

# A Review of Available Resources on Anaerobic Digestion Technologies

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## Abstract

Anaerobic digestion of manures provides multiple environmental benefits for animal feeding operations including odor reduction, green house gas emission reduction, and production of a renewable energy source. This paper provides an overview of information sources available in the United States regarding anaerobic digestion of manures. Selection and implementation of an optimal anaerobic digestion system for a given farm requires significant research regarding digester type, biogas production potential, biogas collection and handling, construction cost estimates, and operation and maintenance cost estimates. Practical information concerning anaerobic digestion is dispersed through a number of sources in the U. S. Information sources in this review include items from the federal and state government agencies, land grant universities, and non-profit organizations. The reviewed items provide information related to methane recovery technologies on U.S. concentrated animal feeding operations, economics of biogas production for on-farm heating, case studies of U.S. animal manure digesters, and various other anaerobic digestion resources. A concise review of available US information sources regarding the anaerobic digestion of animal manures is provided to assist in the decision making process concerning selection and implementation of manure anaerobic digesters.

**Keywords:** anaerobic digestion, methane, review, resources

## Introduction

There are approximately 114 manure anaerobic digesters operational in the U.S. (AgSTAR 2008). Although more complex systems are available, most on-farm units in the U.S. use plug-flow, complete-mixed, or covered lagoon digesters (Ileleji et al.). Plug flow digesters are the most frequently used manure digester type in the United States. Plug-flow digesters are primarily used with scraped dairy manure. Approximately 28 percent of all manure digesters in the U.S. are complete-mixed digesters. Complete-mixed digesters are typically more expensive than many other manure digester types, but they work well for operations across a wide range of solids content. Covered lagoons are a lower cost digestion option that are better suited to the warmer regions of the U.S. Approximately 18 percent of all digesters in the U.S. are of this system type. Information on manure digesters is available from a number of internet and printed publications, programs and courses, and software programs. This paper provides detailed summaries for several useful U.S. resources as well as a more complete list of other available U.S. resources.

## Programs

AgSTAR The U.S. EPA AgSTAR program is designed to provide information and resources to aid in the establishment of farm manure digester systems. AgSTAR has developed an informative and interactive resource that has proven to be beneficial in the process of

implementing anaerobic digestion systems on individual facilities (AgSTAR, 2008). One of the tools is the AgSTAR handbook, which provides information used to determine digester options for different facility types. The handbook discusses facility size and location as well as securing contracts, obtaining funding, and locating project consultants. AgSTAR provides an industry directory, a newsletter “The AgSTAR Digest”, and the software program “FarmWare”.

AgSTAR developed an interactive software program, FarmWare, to help estimate project expenses and projected cost savings of an anaerobic digestion system on an individual site. This software program allows the user to include specific information about an individual facility and provides a form to determine digester type and feasibility. This program can be used as a first step in determining if anaerobic digestion is a viable option.

### **Publications**

Natural Resources Conservation Service Practice Standards The Natural Resources Conservation Service (NRCS) Practice Standards for anaerobic digesters offer publications on ambient temperature digesters, controlled temperature digesters, waste facility covers, and waste storage facilities (NRCS, 2003). The NRCS standards provide a guide for individual states to form state specific standards. They should not be used for specific planning and installation of an anaerobic digester due to the generic content, but they are a useful guide to move general planning and implementation in the correct direction. The standards provide the definition, purpose, conditions, criteria, consideration, plans and specifications, and operation and maintenance information for each of the given sections.

Technical Note No. 1-An Analysis of Energy Production Costs from Anaerobic Digestion Systems on U.S. Livestock Production Facilities This NRCS technical note (USDA-NRCS, 2007) provides useful information on manure digestion systems. The analysis shows that it may be more cost effective to omit electricity generating equipment in the system and instead use the biogas on the farm as a natural gas replacement. This provides a decrease in capitol costs in comparison to the electricity generation systems. Lower capitol costs coupled with increasing natural gas prices in the U.S. provides considerable savings in the areas of equipment, installation, maintenance, and heating for animal housing on the farm (USDA-NRCS, 2007). Additional publications are provided in the summary table.

### **Web sites**

Iowa State University - Anaerobic Digestion The Anaerobic Digestion Web site, available through Agricultural and Biosystems Engineering at Iowa State University, provides a clearinghouse of information on anaerobic digestion including a publication list, current AD news items and events, and a list of links to other useful web sites.

Penn State - Biogas and Anaerobic Digestion The Biogas and Anaerobic Digestion Web site, available through Agricultural and Biosystems Engineering at Pennsylvania State University, provides basic information on anaerobic digestion options for design, installation, and costs. It also provides documents on research results and digester effectiveness. A study on centralized (community) digesters is also presented as an option for farmers who are unable to construct one on their site due to expense, location requirements, or low animal numbers.

Cornell University - Pro-Dairy Manure Management Program The Pro-Dairy Manure Management Program at Cornell University is a leader in anaerobic digestion research efforts in the northeastern U.S., especially for dairy facilities. This site provides several papers and research reports on anaerobic digesters including research results on co-digestion of manures and food waste to increase biogas production. This site provides resources from Cornell University, and acts as a clearing house of web sites, projects, and publications from other universities and programs. Additional Web site resources are provided in the summary table.

### **Case Studies**

Agricultural Biogas Case Book-Updated 2008 This is a recent publication containing 17 case studies for dairy farms in Wisconsin; 22 anaerobic digesters are included. The dairy facility size ranges from 800-4,000 animals. This book provides detailed information on five types of digester systems used for manure collection and gas production. The majority of the case study sites used the generated biogas for heat and electricity. Herd size, biogas production rate, digester type, system designer, and digester additives are all provided in the analysis.

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## Summary Table

Web site	Web Address	Description
AgSTAR Program <i>US Environmental Protection Agency</i>	<a href="http://www.epa.gov/agstar">http://www.epa.gov/agstar</a>	Includes multiple resources for those considering installation of an anaerobic digester including publications, consultant contacts, grant options, and the software program FarmWare.
Agricultural Waste Management- Anaerobic Digestion <i>Iowa State University</i>	<a href="http://www.abe.iastate.edu/wastemgmt/anaerobic-treatment.html">http://www.abe.iastate.edu/wastemgmt/anaerobic-treatment.html</a>	Acts as a clearing house of anaerobic digestion resources. This web page links to all resources listed in this paper as well as many others.
Wisconsin Focus on Energy	<a href="http://www.focusonenergy.com/renewable/biogas">http://www.focusonenergy.com/renewable/biogas</a>	Provides a section devoted to biogas digester system information and includes energy efficiency information as well as site assessment and maintenance information. A case study book is also available through this site.
Biogas and AD Web site <i>Pennsylvania State University</i>	<a href="http://www.biogas.psu.edu/">http://www.biogas.psu.edu/</a>	Provides basic digester information as well as case studies, reports and common misconception information.
Iowa Manure Management Action Group <i>Iowa State University Extension</i>	<a href="http://www.agronext.iastate.edu/immag/">http://www.agronext.iastate.edu/immag/</a>	Provides a list of publications, current AD news items and events, and a list of links to other useful University web sites.
ProDairy <i>Cornell University</i>	<a href="http://www.ansci.cornell.edu/prodairy/">http://www.ansci.cornell.edu/prodairy/</a>	ProDairy has done extensive work in the area of AD for Dairy cattle operations. This site provides several papers, reports, newsletters and case studies about AD.
Waste2Profits.com <i>Environomics LLC</i>	<a href="http://www.waste2profits.com/SelectDisgner.htm">http://www.waste2profits.com/SelectDisgner.htm</a>	Provides a helpful questionnaire to determine if a digester is a good option for individual operations and digester suggestions for different types of operations.
Publication	Availability	Description
An Evaluation of a Mesophilic, Modified Plug Flow Anaerobic Digester for Dairy Cattle Manure <i>John Martin, 2005</i>	AgSTAR Program Web site <a href="http://www.epa.gov/agstar/resources.html">www.epa.gov/agstar/resources.html</a>	A report on a 12 month study in Wisconsin on a plug-flow anaerobic digester system for dairy manure. It includes an analysis of digester performance in a colder climate as well as the performance of a screw press separator for the system.
Managing Manure with Biogas Recovery Systems: Improved Performance at Competitive Costs <i>The AgSTAR Program</i>	AgSTAR Program Web site <a href="http://www.epa.gov/agstar/resources.html">http://www.epa.gov/agstar/resources.html</a>	Contains a basic description of anaerobic digestion opportunities for commercial use as well as basic digester type recommendations and requirements.
NRCS Anaerobic Digestion Practice Standards <i>USDA/NRCS</i>	NRCS Web site <a href="http://www.nrcs.usda.gov/technical/standards/nhcp.html">http://www.nrcs.usda.gov/technical/standards/nhcp.html</a>	Description of practice standards developed by the Natural Resources and Conservation Service used as a guide to develop standards for individual regions of the United States.
NRCS Tech. Note No. 1 An Analysis of Energy Production Costs from Anaerobic Digestion <i>USDA-NRCS., 2007</i>	Iowa State University –Agricultural Waste Management Web site <a href="http://www.abe.iastate.edu/wastemgmt/publications.html">http://www.abe.iastate.edu/wastemgmt/publications.html</a>	Evaluates the cost of an AD system that uses biogas for on farm heating purposes and not for energy production or sales. This saves in initial capital and maintenance costs as well as in heating of the facility.

A Comparison of Dairy Cattle Manure Management with and without Anaerobic Digestion and Biogas Utilization <i>Eastern Research Group, Inc.</i>	AgSTAR Program Web site <a href="http://www.epa.gov/agstar/resources.html">http://www.epa.gov/agstar/resources.html</a>	This study found that AD of dairy manure not only had significant environmental and odor reduction benefits but also economic benefits in the form of energy production.
Anaerobic Digestion in the United States <i>Curt A Cooch, P.E.</i>	Pro-Dairy Program at Cornell University <a href="http://www.manuremanagement.cornell.edu/HTMLs/AnaerobicDigestion.htm">http://www.manuremanagement.cornell.edu/HTMLs/AnaerobicDigestion.htm</a>	Gives a description of different types of digesters used in the United States as well as some considerations before implementing AD in a nutrient management plan.
An Evaluation of a Covered Anaerobic Lagoon for Flushed Dairy Cattle Manure Stabilization and Biogas Production <i>Eastern Research Group, Inc. 2008</i>	AgSTAR Program Web site <a href="http://www.epa.gov/agstar/resources.html">http://www.epa.gov/agstar/resources.html</a>	Evaluates the performance of an unheated, covered lagoon digester in a subtropical region in California for biogas production, cost, and energy recovery from a flushed dairy cattle manure system.
Field Experience with Two Iowa Dairy Farm Plug-Flow Digesters <i>Daniel Meyer and Jeff Lorimor</i>	Iowa State University Agronomy Extension <a href="http://www.agronext.iastate.edu/immag/info/iadairyfarm.pdf">http://www.agronext.iastate.edu/immag/info/iadairyfarm.pdf</a>	Details the experiences of the development of two separate AD systems located in Iowa. A breakdown of cost and adjustments made during the examination are included for both systems.
Anaerobic Biotechnology for Industrial Wastewaters <i>R.E. Speece</i>	Out of print	A textbook in which the basics of the anaerobic process, AD requirements, and soluble substrates are discussed in detail. Great as a course book and as a reference tool for consultants.
<b>Case Studies</b>	<b>Availability</b>	<b>Description</b>
Haubenschild Dairy Farm Digester <i>The Minnesota Project</i>	The Minnesota Project Web site <a href="http://www.mnproject.org/e-haubenschildfarm">www.mnproject.org/e-haubenschildfarm</a>	Haubenschild Farms is a dairy operation that installed a plug flow anaerobic digester on their facility in 1999. The web site provides a full research report as well as fact sheets and cost analysis.
Swine USA Final Report <i>Lorimor et al., 2004</i>	ISU Agronomy Extension Web site <a href="http://www.agronext.iastate.edu/soilfertility/info/swineusa04.pdf">http://www.agronext.iastate.edu/soilfertility/info/swineusa04.pdf</a>	Swine USA is a 5000 sow gestation-farrowing operation in Iowa using a complete mix digester. This 90-day study determined the nutrient requirements, gas production, and chemical results from this digester under Iowa conditions.
Dairy Methane Digester System 90-Day Evaluation Report-Hilarides Dairy <i>Western United Resource Development, Inc.</i>	The California Energy Commission <a href="http://www.energy.ca.gov/publications/search/Reports.php">http://www.energy.ca.gov/publications/search/Reports.php</a>	Hilarides Dairy owns and operates a covered lagoon anaerobic digester on their 9,900 cow facility in the Central Valley of California. Cost analysis, system performance, and energy production and usage are included in this report.
Agricultural Biogas Case Book-Updated 2008 <i>Public Service Commission of Wisconsin</i>	Focus on Energy Web site <a href="http://www.focusonenergy.com/Information-Center/Renewables/Fact-Sheets-Case-Studies/Biogas.aspx">http://www.focusonenergy.com/Information-Center/Renewables/Fact-Sheets-Case-Studies/Biogas.aspx</a>	This is a recent case study book on all 17 dairy farms with anaerobic digesters across the state of Wisconsin. Operation size ranging from 800-4,000 head, manure collection, and bedding type are all considered in this evaluation.
Methane Recovery from Animal Manures-The Current Opportunities Casebook <i>P. Lusk, 1998</i>	National Renewable Energy Laboratory <a href="http://www.nrel.gov/docs/fy99osti/25145.pdf">http://www.nrel.gov/docs/fy99osti/25145.pdf</a>	Although slightly outdated, this book does examine opportunities for methane recovery as well as financial obligations and benefits, and several case study examples.

