Final Technical Report

Project Title: University of Wisconsin Oshkosh Anaerobic Dry Digestion Facility

Award Number: DE-EE0003135

Recipient: University of Wisconsin Oshkosh

Project Location(s): Oshkosh, Wisconsin

Project Period: September 1, 2011 to September 30, 2012
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Subcontractors: BioFerm Energy Systems

Cost-Sharing Partners: University of Wisconsin Oshkosh Foundation

Draft Document for Technical Close out Review

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Executive Summary

3. **Provide an executive summary, which includes a discussion of 1) how the research adds to the understanding of the area investigated; 2) the technical effectiveness and economic feasibility of the methods or techniques investigated or demonstrated; or 3) how the project is otherwise of benefit to the public. The discussion should be a minimum of one paragraph and written in terms understandable by an educated layman.**

The University of Wisconsin Oshkosh Anaerobic Dry Digestion Facility is a demonstration project that supported the first commercial-scale use in the United States of high solids, static pile technology for anaerobic digestion of organic waste to generate biogas for use in generating electricity and heat. The research adds to the understanding of startup, operation and supply chain issues for anaerobic digester technology. Issues and performance were documented for equipment installation and modifications, feedstock availability and quality, weekly loading and unloading of digestion chambers, chemical composition of biogas produced, and energy production. This facility also demonstrated an urban industrial ecology approach to siting such facilities near sewage treatment plants (to capture and use excess biogas generated by the plants) and organic yard waste collection sites (a source of feedstock).

4. Provide a comparison of the actual accomplishments with the goals and objectives of the project. Where applicable, address any comparisons of actual results to programmatic technical barriers and milestones.

Preliminary studies were conducted to provide information relevant to equipment selection for this demonstration project on the first commercial-scale dry (high solids) anaerobic fermentation facility in the United States. These studies included preliminary facility designs and testing of potential feedstock.

The University of Wisconsin Oshkosh contracted BioFerm Energy Systems of Madison, WI to make preliminary designs and equipment specifications for a dry anaerobic fermentation facility in Oshkosh WI. The facility features included: processing high solids organic matter without generating wastewater; indoor feedstock storage and odor management; producing biogas suitable for use in a combined heat and power generator exporting power to the electrical grid serviced by the local utility, Wisconsin Public Service. The project and designs were continually reviewed by University of Wisconsin Oshkosh staff. This included the Director of Facilities, Director of Sustainability, and Vice Chancellor of Administrative Services. The site where the digester was constructed is approximately 2 acres of land zoned for light industry, with adjacencies to a municipal wastewater treatment plant that serves a city with a population of 65,000, a city yard waste collection site, and a university facilities management shop building. These adjacencies present opportunities for energy generation from biogas that was being flared by the treatment plant, for feedstock from yard waste, and for a customer for heat in the university building.

The design was also reviewed by staff from the City of Oshkosh and the State of Wisconsin to determine required permits and to gather their input for public safety, vehicle traffic impacts, environmental protection, and aesthetic recommendations. Public meetings were conducted by the City of Oshkosh Planning Department, Sustainability Board, and Common Council for permit approvals. Environmental permits for air emissions, water protection, and a biosolids management plan were acquired from the Wisconsin Department of Natural Resources. The final design was approved by the University of Wisconsin Vice Chancellor for Administrative Services and the University of Wisconsin Oshkosh Foundation Board of Directors. Public outreach efforts included presentations to:

- NEW North (regional economic development agency)
- Wisconsin Green Building Alliance
- Wisconsin Bio Industry Alliance
- Oshkosh Rotary Club
- Regional Chamber of Commerce (Oshkosh, Fox Cities, Green Bay)
- Fox Cities Food Waste Task Force
- BioForward BioTechnology Conference
- State Sustainable Communities Roundtable
- State Conference for Student Facility Directors
- University of Wisconsin Oshkosh Renewable Energy Institute
- University of Wisconsin Oshkosh Learning in Retirement

- University of Madison Engineering Professional Development course on Net Zero Energy
- National Association of College and University Business Officers
- Association for the Advancement of Sustainability in Higher Education
- Upper Midwest Association for Campus Sustainability
- BioCycle Conference
- Sustainable Packaging Forum

Feedstocks were identified from local sources and tested for biogas production potential and physical-chemical characteristics. Testing was conducted at the University of Wisconsin Oshkosh Environmental Research and Innovation Center. Test results are summarized below under Project Activities.

Grant-funded equipment purchases included the equipment outlined in the project objectives in the grant proposal submitted to US DOE have been met.

Project Activities

Summarize project activities for the entire period of funding, including original hypotheses, approaches used, problems encountered and departure from planned methodology, and an assessment of their impact on the project results. Include, if applicable, facts, figures, analyses, and assumptions used during the life of the project to support the conclusions.

1. Feedstock

Tests were conducted by the University of Wisconsin Oshkosh Environmental Research and Innovation Center. Feedstocks were obtained from potential sources, including:

- Food Waste from supermarket produce; the main supplier is a waste hauler, Sanimax that holds contracts with large supermarket chains to pick up unpackaged produce and baked goods.
- Bedding waste from cattle; there are two regular sources, one a small dairy (bedding consists of corn stover, soybean litter, dried manure) and the other a large dairy, a confined feeding operation (which provides fiber mechanically separated from sand bedding)
- Yard waste – Brown: the main supplier is the City of Oshkosh, with a minor contribution from the UW Oshkosh campus (chipped wood and leaves)
- Yard waste – Green: the main supplier is the City of Oshkosh (grass clippings)

Limited testing was also conducted on structural materials that were added to the feedstock to increase solids content and maintain a solid pile during the 28-day fermentation process. These included wood chips, hay, and paper fiber waste. The digestate resulting from the fermentation process was also tested as it is mixed with fresh material, to serve as an inoculant and to help establish fermentation conditions quickly.

Feedstocks were tested for:

- Bulk Characteristics (Total Solids, organic dry matter, pH)
- Biochemical composition (Total Volatile Fatty Acids)
- Elemental Composition (nitrate, ammonium, total nitrogen, organic carbon, phosphorous, potassium, iron)
- Metals
- Reactivity (Chemical Oxygen Demand, Biological Oxygen Demand, fermentation batch test for biogas production)

The key operational values for deriving a feedstock mix for the high-solids (dry) anaerobic digester are total solids (% of fresh material), volatile solids (% of total solids), and biogas yield (cubic feet per ton fresh material). Table 1 lists test results for the main feedstocks available locally. Test results and average values are used by the biodigester operators to plan the feedstock mix and estimate gas production in batch reports for each fermenter.

Table 1. Test results from feedstocks used at the UW Oshkosh Biodigester. "Digestate Recycled" is material from a previous fermentation batch mixed that will be mixed approximately 1:1 with fresh material.

Feedstock	**Total Solids (% of Fresh Material)**			**Volatile Solids (% of Total Solids)**			**Biogas Yield Factor (ft^3/ton)**
	Mean (SD)	*Range*	*n*	*Mean (SD)*	*Range*	*n*	
Food Waste	15.4 (3.9)	9.0-25.5	27	92.7 (2.1)	88.1-96.3	24	3103
Yard Waste - Brown	55.9 (13.1)	38.1-73.8	10	84.1 (4.5)	74.1-88.8	9	1200
Yard Waste - Green	35.6 (8.4)	22.0-49.2	9	88.5 (4.1)	81.8-94.4	10	2473
Dairy Bedding	39.1 (14.5)	20.2-81.1	33	75.3 (11.4)	51.2-92.2	31	3607
Pressed Fiber	26.4 (2.4)	23.7-30.3	6	66.0 (11.9)	46.7-78.2	6	2807
Hay	75.6 (13.5)	55.0-88.1	6	89.5 (2.9)	85.6-92.2	4	1513
Digestate Recycled	24.5 (5.0)	14.4-36.1	27	59.6 (10.9)	41.2-82.5	24	532

2. Operations

Project review meetings have monitored installation of all purchased equipment. The system designer, BioFerm Energy Systems remains a partner and helps insure that the installed equipment is functioning as designed. The final planned modification of the system was completed in August 2012 with the connection of a pipeline to deliver excess biogas from a neighboring wastewater treatment plant. The combined heat and power system was changed to remove siloxanes and other gas impurities. Additionally, the engine operational programming schedules were adjusted to allow storage and utilization of the additional biogas.

Project Reviews have also refined a reporting system for operations and performance. Some of the key pieces of equipment, the generator and gas storage, is under constant data surveillance by automated software, alarm systems, and operator manual checks. Each batch of the fermentation process requires Batch Reports for each of the four fermenters in order to track organic loadings and biogas formation. With 4 fermenter chambers and a 28-day process, one chamber is loaded/unloaded per week. Batch reports are started with each 28-day run,

recording feedstock source, type, and weight; results from lab testing of feedstock; physical condition and volume of feedstock loaded. At the end of the batch run, data is added for the amount and quality of biogas produced, amount and quality of digestate produced, and physical condition of the digestion chamber and other equipment. From these reports, operators can compare predicted to actual biogas production and track the maintenance of equipment.

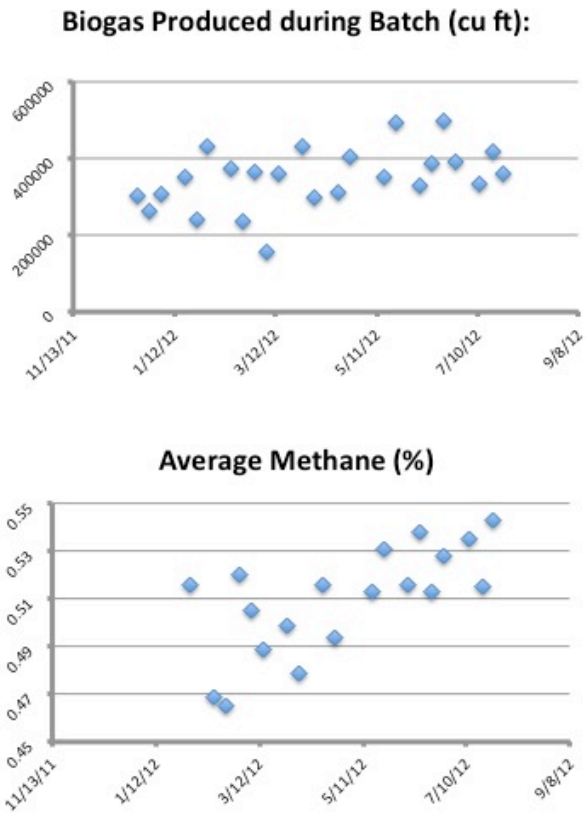

Figure 1 shows the improvement in biogas production capacity and methane content during the startup phase of biodigester operations.

Electricity production also increased with biogas production over the same period, and doubled in September after the gas line to the wastewater treatment plant was completed (Figure 2 below). Biogas from the wastewater treatment plant will be seasonal, and this September 2012 production shows the summer peak expected in future years.

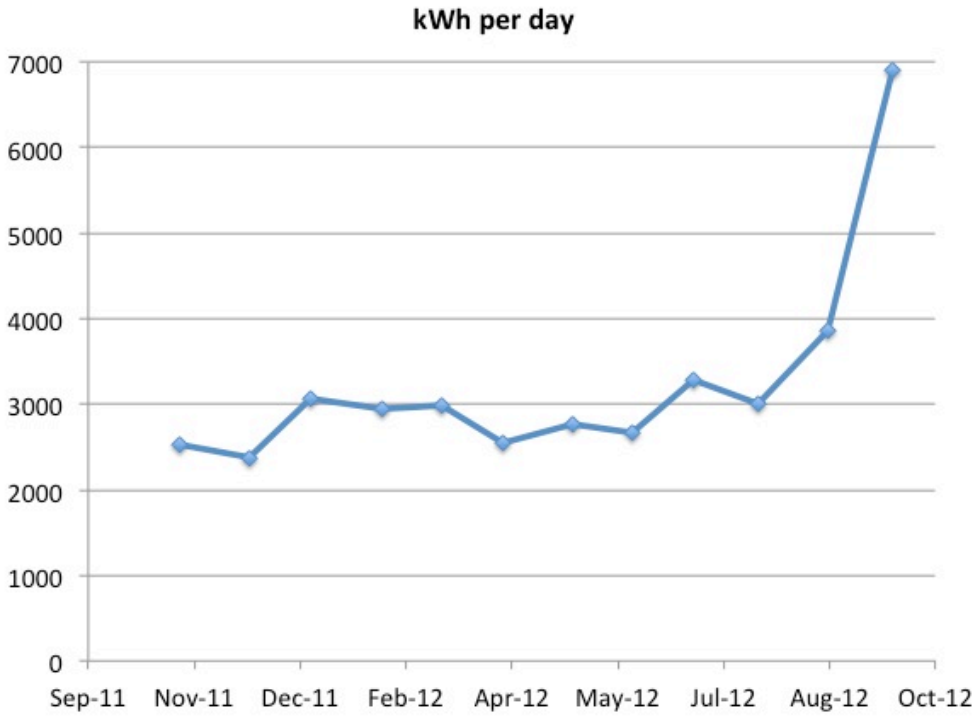

Figure 2. kWh produced per day during initial start-up period.

Heat is currently used in the plant, but there is excess capacity for future development to neighboring buildings. The combined heat and power system was instrumental in solving one unforeseen operational problem: indoor fog formation after fermenter opening in winter. A small amount of the excess thermal capacity was tapped for additional heating in the enclosed mixing parlor of the facility, which has addressed this safety problem for front-end loader operations in winter.

Products Developed Under the Award

a. Publications (list journal name, volume, issue), conference papers, or other public releases of results. If not provided previously, attach or send copies of any public releases to the DOE Project Officer identified in Block 11 of the Notice of Financial Assistance Award;

Lizotte, M., T. Sonnleitner. 2011. Community Partnerships for a University-based Renewable Energy Biodigester. **Smart and Sustainable Campuses Conference**, April 3-5, College Park, MD. Presentation to higher education leaders on project initiation, design and financing.

Lizotte, M. 2011. Biofuels and Renewable Energy from Biodigesters. **Zero Net Energy Approaches for Building Systems**, May 20, Madison WI. Presentation to professional managers and engineers in a professional development course.

Lizotte, M. 2011. Community Partnerships for a University-based Renewable Energy Biodigester. **Upper Midwest Association for Campus Sustainability**, September 23-24, Morris, MN. Presentation to campus sustainability leaders on project integration with campus and community, including feedstock procurement.

Lizotte, M. 2011. Community Partnerships for a University-based Renewable Energy Biodigester. **Association for the Advancement of Sustainability in Higher Education Conference**, October 9-12, Pittsburgh PA. Presentation to campus sustainability leaders on project integration with campus and community, including feedstock procurement.

University of Wisconsin Oshkosh. 2011. Featured tour for **BioCycle Conference on Renewable Energy From Organics Recycling** – October 31-November 1-2, 2011 in Madison, Wisconsin. Provided tours of the facility, operations, and community partnerships to 45 participants.

Lizotte, M. 2012 Future of Recycling and the Opportunity of Anaerobic Digestion. **Sustainable Packaging Forum**, September 10-11, Pittsburgh, PA. Presentation focused on research on food waste collections from food courts for feedstock, based on use of new bioplastics that degrade in anaerobic digesters.

Lizotte, M. and J. Baldus. 2012 Energy Recovery from Packaging and Food Waste Using Anaerobic Fermentation. **Sustainability in Packaging Conference**, March 13-15, Orlando FL. Invited presentation focused on research on food waste collections from food courts for feedstock, based on use of new bioplastics that degrade in anaerobic digesters.

b. Web site or other Internet sites that reflect the results of this project.

University of Wisconsin Oshkosh Biodigester: http://www.uwosh.edu/biodigester

2010 Wisconsin Energy Statistics Book, page 141:
(http://energyindependence.wi.gov/docview.asp?docid=20157&locid=160)

BioFerm Energy Systems website:
(http://www.biofermenergy.com/?page_id=120346&preview=true)

c. Networks or collaborations fostered.

BioFerm Energy Systems: has worked with UW Oshkosh on two more digester projects. One is a small-scale system for a family dairy (ca. 150 cattle) and the other is for the state's largest dairy (ca. 9,000 cattle). The parent corporation, Viessmann, recently announced a major donation for an Endowed Chair at UW Oshkosh, which will be used to hire a new professor of engineering.

Wisconsin State Energy Office: has funded research project to test anaerobic digestion of experimental bioplastics. Has also funded a small-scale biodigester installation on a family dairy farm, a collaboration between UW Oshkosh, BioFerm, and Allen Farm.

Bioplastics manufacturers (BASF, Natureworks, Tellus) have provided in-kind donations for research.

Milksource: Manages the largest dairy heard in Wisconsin, and has entered into a partnership with UW Oshkosh and BioFerm to install a wet digestion biogas facility with some advanced technology for fiber capture and recycling.

Met with University of California Davis, City of San Jose, and others in California to discuss future collaboration in anaerobic digester technology development and demonstration.