is used as a tool to track the overall progress of the project.

The major tasks of a project baseline schedule should include some or all of the following:

- Discovery
- Design and engineering
- Bid package preparation
- Project bid period
- Pre-bid meeting
- Bid opening and review
- Contract award(s)
- Construction initiation meeting
- Submittal review
- Construction period
- Final inspection and acceptance

The schedule will change as the project progresses through various stages of completion. Subsequent schedule updates will ensure continued forethought and could improve the overall project.

Notes:

Many of the tasks shown above will have associated subtasks under each of them. For example, the construction of the digester vessel and associated austere equipment could have the following subtasks:

- Preliminary layout
- Site preparation
- Primarily site layout
- Site excavation
- Footer construction
- Concrete – vessel and pit forming and rebar placement
- Inspection
- Concrete – placement
- Install below-grade insulation
- Inspection
- Backfill and grade
- Install underground electric and plumbing
- Complete insulation
- Install in-vessel heat exchangers
- Install in-vessel agitators/mixers
- Install biogas collection/transport system
- Inspection
- Install digester top cover
- Complete wiring, plumbing, and heating
- Inspection
- Punch list development
- Final grading
- Punch list resolution

An example of a Ghant chart is shown in Figure 12 for a sample construction schedule. Ghant charts are used to depict construction tasks and show how they are interconnected to other tasks, based on schedule of work. Ghant charts are commonly used by construction managers to track the overall progress of the execution of the project scope of work.

5.2.3. Cost

Project cost establishment and tracking are key items to establish and tract throughout the construction project. The established construction project cost is stated in the contract between the farm and general contractor or individual subcontractors, depending on the establishment of a GC or not for the project.

Notes:

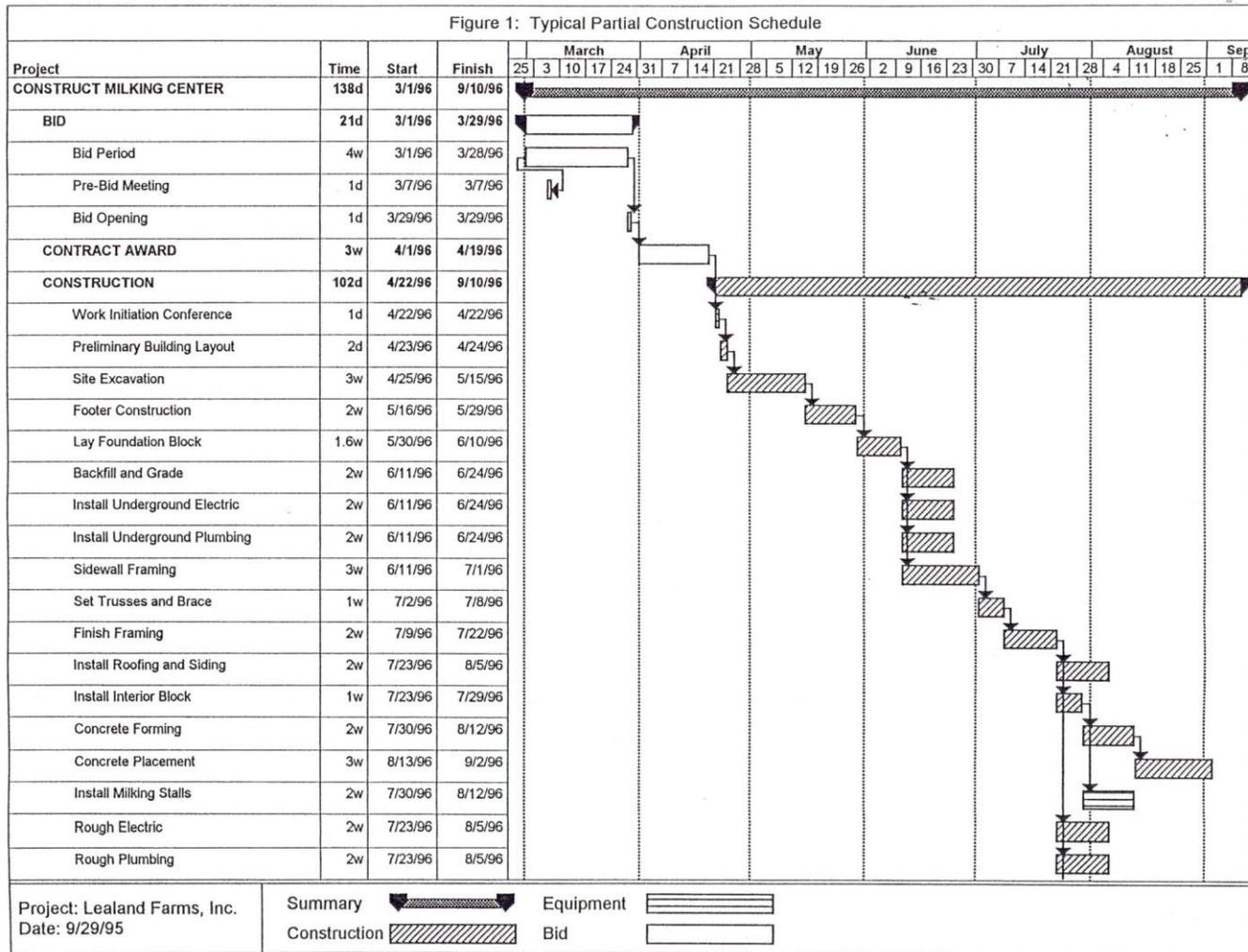


Figure 12a. Typical Partial Construction Schedule

Notes:

5.3. Construction management options

A construction manager is required to schedule, coordinate, manage, and supervise all construction and equipment installations. The role of a construction manager is not to be taken lightly. Large capital investments are necessary to construct an anaerobic digester system. This capital is typically borrowed from a lending institution and also provided by a grant agency. A good construction manager will work within the available budget to ensure that the resulting facility represents quality construction; is a reflection of the construction documents; and is truly worthy of the monies spent. Thus, expect a construction manager to exert significant time and effort throughout the project.

Just as there are many different manufacturers of milking equipment on the market, there are many different methods for managing anaerobic digester construction projects. In general, a producer can follow one of three paths to provide construction management for a project:

1. Hire a general contractor who will be responsible for construction and perform the construction management function.
2. Hire an independent construction manager.
3. Act as the general contractor/construction manager.

Each of the three options are discussed in detail below. Overall, the option selected depends on a number of variables: the amount of time the producer has available on a daily basis; the producer's familiarity with construction methods, trades and practices; the ability or desire of the producer to coordinate, direct, and manage subcontractors; and the producer's desired level of involvement.

GENERAL CONTRACTOR

Pursuing the first option involves hiring a general contractor (GC) to coordinate and manage all aspects of the construction project. This means that the producer will have more time, to perform daily and seasonal chores and be with the family. However, the producer will need to perform regular field observations of the ongoing construction to ensure that the final product will meet all of the needs. Since the GC is tasked with the full responsibility of hiring, coordinating, scheduling, and managing all subcontractors, the expense for this responsibility and effort is factored into the overall contract amount.

Notes:

INDEPENDENT CONSTRUCTION MANAGER

The second option involves hiring an independent construction manager. The independent construction manager is typically a consultant or firm that has expertise in specific types of construction projects and is responsible for part or all of the construction phase. The producer should contract with an individual consultant or firm that has knowledge of agricultural facilities and construction practices. The level of their responsibility should be defined by specific contractual arrangements.

Under this scenario, if the producer contracts for complete construction management services, the producer could be away from the site for multiple days without undue concern for the project. The producer should make periodic field observations to ensure that construction work is progressing towards the ultimately desired facility and discuss any problems with the construction manager.

PRODUCER AS A GENERAL CONTRACTOR/CONSTRUCTION MANAGER

The third option, the producer acting as a general contractor/construction manager, is most common for most on-farm construction projects but may not be appropriate for an anaerobic digestion project.

This option requires the producer to hire subcontractors for all major trades of work required to complete the project. Typically, this includes a separate subcontractor to perform:

- excavation
- carpentry
- concrete and masonry
- equipment installation
- electrical
- electromechanical
- plumbing

After these firms are hired, the producer has the responsibility to coordinate all work so that a pre-defined schedule can be met.

This method gives the producer the greatest degree of involvement in all decisions; however, it is the most time-consuming. Some producers could feel alienated while performing construction management tasks due to the amount of time required. Many times, the owner or

Notes:

foreman of the carpentry or other crew is experienced in various facets of construction management and may be willing to offer assistance.

5.4. Pre-construction: Project bidding

BID DOCUMENTS (BID PACKAGE)

The bid documents consist of a complete set of project plans (drawings) and specification (written documents) developed by the designer/engineer, a letter providing instructions to potential bidders (including the bid due date and time, location of the pre-bid meeting, contact information for technical questions and contractual questions, etc.), a bid response form, and other related materials as appropriate.

BID PERIOD

After assemblage of the bid package is completed, the first step is to obtain competitive bids from all of the various trades required to complete the project. Solicit bids only from reputable firms which seem genuinely interested in the project. If necessary, check a subcontractor's references prior to providing them with a set of bid documents. This requires additional work up-front, but may save hours of problems and aggravation once construction is underway. Allow ample time (up to 4 or 5 weeks for large projects) for potential bidders to review the drawings and specifications as it takes time to do take-offs (a process in which a list of materials for the job is generated from the plans) and obtain price quotes from material suppliers. This will permit bidders to provide their best price for the work. Be sure that the bid due date and time are established and provided to all potential bidders when they obtain a copy of the bid documents.

PRE-BID MEETING

A pre-bid meeting should be held at the construction site. The meeting should be held relatively early in the bid period. The objective of the meeting is to review the bid documents with the potential bidders and provide an opportunity to ask questions. The design engineer should be present so that questions can be answered. Extra copies of the bid documents should be available for distribution at the meeting.

BID ADDENDUM

It is difficult to create a perfect set of bid documents. Often, during the bid period, a potential bidder will find an error, conflict, or have a suggestion which will improve the project. The project manager and/or the producer must decide if the suggested change is desired or warranted. This determination may require consultation with the design engineer. If the suggested or

Notes:

required change is deemed warranted, the bid documents must be modified. This modification is accomplished by issuing a written document called an addendum.

The addendum will detail all changes or corrections to the scope of work and is provided to all bidders. Usually, an addendum should be issued by the design engineer as this individual is most familiar with the plans and specifications. When major changes occur in project scope or the issuance of an addendum falls close to the bid due date (less than 7 calendar days), add a time extension to the bid period. There is no set time for a bid extension.

Suggestion: The project manager and/or the producer should attempt to make all desired changes in the project scope during the bid period as this will allow the best pricing and a better final product.

BID OPENING

The bid opening should occur at the established bid due date and time. Caution should be taken in accepting bid proposals after the bid due date as this may indicate the bidder has a possible inability to complete work on schedule.

5.5. Pre-construction: Construction contracting

CONTRACT RATIFICATION

After all bids are opened and reviewed with the design engineer, the GC or subcontractor(s) are chosen and notified. Require that all necessary documentation, such as certificate of insurance, performance bond, etc. are provided before executing contracts. This step in the overall construction process may require involvement with the lending institution. Therefore, it is recommended that the producer contact the lender in advance to determine what they may require during this phase.

5.6. Construction

CONSTRUCTION INITIATION MEETING

After the contracts have been signed by each subcontractor, the producer should schedule and conduct a construction initiation meeting at the site. The scope of a construction initiation meeting should be to:

- Provide a meeting between principles.
- Discuss any potential problem areas.

Notes:

- Have general discussion and question and answer opportunity.

The principles who participate in this meeting should include: the producer, the design engineer, an individual from each subcontractor who represents that firm, and a representative from the lending institution.

Specific topics to be covered during the construction initiation meeting are:

- Submittals
- Material testing services
- Inspection services
- Progress payments
- Changes in work
- Progress meetings
- Project schedule
- Contact numbers for principles

It is imperative that a principle from each subcontractor attends the meeting to establish the communication link needed to coordinate schedules.

MEETING MINUTES

Meeting Minutes are a written record of what transpired during a meeting and all decisions made. For all meetings which occur during the duration of the project, Meeting Minutes should be taken and a copy distributed to each subcontractor's representative. It is helpful if the producer and/or construction manager can have a person not actively participating in the meeting take the minutes. This will allow the meeting duration to be kept to a minimum.

SUBMITTALS

A submittal is a written or physical sample of material or equipment proposed for installation by the subcontractor. The written submittal may be in the form of a cut sheet from the manufacturer (refer to Figure 14). The subcontractor should present submittals to the producer. Next, the submittals are reviewed by the design engineer and/or producer. Then, an approved or disapproved copy is returned to the subcontractor and a copy should be filed by the producer for future reference.

The submittal procedure should be clearly stated in the contract documents and subsequently reiterated to all subcontractors during the construction initiation meeting. Further, it is important to provide a quick turnaround of submittals to enable a subcontractor to confirm

Notes:

material orders or make necessary changes for resubmittal. An advantage that submittals give to the producer and/or construction manager is they may indicate the manufacturer's recommended installation methods. This information can then be used to check for proper installations during inspections.

CONSTRUCTION INSPECTIONS

Inspections should be made with the design engineer on a regular basis with the frequency dependent on the progress of construction elements and sensitivity of the inspection with respect phase of the work. Also, the producer should conduct announced and unannounced construction inspections without the design engineer.

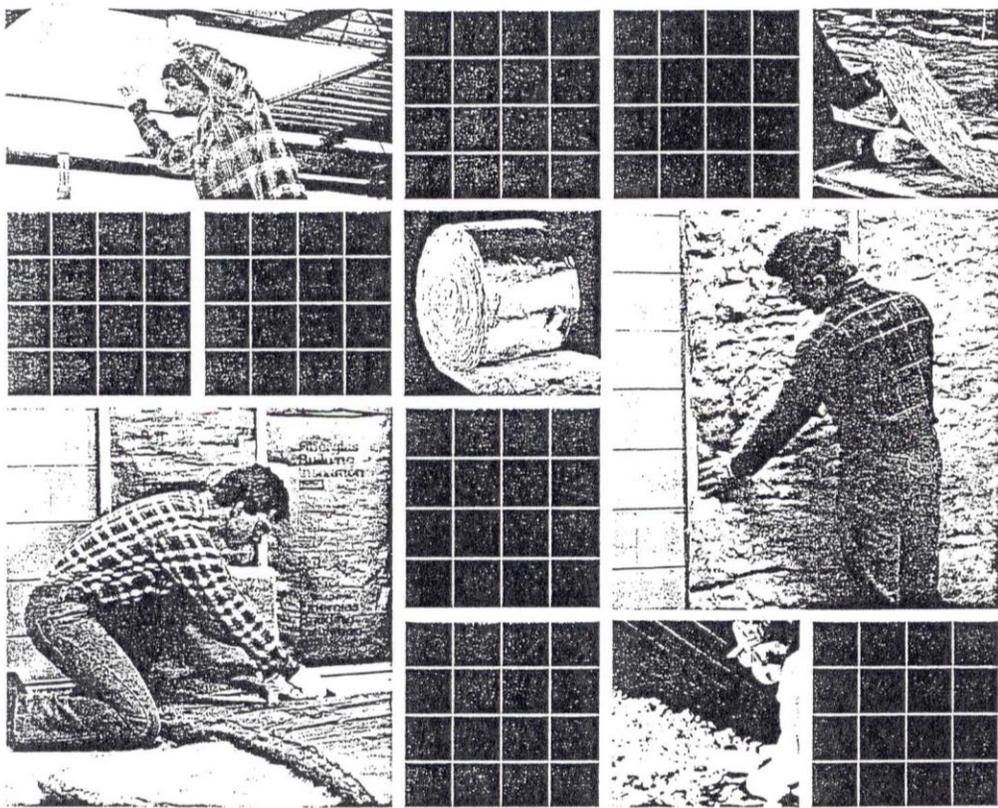
A strong attempt should be made to perform an inspection prior to completion of a work element which will not visibly allow for checking after the element is completed. For example, it is impossible to check for concrete reinforcement (rebar) for spacing, sizing, numbers, and placement after the concrete has been placed. On the other hand, the characteristics of certain wooden structural members can be determined after they are installed.

Based upon construction plans and specifications, the construction manager has the final authority to rule on inspection issues after consulting with the design engineer or others.

Notes:

Building Insulation Submittal Sheet

This submittal sheet is provided to help you select and specify the proper Owens-Corning Fiberglas insulation. Specification compliances and basic performance data are included. For more information and technical assistance, contact your local Owens-Corning Fiberglas sales office or the Owens-Corning Fiberglas Corporate Headquarters.



Submitted to: Curt Gooch, Lealand Farms, Inc.

Submitted by: Jim Simmonds, Simmonds Construction Co.

Job Reference: E-95129

Job Name: Lealand Farm Milking Parlor

APPROVED FOR CONSTRUCTION
CA Simmonds 7/26/95 Date: 7/17/95

Figure 14a. Building insulation submittal sheet example

Notes:

PRODUCT PROVIDED	DESCRIPTION	SIZE		THERMAL RESISTANCE	APPLICABLE STANDARD
		Nominal Thickness		R-Value	
<input type="checkbox"/> Friction Fit® Unfaced Insulation	Unfaced Fiberglas® insulation designed to be installed between framing and held in place by friction. Vapor resistant facing is installed separately.	<input type="checkbox"/> 3½"	<input type="checkbox"/> 6"	11	Federal Specification HH-I-521F, Type I.
		<input type="checkbox"/> 3¾"		13	
		<input type="checkbox"/> 6¼"		19	
		<input type="checkbox"/> 9½"		30	
		<input type="checkbox"/> 12"		38	
<input checked="" type="checkbox"/> Kraft-Faced Insulation	Fiberglas® insulation with a strong asphalt coated kraft paper facing on one side with stapling flanges available on wood framing widths only. The kraft facing has a perm rating of 1.	<input type="checkbox"/> 3½"	<input type="checkbox"/> 6"	11	Federal Specification HH-I-521F, Type II, Class C.
		<input type="checkbox"/> 3¾"		13	
		<input checked="" type="checkbox"/> 6¼"		19	
		<input type="checkbox"/> 9½"		30	
		<input type="checkbox"/> 12"		38	
<input type="checkbox"/> Foil-Faced Insulation	Fiberglas® insulation with an aluminum foil-kraft facing on one side with stapling flanges at edges available on wood framing widths only. The foil facing has a perm rating of 0.5.	<input type="checkbox"/> 3½"	<input type="checkbox"/> 6"	11	Federal Specification HH-I-521F, Type III, Class C.
		<input type="checkbox"/> 6¼"		19	
<input type="checkbox"/> Flame Spread 25 Insulation	A Fiberglas® insulation with reinforced foil laminate facing with perm rating of 0.5. Recommended for exposed applications requiring a facing.	<input type="checkbox"/> 3½"	<input type="checkbox"/> 6"	11	Federal Specification HH-I-521F, Type III, Class A.
		<input type="checkbox"/> 6¼"		19	
<input type="checkbox"/> Sonobatts®	Commercial insulation batts for commercial ceiling panels in suspended ceilings. Adds thermal resistance and improves acoustical performance of commercial ceilings. Available unfaced, kraft-faced or FS-25 foil-reinforced faced.	<input type="checkbox"/> 3½"	<input type="checkbox"/> 6"	11	Federal Specification HH-I-521F Type I. . . Unfaced Sonobatts®
		<input type="checkbox"/> 6¼"		19	Type II. . . Kraft-Faced Sonobatts®
		<input type="checkbox"/> 9½"		30	Type III. . . Flame Spread 25 Sonobatts®
		<input type="checkbox"/> 12"		38	
		Available 24" x 48".			
<input type="checkbox"/> Fiberglas® Noise Barrier Batts	Intended for use in residential and commercial construction where sound control between rooms is required. Reduces sound transmission by increasing STC rating. Also can improve the thermal performance of wall systems.	<input type="checkbox"/> 2½"	<input type="checkbox"/> 3½"	8	Federal Specification HH-I-521F, Type I (except for identification marking.)
		<input type="checkbox"/> 3½"		11	
		Available in 96" lengths, widths of 16" and 24".			
<input type="checkbox"/> Fiberglas® 700 Series	Lightweight, flexible. Particularly suited for irregular-shaped surfaces, and where product is protected. Density 1.5 PCF. Available unfaced only.	<input type="checkbox"/> 1½"	<input type="checkbox"/> 2"	6.2	HH-I-558B, Form A, Class 1; Form B, Type I, Class 7 (except for comprehensive strength).
<input type="checkbox"/> 701		<input type="checkbox"/> 2½"	<input type="checkbox"/> 3"	8.3	
		<input type="checkbox"/> 3"	<input type="checkbox"/> 4"	10.3	
		<input type="checkbox"/> 4"		12.4	
				16.5	

Figure 15b. Building insulation submittal sheet example

Notes:

MATERIAL TESTING SERVICES

To ensure the quality of some materials used during the project, a material testing services agency should be retained. Their testing results will ultimately ensure adequate structural strength of soil, concrete, and other materials. There are two ways to obtain the services:

1. The producer and/or construction manager can contract directly with a materials testing service.
2. The contract documents can be prepared to define what materials are to be tested and require that the subcontractor must secure, schedule, and pay for the services.

This testing is an important and yet often overlooked item in the overall project. The cost for the testing service is relatively low compared with that of the overall project. Without utilizing such a service, the digester may appear to be structurally sound at the time of completion but settlement could occur causing cracks in footers, vessel walls, and building sidewalls, in some cases leaving the digester inoperable.

INSPECTION SERVICES

The producer and/or construction manager should contact the local authority (e.g. county, township, etc.) to determine the requirements regarding permits and inspections for dairy construction projects, including anaerobic digester systems. This step is important since the local regulations dictate if any action is necessary. Some insurance companies may also require certificates for some work.

These requirements may necessitate that the producer and/or construction manager obtain the services of an independent inspection agency. There are two methods to obtain these services:

1. The producer and/or construction manager can contract directly with an independent inspection agency.
2. The contract documents can be prepared to specify that the subcontractor must secure, schedule, and pay for all required independent inspection services.

Either method chosen should ultimately provide the producer and/or construction manager with an inspection certificate from the independent agency certifying the work. For example, an

Notes:

electrical inspection certificate will verify that all electrical work completed for the referenced project was performed in accordance with the National Electrical Code (NEC) and the local electrical code. All certificates should be retained in a permanent file.

DAILY MEETINGS

The producer and/or construction manager may want to hold a short meet before work starts each day. This will allow a quick overview of the day's activities. Any pending problems can be identified, discussed, and either fully resolved or if not action steps towards resolution can be developed. The producer and/or construction manager's goal should be to have a complete understanding of the work which will be occurring that day and to coordinate the construction workers (possibly from various trades *concurrently* in the same area of the site) to work efficiently.

PROGRESS MEETINGS

Progress meetings are meetings held every one to two weeks or otherwise, as required for the principles from all parties to meet and discuss the project. It is the responsibility of the producer and/or construction manager to arrange the meetings in advance so maximum attendance can be achieved. The goals of a progress meeting should include some or all of the following:

1. Review the work accomplished since the previous meeting.
2. Check progress made against the construction schedule and adjust as required.
3. Resolve any conflicts caused by the need for more than one subcontractor to work in the same area concurrently.
4. Discuss any proposed changes or suggestions that may improve the overall facility.

A good construction manager should keep the meeting on track by working from an agenda prepared in advance that is developed based on input received in advance from meeting participants. This will minimize the meeting length and allow attendees to return to work in a timely manner.

CHANGE ORDERS

A change order is a written agreement that adjusts the governing contract that states a change in the project scope, schedule, and/or costs. Change orders can be additive or deductive in

Notes:

--

contract value for an increase or decrease in project scope. A change in project scope is defined as:

- 1) Any work and/or material that is required to permit project completion that is not originally specified by the bid documents (including bid addenda).
- 2) The revision of the plans or specifications requiring something different than originally specified.

For example, if the excavation contractor encounters rock during earth moving activities and is required to spend additional time to remove the rock and the specifications do not contain a rock removal clause, then the excavation company is entitled to additional compensation.

To process a change order, first the producer and/or construction manager must determine if the subcontractor is asking for additional money for a legitimate reason. The subcontractor's statement, "I didn't see that requirement when I reviewed the bid documents" is not a legitimate reason to grant a change order. Next, the producer and/or construction manager should request a written proposal quote from the subcontractor which details the proposed change in the work along with any associated costs or savings. Thirdly, the proposal needs to be carefully reviewed. If deemed acceptable, the proposal should be signed by the producer and/or construction manager and subcontractor. This signed proposal then becomes the change order document which officially authorizes the subcontractor to proceed with the work. All parties including the lending institution should retain an executed copy for their files.

Do not authorize any changes in work before a written change order document is executed by all parties. It is important to note that some changes in work will require modifications to the construction schedule. From a budgetary standpoint, a construction loan usually has a built-in 10 percent increase in contract value to cover changes in scope of work.

PROGRESS PAYMENTS

Progress payments are made at predetermined points of construction completion. They are designed to provide the subcontractor with compensation for work completed during the defined period. *The defined periods are not time oriented, they are progress oriented.* To have a basis for approving progress payments, the producer and/or construction manager should obtain a suggested payment breakdown from each subcontractor before construction initiates, review it, negotiate changes as needed and finalize/approve for use. The breakdown should show the cost of major completion points throughout the construction project. For

Notes:

example, the electrical breakdown submitted by an electrician for an anaerobic digester project may be as follows:

Temporary electrical service	\$ 15,500
Main service installation	25,750
Utility interconnection	20,000
Rough wiring	50,500
Final wiring	12,000
Inspection	3,000
Punch list resolution	3,000

This breakdown is used as a guideline for making progress payments to subcontractors as work progresses.

Generally, the lending institution receives the progress payment request directly from the subcontractor and is responsible for making the payment. However, the agreement with the lender should allow the producer and/or construction manager to certify the request for payment based upon satisfactory completion of the work. It is up to the producer and/or construction manager to determine if the work has been completed in accordance with the plans and specifications. This may require the assistance of the design engineer or testing agency before the request can be certified.

The producer and/or construction manager should not authorize any payment request for:

- Work not started
- Materials not delivered to the construction site
- Work not satisfactorily completed
- Work requiring an inspection certificate

RETAINAGE

The producer and/or construction manager should discuss a retainage policy with the lender during the loan application period. Retainage is a pre-defined percentage withheld from each progress payment request that is used as a leverage tool to ensure satisfactory completion of the project. If a retainage policy is agreed to by the lender, then the bid documents must have a segment describing it. An acceptable retainage amount is five (5) percent of each request. The retainage balance is payable to each applicable subcontractor at the satisfactory completion of the entire project.

Notes:

FINAL INSPECTION

A final inspection is scheduled to be conducted subsequent to substantial completion of the required work. The producer and/or construction manager should schedule this inspection with all subcontractors, owners, and lending representatives. This inspection provides the opportunity to develop a list of items found deficient or outstanding under the terms of the contract.

PUNCH LIST

A punch list is developed as a result of a final inspection conducted subsequent to substantial completion. As stated above, the purpose of a punch list is to identify items which are found to be incomplete or deficient according to contract documents. Once the punch list is developed, a copy should be given to each subcontractor for resolution. The producer and/or construction manager should use the punch list as a check-off tool and conduct follow-up inspections until the resolution of all punch list items.

BENEFICIAL OCCUPANCY

Sometimes occupancy or use of the facility can take place during resolution of punch list items. This is termed "beneficial occupancy." If beneficial occupancy is desired during punch list resolution, it is essential that the punch list items are identified and reviewed with each subcontractor to ensure that the list is accurate. The subcontractor is not liable for damage caused during beneficial occupancy by operators. Likewise, a subcontractor cannot escape responsibility by not finishing items required by the contract documents.

The date of beneficial occupancy is established in writing and is the basis of the beginning of the project warrantee period in most cases.

FINAL PAYMENT

When each subcontractor has satisfactorily completed all required work, the final payment request should be reviewed and certified by the producer and/or construction manager. This final payment request should include all work completed since the previous progress payment request and retainages (if applicable).

Notes:

5.7. Post-construction

WARRANTY PERIOD

The warranty period for the anaerobic digester and equipment components should be specified and understood prior to execution of the contracts. A warranty for the structure should be at least one (1) and preferably two (2) years. Equipment warranties are usually stipulated by the manufacturer and often vary. Warranty periods should be specified to begin after final acceptance, if possible.

The producer and/or construction manager should obtain written warranties from each subcontractor for the work they completed and the equipment they installed. The producer and/or construction manager should maintain this information in a central file.

DEVELOPMENT OF MAINTENANCE MANUALS

The producer and/or construction manager should solicit and organize product and maintenance data for all major electrical and mechanical equipment installed during the course of the project. Examples include:

- Influent/effluent pumps and agitators
- Biogas blowers
- Engine-generator set
- Switch gear
- Utility interconnection equipment
- Flare
- Boiler
- Hot water circulation pumps
- Control systems
- Solid-liquid separator
- Solids conveyor

The resulting manuals will prove useful for future preventative maintenance work and emergency repairs. Suggestion: The producer and/or construction manager should incorporate the warranty information with the appropriate maintenance manual.

AS-BUILTS

Notes:

As-builts are an exact record of what was built and where equipment was installed during the construction project. As-builts are important because the final facility is not usually 100 percent representative of the initial construction documents. Most as-builts stem from an original set of construction drawings which are continuously updated during the course of construction. The producer and/or construction manager is advised to indicate the changes to the original documents in red ink and have the design engineer integrate the changes into the original CAD (computer-aided design) drawing file. After this is done, a set of permanent as-builts can be produced on mylar. Mylar is suggested because of its durable, long-lasting characteristics. As-builts can be filed for use as a reference document to assist with maintenance and repair or expansion operations.

5.8. Suggestions for prudent construction management

A construction manager should ensure that open communication is maintained among the design engineer, subcontractors, inspection and testing services representatives, loan representatives, and any other parties close to the project. All significant matters should be confirmed in writing so there is no "He said, She said" misunderstandings.

Most importantly, be proactive at solving problems or discrepancies between parties. Do not let problems build; solve them immediately. This will help maintain a positive attitude for all during the project. During times of disagreement, remind everyone involved of the common goal: to construct a milking center in a clean, concise, and profitable manner which conforms with the governing plans and specifications. Be fair but firm when conducting business.

There are generally three options for obtaining construction management during construction of an anaerobic digester system. The choice of the producer acting as a general contractor requires the performance of construction management tasks in addition to those of the dairy operation. This is a good way to save costs, be intimately involved with the project, and be in a position of control. However, being a construction manager is demanding and will require countless hours over and above those generally involved in a dairy operation. Therefore, it is suggested that the producer carefully review daily workload demands anticipated during the duration of the construction project. This review process should determine if the producer acts as the construction manager or contracts for this service.

References

Notes:

Brugger, M. F. and Wille, J.R. "Using Design Assistance for Planning the Modern Dairy Facility." *Proceedings of the Third International Dairy Housing Conference*. ASAE Publication No. 02-94. American Society of Agricultural Engineers, St. Joseph, MI. pp. 539-447. 1994.

Moore, M. E. "Preparing the Bid Package." *Facilities and Financial Planning* (NRAES -77). Ithaca, New York: Northeast Regional Agricultural Engineering Service, pp. 73-77. 1994.

Notes:

6. Considerations of AD process performance

Mixing – Digester mixing is primarily intended to provide a uniform environment, promote efficient utilization of the digester volume, and to prevent solids settling, stratification, as well as temperature gradients. However, although some degree of mixing is important, high mixing intensity, especially over long periods of time, can increase energy consumption. Further, microbial community interactions can be disrupted, consequently decreasing biogas production and overall digester performance.

Agitation can be conducted continuously or intermittently during the day; however, the required agitator operating time and intervals (if any) are determined individually for a specific configuration and operation (Deublein & Steinhauser, 2011). In general, agitators operated continuously are usually run at low speeds, while intermittently-operated agitators run at high speeds. For example, most farm digesters are mixed every hour for a fraction of the hour (e.g. 15 – 30 min) at high RPMs.

Depending on the geometry and type of vessel, agitator configurations can include large and small diameter impellers, single-shaft multiple impellers, motor-propeller agitators, etc. Although, a standard plug-flow type digester does not incorporate any mixing components, there are variations that utilize impellers or recirculated biogas injected at the bottom to provide mixing throughout the length of the vessel.

Overall, regardless of the mixing strategy and design configuration, the goal of mixing is to homogenize the material within the AD vessel in order to optimize digester performance and process stability.

Substrate additions – When including substrates other than manure to a farm-based AD system (co-substrates), several factors need to be assessed to determine the ability of the co-substrate(s) to be incorporated without disruption to the system. Periodic monitoring and testing should be performed to assess potential inhibition and toxicity and ensure process stability. Some factors that should be considered are the co-substrate's chemical strength and loading rate (with respect to manure). The chemical strength of the substrate can be measured by its chemical oxygen demand (COD) and its volatile solid (VS) concentration; both parameters are essential to determine the amount to be added to the manure digester. Regardless of the amount of co-substrate available, the quantity to be added should be directly related to the strength; low-strength substrates can be added in higher quantities with respect to manure, while higher-strength substrates must be used sparingly. Lastly, the solids concentration of the substrate will

Notes:

impact handling as well as loading. A more liquid substrate can be pumped easily whereas a more solid material may require pre-treatment or customized handling.

Hydraulic retention time (HRT) and organic loading rate (OLR) – The HRT is the total number of days the organic substrate resides in the digester. In a completely-mixed digester, this time is given by:

$$HRT = \frac{V}{Q}$$

Where,

V: Volume of the digester vessel (gallons)

Q: Influent loading rate (gallons/day)

The digester's HRTs should be designed to provide enough digestion time for stabilization of the substrate. Typical design HRTs for manure-only digesters are between 20 and 25 days, but for easily biodegradable materials, such as food wastes, HRTs can be shorter. Shorter HRTs may increase daily biogas production, but can compromise the efficiency and stability of the process, decreasing organic matter stabilization and increasing the probability of system failure. Longer HRTs would decrease daily biogas production and only slightly increase organic matter stabilization.

For example, a 1,000-cow dairy farm operation producing 150,000 lbs manure (17,974 gal) per day will need a vessel volume of approximately 400,000 gal to achieve an HRT of 22 days.

The OLR is the amount of influent substrate entering the digester per day (lbs/gal-day). For a particular organic substrate concentration and digester HRT, the OLR can be calculated as:

$$OLR = \frac{VS}{HRT} = \frac{VS \cdot Q}{V}$$

Where,

VS: Volatile solids concentration of the substrate (lbs/gal)

Notes:

The OLR can be increased by increasing either the influent loading rate (Q) or the organic matter concentration of the substrate (VS). Typical VS concentration of manure-only digesters in New York State is between 0.67 lbs/gal (80 g/L) and 0.83 lbs/gal (100 g/L) (8 - 10%).

Temperature regime – Anaerobic digestion systems can be operated at mesophilic or thermophilic temperature conditions (Ward et al., 2008). Mesophilic digesters, which are operated between 95 and 105°F, are less energy intensive and usually are more commonly employed in full-scale facilities than thermophilic digesters. In addition, thermophilic digesters have been reported to be less stable than mesophilic digesters, being more susceptible to inhibition (Angelidaki & Ahring, 1994) and sudden environmental changes (Zinder, 1986). However, thermophilic anaerobic digestion presents several important advantages over mesophilic digestion. The capability of thermophilic digestion to inactivate pathogenic organisms has been recognized to be a proven method for producing Class A biosolids (Kim et al., 2002), which are essentially pathogen free streams, with no restrictions on crop type, harvesting, or site access for land application (USEPA, 2000). Additionally, increased growth rates of microorganisms and accelerated interspecies hydrogen transfer at thermophilic temperatures can lead to faster degradation rates, higher solids destruction, and ultimately to increased biomethane yields at shorter retention times (Labatut, 2012).

References:

- Angelidaki, I., Ahring, B.K. 1994. Anaerobic Thermophilic Digestion of Manure at Different Ammonia Loads - Effect of Temperature. *Water Research*, **28**(3), 727-731.
- Deublein, D., Steinhauser, A. 2010. *Biogas from Waste and Renewable Resources: An Introduction*, 2nd, Revised and Expanded Edition.
- Kim, M., Ahn, Y.H., Speece, R.E. 2002. Comparative process stability and efficiency of anaerobic digestion; mesophilic vs. thermophilic. *Water Research*, **36**(17), 4369-4385.
- Labatut, R.A. 2012. Anaerobic biodegradability of complex substrates: performance and stability at mesophilic and thermophilic conditions. in: *Biological and Environmental Engineering*, Vol. Ph.D. , Cornell University. Ithaca, pp. 223.
- USEPA. 2000. *Guide To Field Storage of Biosolids and Other Organic By-Products Used in Agriculture and for Soil Resource Management*, U.S. Environmental Protection Agency, pp. 134.

Notes:

Ward, A.J., Hobbs, P.J., Holliman, P.J., Jones, D.L. 2008. Optimisation of the anaerobic digestion of agricultural resources. *Bioresource Technology*, **99**(17), 7928-7940.

Zinder, S.H. 1986. Thermophilic waste treatment systems. in: *Thermophiles: General, Molecular and Applied Biology*, (Ed.) T.D. Brock, Wiley-Interscience. New York pp. 257-277.

Notes:

7. Value added ventures

7.1. Excess heat usage

There is normally no critical need for heat on dairy farms, thus, the parasitic use of this by-product to heat the AD vessel does not interfere with on-farm energy needs. However, the potential exists to generate revenue from the sale of excess heat, if there is a seasonal business that could make use of the heat in the warmer summer months when the demand for digester heating is low. Examples of this type of venture include: a greenhouse, a car wash, a grain drying operation, or a maple sugar operation.

7.2. Excess biogas uses

The technology exists to make possible several alternate uses of biogas generated from an on-farm AD, however, the main barrier is the cost to integrate these technologies to the system. Raw biogas has limited capabilities to be used in applications off-site, unless an industrial processor or other user exists adjacent to the property, allowing the biogas to be piped a short distance without treatment or compression.

Long-distance transport of biogas requires that it be treated and/or compressed, depending on the usage. There is at least one U.S.-based farm application of treated and compressed biogas used to fuel farm vehicles and milk trucks. Any application that natural gas (mainly methane) is used for, treated biogas (called biomethane) can also be used. This includes compressed natural gas (CNG) vehicles. Biomethane can also be injected into a natural gas pipeline and sold.

7.3. Post-digested separated solids

Separated solids (either composted or not) would first be used to offset stall bedding costs by re-using solids to bed dairy cows. After meeting on-farm needs for bedding material, excess solids could be sold to neighboring farms as a bedding material, or sold to residential and commercial entities as a soil amendment (fertilizer).

7.4. Long term contracts

7.4.1. Power purchasing

Notes:

A power purchase agreement (PPA) in relation to farm-based anaerobic digestion is a long-term agreement between a project developer or farm (depending on the ownership structure) and a designated buyer. The advantage of this arrangement is that the party generating the renewable energy is guaranteed a long-term, stable, pre-negotiated price for the energy generated. This is helpful in projecting the economic outlook of the project, and usually involves a higher payment than electricity net-metered to the utility grid.

7.4.2. Food waste

A farm that plans to pursue co-digestion must first locate at least one source of organic waste substrate to import to the farm AD. The availability of substrate(s) can have a significant effect on the overall project – including AD vessel size, biogas production, capital cost, and revenue. After the necessary substrates are sourced, they must be secured with a long-term contract to ensure uninterrupted biogas production at the same level be maintained. A tipping fee should also be agreed upon, and included in the long-term contract since changes in the tipping fee can have significant impacts on the revenue of the project.

7.5. Food waste inputs

Any organic biomass can be digested. Digestion of various biomass materials is largely a function of materials handling (conveying material from storage into a digester), biodegradability, maintaining a balanced state within the digester vessel, and economics. Many suppliers of co-digestion substrates that are available for anaerobic digestion currently pay significant tipping fees to local landfill authorities in order to dispose of their unwanted processing by-products. More information regarding food waste inputs can be found in Section 3.4

7.5.1. Quantity and type of waste

In New York State, many farmers are interested in mixing food wastes with manure due to:

1. The increased biogas production potential the mixture produces, and/or
2. The associated tipping fees for allowing food waste generators to unload their byproduct(s) on the farm.

In Denmark, mixing of food waste with manure is common practice and the Danish government requires the food waste and manure mixture be pasteurized (70°C for one hour)

Notes:

prior to being land-applied in order for the farm to be in compliance with standard manure application laws. In New York State, farms are limited by the Net Metering Law to importing no more than 50 percent (by weight of the total digester influent) food waste for digestion with manure.

When locating substrates for co-digestion, consistency of the waste stream is one important consideration. For example, the waste stream from an industrial food processing plant is likely to be very consistent compared with restaurant or residential food scraps. Dramatic changes in the consistency of AD influent can negatively impact the microbes working within the AD vessel if not pursued slowly.

7.5.2. Effect on quantity of biogas and subsystem sizing requirements

The energy producing potential of organic waste depends heavily on the characteristic make-up of the waste, including the carbohydrate, lipid and protein concentrations, as seen in Figure 16 (Labatut, R.A. “Experimental and Predicted Methane Yields from the Anaerobic Co-digestion of Animal Manures with Complex Organic Substrates”).

Notes:

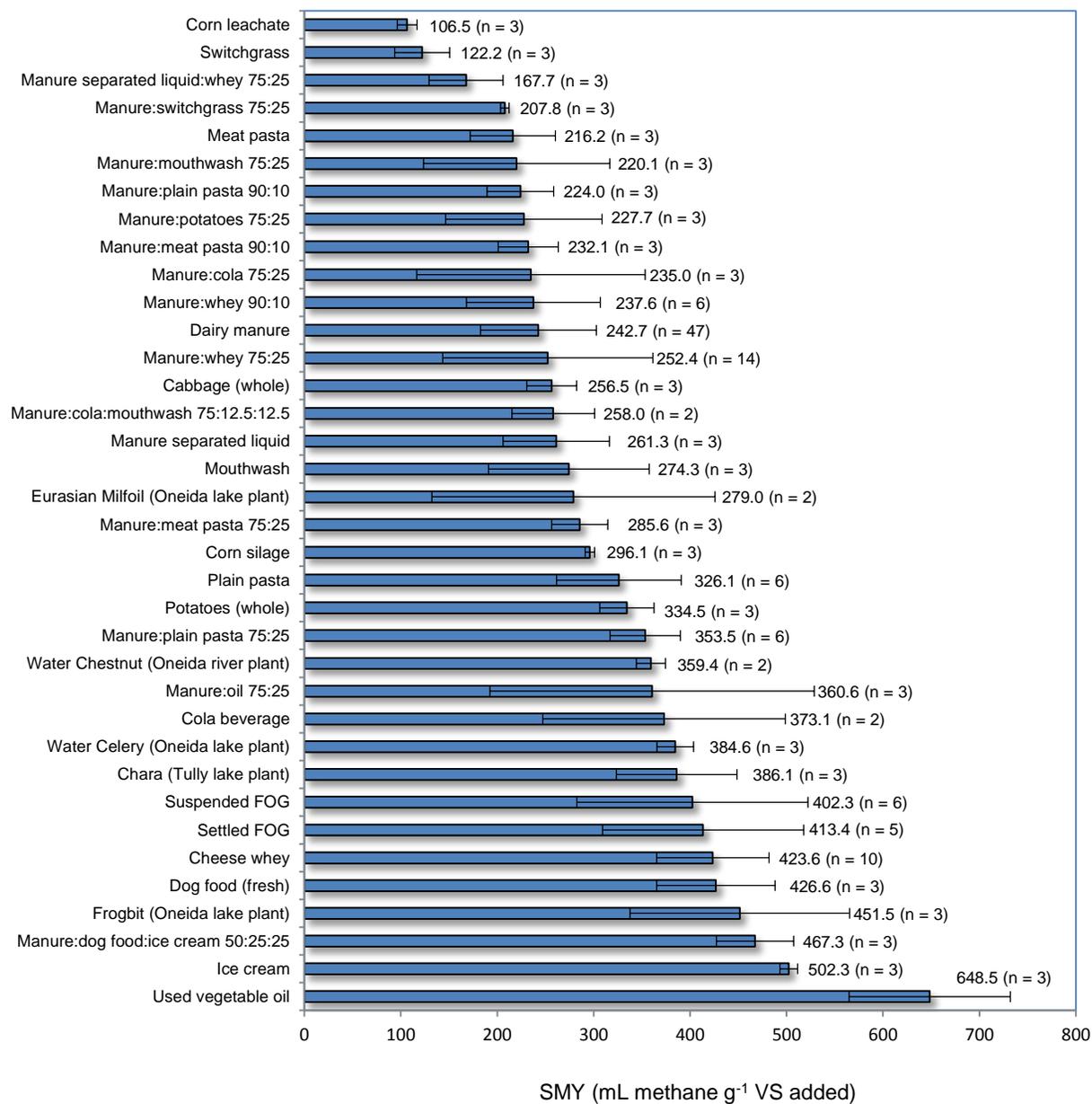


Figure 16. Varying strengths of co-digestion substrates (Labatut, R.A.)

Notes:

7.5.3. Land base requirements

Food waste contains nutrients (nitrogen, phosphorous and potassium) that must be considered when assessing the impact that importing food waste has on the farm's ability to comply with their Comprehensive Nutrient Management Plan (CNMP). Technologies originally developed for treating municipal wastewater are readily available for removing excessive phosphorous from manure (and a manure-food waste blend), but the economics of the implementation of such systems on-farm is not well established.

8. Additional Resources

Two documents are available that provide helpful advice on digester installation at this point in the process:

NRCS Conservation Practice Code 366: This practice applies to systems that intentionally produce and capture biogas and have digestible feedstock available. This document can be found at: http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_026149.pdf

Dairy Practices Guideline 106 "On-Farm Anaerobic Digesters – 100+ Questions to ask": From the Dairy Practices Council website, "This guideline raises a wide range of questions regarding what issues need to be addressed when considering an anaerobic digester system. No single source will have answers to all these questions. This is designed to be a helpful guide that will lead to a successful project completion." This document is available for purchase through this website: <http://www.dairypc.org/catalog/guidelines/waste-management/on-farm-anaerobic-digesters-100-questions-to-ask>

Notes:

References

Scott, Norman et al. Review of Curriculum Content and Programs for Anaerobic Digestion Education and Training. NYSERDA 9446.

Gooch, C.A., S.F. Inglis, and P.E. Wright. 2007. Biogas Distributed Generation Systems Evaluation and Technology Transfer Project – Interim Report. Prepared for: The New York State Energy Research and Development Authority. Albany, NY. April 15, 2007.

Notes:

Appendix 1. Glossary for New York State Manure-Based Anaerobic Digestion

Anaerobic bacteria

Microorganisms that live and reproduce in an environment containing no “free” or dissolved oxygen. Used for anaerobic digestion.

Anaerobic digester

A specifically designed vessel and associated heating and gas collection system to contain biomass under digestion and its associated microbially produced biogas. Particular conditions provided by the digester are oxygen-free, constant temperature, and sufficient biomass retention time.

Anaerobic digestion

A biological process in which microbes “digest” the organic material in manure while giving off biogas as a by-product.

Barn effluent

Material exiting a barn structure, generally consisting of animal excrement (urine and feces) and used bedding materials.

Biodegradable

Capable of being broken down. There are differing degrees of this capability (called biodegradability) which impact the anaerobic digestion process for different types of waste.

Biogas

For the purposes of this document, the raw and un-cleaned gas coming directly from the anaerobic digester, consisting of mainly methane (CH₄) and carbon dioxide (CO₂), 60% and 40%, respectively.

British Thermal Unit (Btu)

The English standard measure of heat energy. It takes one Btu to raise the temperature of one pound of water by one degree Fahrenheit at sea level. For example, it takes about 2,000

Notes:

Btu's to make a pot of coffee. One Btu is equivalent to 252 calories, 778 foot-pounds, 1055 joules and 0.293 watt-hours. 1TBtu is one trillion Btu's and 1 mmBtu is one million Btu's.

CAFO farm

Concentrated Animal Feeding Operation: a farm with a specified number of animals housed on-farm; in NYS a medium sized CAFO has 200-699 cows and a large CAFO has more than 699 cows.

Capacity factor

The ratio of the total measured energy generated, for the period of time considered, to the energy that could have been generated at continuous full-power operation during the same period. For anaerobic digester systems, this value is used as one way to quantify the engine-generator set performance.

Capital cost

The initial cost of field development and plant construction and the equipment required for the generation of electricity.

Centralized digester

An anaerobic digester which uses feedstock from several individual source farms within a relatively proximate distance to the digester location.

Co-firing

The use of two or more different fuels (e.g. wood and coal) simultaneously in the same combustion chamber of a power plant.

Combined Heat and Power (CHP) or Co-generation

The sequential or simultaneous generation of two different forms of useful energy – mechanical and thermal – from a single primary energy source in a single, integrated system. CHP systems usually consist of a prime mover, a generator, a heat recovery system, and electrical interconnections configured into an integrated whole.

Contact digester (fixed film)

High-rate complete mix or plug-flow digester which is operated in the thermophilic or mesophilic range to treat dilute and concentrated waste in a contact reactor.

Notes:

Electric utility

A company that is involved with the generation, transmission and distribution of electricity for sale; typically a public utility.

Emission

The release of a substance into the environment; generally refers to the release of gases or particulates into the air.

Engine-Generator Set

The combination of an internal combustion engine and generator for the production of electricity. May be single or dual fueled depending on the location and set up.

Flare

A device used to safely combust extra or surplus biogas.

Food waste

Uneaten food and food preparation wastes from residences and commercial establishments such as grocery stores, restaurants, and produce stands, institutional cafeterias and kitchens, and industrial sources, which can be added to an anaerobic digester to enhance biogas production capabilities (*adapted from EPA's definition of food waste*).

Generator

A device for converting mechanical energy to electrical energy.

Greenhouse Gas (ghg)

A gas, such as carbon dioxide or methane, which contributes to potential climate change.

Grid

The electric utility companies' transmission and distribution system that links power plants to customers through high power transmission line service; high voltage primary service for industrial applications; medium voltage primary service for commercial and industrial applications; and secondary service for commercial and residential customers. Grid can also refer to the layout of gas distribution system of a city or town.

Hydraulic retention time (HRT)

The length of time (in days) organic material remains in the anaerobic digester

Hydrogen sulfide (H₂S)**Notes:**

A colorless gas that has an offensive odor of rotten eggs, is soluble in water and alcohol, and can be a dangerous fire and explosion hazard under certain circumstances; it is also a strong irritant.

Influent

Liquid flow into a treatment, storage, or transfer device

Kilowatt-hour (kWh)

The most commonly used unit of measure expressing the amount of electrical energy consumed over time. It means one kilowatt of electricity supplied for one hour.

Leachate

Liquids that have percolated through a soil and that carry substances in solution or suspension.

Lost capital

The portion of a capital investment that cannot be recovered after the investment is made usually used to express the immediate lost in value of a purchased or constructed item.

Manure

Urine and feces excreted by livestock.

Methane (CH₄)

A flammable, explosive, colorless, odorless, tasteless gas that is slightly soluble in water and soluble in alcohol. Methane is the major constituent in natural gas, and is used as a source of petrochemicals and as a fuel.

Methanogens

Bacteria responsible for converting acetic acid, hydrogen and carbon dioxide into methane (CH₄).

Microturbine

A small combustion turbine with a power output ranging from 25- to 500-kW. Microturbines are composed of a compressor, combustor, turbine, alternator, recuperator, and generator.

Mixed digester

Notes:

An anaerobic digester vessel that contains one or several mixing units used intermittently or continuously to agitate AD contents.

Net generation

Gross generation minus the parasitic energy consumed at the generating station for its use.

Net metering

A billing practice used by utilities for certain customers who generate electricity. “Net” refers to the difference between the electricity used from the grid by the customer-generator and the electricity sent to the grid by that customer-generator.

Plug-flow digester

A design for an anaerobic digester where the material enters at one end and is theoretically pushed in plugs towards the other end, where the material exits the digester after being digested over the design HRT.

Renewable resources

Naturally replenishable, but flow-limited energy resources. They are virtually inexhaustible in duration but limited in the amount of energy that is available per unit of time. Some resources may be stock-limited in that stocks are depleted by use, but on a time scale of decades, or perhaps centuries, they can probably be replenished. Renewable energy resources include: biomass, hydro, geothermal, solar and wind. In the future they could also include the use of ocean thermal, wave and tidal action technologies. Utility renewable resource applications include bulk electricity generation, on-site electricity generation, distributed electricity generation, non-grid connected generation, and demand-reduction (energy efficiency) technologies.

Scrubbed (gas)

Gas can be scrubbed to remove certain impurities, such as hydrogen sulfide, to improve the performance of an energy-generating unit. There are several technologies available to scrub biogas.

Self-generation

A generation facility dedicated to serving a particular retail customer, usually located on the customer’s premises. The facility may either be owned directly by the retail customer or owned by a third party with a contractual arrangement to provide electricity to meet some or all of the customer’s load.

Notes:

Service charge

Each metered service has a basic service charge that utilities bill for that service. This charge is above and beyond the energy and delivery charges that are a function of use at that site.

Tipping fees

Monies that are paid to the site with an anaerobic digester that is accepting outside sources of organic material (food waste).

Ton

US short ton equals 2,000 lbs

Tonne

Metric ton equals 1,000 kg

Total dissolved solids (TDS)

The total amount in milligrams of solid material dissolved in one liter of water (mg/l).

Treatment volume

Inside volume of the AD that, under normal operating conditions would be full of material undergoing anaerobic decomposition.

Turbine

A device for converting the flow of a fluid (air, steam, water, or hot gases) into mechanical motion.

Volatile solids

Dry solids that are lost on ignition of the dry solids at 550 degrees centigrade.

Volt

A unit of electrical pressure. It measures the force or push of electricity. Volts represent pressure, correspondent to the pressure of water in a pipe. A volt is the unit of electromotive force or electric pressure analogous to water pressure in pounds per square inch. It is the electromotive force which, if steadily applied to a circuit having a resistance of one ohm, will produce a current of one ampere.

Notes:

Watt

A standard unit of measure for the rate at which power is consumed by equipment or the rate at which energy moves from one location to another. It is also the standard unit of measure for electrical power.

Watt-hour

A standard unit of measure for the amount of energy that is consumed by equipment, the amount of embodied energy or the amount of energy moved from one location to another. It is also the standard unit of measure for electrical use. Generally expressed in 1,000 Watt-hr increments or kWh.

Notes:

Appendix 2. PSC Role for Distributed Energy Generation Systems

Step 1: The applicant initiates communication with the appropriate utility company.

Step 2: The utility company performs an initial review of the project, and a representative is assigned to the project to be the point contact person.

Step 3: The application for interconnection is submitted by the applicant; this application must include a completed standard application form.

- Each utility must provide a web-based system for applicants to see the status and progress of the SIR application.

Step 4: The utility company performs a review of the application and develops a cost estimate for the “Coordinated Electric System Interconnection Review (CESIR)”.

- The utility will inform the applicant whether they believe the project to be feasible.
- The utility will provide the applicant with an estimate of costs to complete the CESIR.
- This review and the estimates should be provided to the applicant within 15 days.

Step 5: The applicant approves and commits to the CESIR.

Step 6: The utility company performs the CESIR to determine whether the generation project will disrupt the grid in any way or present any safety concerns for other customers on the line.

- A full CESIR may not be necessary if the generation is less than 150-kW on a single distribution feeder line. The CESIR must be completed within 60 business days of the information being provided by the applicant in Step 5.
- After the CESIR is completed, the utility will inform the applicant of any issues the project presents for interconnection to the grid and whether the system meets all regulation criteria.

Notes:

- In terms of the cost estimates for utility upgrades associated with the project:
 - 1) If the applicant will be net metered, the applicant does not have the responsibility to pay costs associated with any required modifications to the utility system, administration, metering, and on-site verification testing, and the utility must provide a statement showing the applicant's cost to install any dedicated transformer(s) and other safety equipment.
 - 2) If the utility determines a dedicated transformer(s) or other safety equipment must be installed, a farm waste customer-generator up to 500-kW capacity has a maximum equipment responsibility of \$5,000.

Step 7: The applicant commits to construction of the utility's system modifications.

Step 8: Project construction

- The generation facility will be constructed following the design plan being accepted by the utility company.
- The utility company will install at this time any equipment on-site that is determined in Step 6 to be needed for net metering of the system.

Step 9: The applicant's facility is tested in accordance with the Standardized Interconnection Requirements.

- This testing step will occur 10 business days within the commissioning of the project.

Step 10: Interconnection

- The applicant may begin operations.

Step 11: Utility cost reconciliation

Notes: