Final Report

Oberlin College Energy Transmission and Infrastructure Northern Ohio, Department of Energy, National Energy Technology Laboratory Grant

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SOLUTIONS IN SUSTAINABILITY, LLC

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DEFINITIONS

Anaerobic digestion (AD): The degradation of organic matter through the natural action of microorganisms in the absence of elemental oxygen.

Biogas: The gas produced from the decomposition of organic matter under anaerobic conditions and consisting of a mix of methane, carbon dioxide, and traces of other gases.

British thermal unit (BTU): The amount of heat required to raise the temperature of one pound of water one degree Fahrenheit. One cubic foot of biogas typically contains about 600 to 800 BTUs of heat energy. By comparison, one cubic foot of natural gas contains about 1,000 BTUs.

Combined heat and power (CHP): 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.

Complete mix digester: A constant volume, mechanically mixed vessel designed to achieve biological treatment and methane production as part of a manure management facility with methane recovery.

Digestate: The solid material residual following the anaerobic digestion of a feedstock.

Genset: An engine-generator specifically adapted to burn biogas to produce electricity.

Methane: A combustible gas with the chemical formula CH_4 that can be derived from fossil or renewable processes. The Fourth Assessment Report from the Intergovernmental Panel on Climate Change (IPCC) has determined that the heat trapping potential of methane in the Atmosphere is 25 times greater than CO_2 over 100 years (IPCC, 2007).

Natural gas: A combustible mixture of methane, other hydrocarbons and traces of other gases used chiefly as a fuel, usually extracted from sedimentary deposits as a fossil fuel. The typical energy content of natural gas is 1,000 Btus per cubic foot.

Plug-flow digester: A constant volume, flow-through biological treatment unit designed to achieve biological treatment and methane production as part of a manure management facility with methane recovery.

EXECUTIVE SUMMARY

Oberlin College's "Energy Transmission and Infrastructure Northern Ohio" project, funded by the Department of Energy, seeks to identify opportunities for northern Ohio to play a leadership role nationally in the development of an efficient, sustainable, post-fossil fuel energy economy. It provides a context for identifying ways in which communities in Northern Ohio can transition to sustainable energy sources. A review and assessment of the biogas potential from anaerobic digestion of animal waste, crop residue and food processing waste with conversion to electrical, heat, or conditioned for pipeline injection determined that the 9th Congressional District has resources that could be developed. The study identified policy, regulatory, and financial barriers that impede development of farm-based, biogas generation systems that could be part of a diversified, sustainable and renewable energy system.

Biomass Data

Animal Manure Results showed modest, biogas resources.

Table 4: Potential Animal Biogas and Energy Estimates by County

	Lorain	Lucas	Erie	Ottawa
Biogas (m^3/yr)*	0.79	0.15	0.07	0.16
Pipeline Methane (m^3/yr)*	0.47	0.09	0.04	0.10
Electrical Energy (MWh)	158	30	14	32
Thermal Energy (MWh)	237	45	21	48

*x100,000 (Source: OARDC/OBIC, 2011)

Manure sources in the 9th District are most likely distributed among many small operations that would not currently be collecting manure. There is a benefit to working with other counties to locate enough manure biomass to make a regional "community" digester economically feasible.

Crop Residue Results showed significantly more biogas resource.

Table 6: Potential Corn Stover Biogas and Energy Estimates by County

	Lorain	Lucas	Erie	Ottawa
Biogas (m^3/yr)*	9.1	5.98	9.2	8.8
Pipeline Methane (m^3/yr)*	5.5	3.6	5.5	5.3
Electrical Energy (MWh)	1820	1196	1840	1760
Thermal Energy (MWh)	2730	1794	2760	2640

*x100,000 (Source: OARDC/OBIC, 2011)

TABLE 7: Potential Wheat Straw Biogas and Energy Estimates by County

	Lorain	Lucas	Erie	Ottawa
Biogas (m^3/yr)*	1.6	1.7	1.7	2.2
Pipeline Methane (m^3/yr)*	0.96	1.02	1.02	1.32
Electrical Energy (MWh)	320	340	340	440
Thermal Energy (MWh)	480	510	510	660

*x100,000 (Source: OARDC/OBIC, 2011)

However, researchers concluded that crop residue sources in the 9th District are likely distributed among many small operations that would not currently be collecting residue and using crop residue for anaerobic digestion would probably require a significant change in current corn stover and wheat straw handling practices and equipment, which may add a significant economic hurdle to smaller operations. Moreover, transportation costs and the chemical makeup of corn stover and wheat straw make them poor candidates for anaerobic digestion as compared to animal manure and food processing waste.

Food processing waste did not show significant biogas resources, but due to the nature of the feedstock it contains significant energy potential.

Table 10: Potential Food Processing Waste Biogas and Energy Estimates by County

	Lorain	Lucas	Erie	Ottawa
Biogas (m^3/yr)*	0.13	0.27	0.15	0.06
Pipeline Methane (m^3/yr)*	0.08	0.16	0.09	0.04
Electrical Energy (MWh)	250.9	544.8	303.4	120.4
Thermal Energy (MWh)	383.8	831.3	462.9	183.8

*x100,000 (Source: OARDC/OBIC 2011)

Food processing waste is a biomass resource for anaerobic digestion in its own right, but in this context it was examined due to its potential as a feedstock for co-digestion (using multiple feedstock types). Research has shown that co-digestion can significantly boost biogas production. The U.S. Bureau of Economic Analysis indicates that Ohio ranks 4th in food waste biomass, but there is no data regarding its amount and location. Researchers for this project attempted primary data gathering, but were not successful in achieving a large enough sample to create reliable estimates given time and scope limitations. Therefore, extrapolation methodologies were developed based on literature and prior waste stream studies, and estimates of food processing waste were created and validated. A survey-based study focused on this biomass is recommended in order to pinpoint sources, types and volumes of available biomass.

Economic Feasibility

Animal agriculture in the 9th District consists mainly of small to medium sized farms. There are no Concentrated Animal Feeding Operations (CAFOs) and few large scale operations (>$50K sales). With few large farms that would have concentrated sources of manure for biogas production, a cost/benefit analysis was created for a 0.5MW digester that would be operated as an independent business, accepting or purchasing manure and other wastes from multiple sources as feedstock.

Our model assumed the digester would be operated in partnership with an existing dairy farm of 1145 animal equivalents (ae), with additional manure hauled 10 miles, a 25% grant to support implementation, accelerated depreciation, the simple payback period was 10 years with a net present value of $1,800,000. Hauling manure 20 miles to the digester increased the simple payback to 21 years, pointing out that careful attention to location and distance would be warranted to minimize transportation costs. In the 10-mile scenario, adding modest potential Renewable Energy Credit (REC) and Carbon Credit revenue streams, the simple payback was reduced to 6.5 years with a net present value of $2,500,000. The regional community digester economic feasibility exercise clearly showed the importance of existing and proposed federal incentives.

Feasibility scenarios were created for the 0.5MW digester to produce and condition biogas for natural gas pipeline injection. At an assumed price of $.492/ccf[1] the scenarios showed negative net present values and simple payback periods indicating this model is not feasible (even with projected carbon credit sales). However, at prices of $1.2374/ccf, the simple payback rose to 35 years.

Case Study

A case-study analysis of the biogas potential and utilization options at an Oberlin-area dairy farm was conducted as a representative example for the 9th District. Using EPA AgSTAR's FarmWare 3.5, the economic feasibility showed a simple payback of 5 years. Taking advantage of REC and carbon credit sales, the simple payback dropped further showing the positive impact of robust REC and carbon credit markets.

Policies Needed

The economic feasibility analysis illustrated the importance of various federal policies on the feasibility of biogas to energy projects. A comprehensive policy study by the Great Plains Institute in 2010 and a review by Policy Matters Ohio highlighted numerous policies that should be considered for extension, modification, or implementation. A summary listing follows.

Federal Policy

Existing Best in Class Policies:

- Environmental Quality Incentives Program (EQIP)
- Rural Energy for America Program (REAP)
- Business and Industry Guaranteed Loans, USDA
- Business Energy Investment Tax Credit (ITC)
- Renewable Electricity Production Tax Credit (PTC)
- U.S. Department of Treasury, Section 160B: set to expire 2011, and should be continued.

Policies that "Need a Push"

- Biogas Production Incentive Act (S. 306, H.R. 1158)
- Federal Cap on Carbon Emissions
- Federal Renewable Electricity Standard (RES)
- Investment Tax Credit for Biomethane Projects

Promising New Policies that Need a Champion

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[1] Natural gas prices are usually expressed in $/dekatherm (1000cf). Ohio, however, does not use this convention and prices by ccf.

- National Nutrient Trading Program
- Rural Infrastructure Development Fund
- Tradable Tax Credits

Other Ideas

- Carbon Credit Certification Assistance
- Closed-loop Projects
- Integrate Existing USDA Programs

State Policy

Pricing Policy:

- Require electric utility companies to bear the full cost of generating electricity by increasing standards for efficiency, technology, and emissions and require them to upgrade the electricity grid.

Cost Share and Incentive Programs:

- Extend and expand the Ohio Advanced Energy Fund.
- Remove the property tax or payments in lieu of requirement for all renewable energy and advanced energy projects.

Conclusions and Potential Next Steps

Viewed conventionally, biogas to energy from the anaerobic digestion of animal manure, crop residue, and food processing waste can be economically feasible, with attention to feedstock type. Viewed in the context of developing decentralized renewable energy options to aid in the transition from a heavily fossil-based, geopolitically insecure energy system to a post-fossil fuel, carbon neutral, sustainable energy system the conclusions are different. With moderate grant and incentive support, the technology is economically feasible on a relatively small scale. In a region that has struggled to maintain its agricultural economic base, digesters can provide farmers an additional means to offset costs, generate income, and supply their own electrical energy with local, carbon-neutral sources; and they create jobs.

Our high-level economic feasibility exercise for deploying a 0.5MW community digester with REC and Carbon Credit revenue assumptions shows the positive impact these two revenue streams can have. This point is not to be understated. Federal policy that drives REC and Carbon prices into market is essential. Other federal policy options are also important: integration of USDA programs to make it easier for busy farmers (who are not in the energy business, but in the farming business) to navigate the complex system of grants, cost-share, and loan programs to implement digester projects; a federal renewable energy or clean energy standard; extension of the accelerated depreciation for renewable energy projects; and, continuation of the 30% Treasury

Department grant program. Without these basic policies, anaerobic digestion to produce energy is significantly more difficult. These policies make good economic sense: they create clean energy jobs and support the rural backbone of the country.

Dovin Dairy Farms, LLC

The case study at Dovin Dairy Farms suggests that a digester would be economically feasible and provide other benefits. A preliminary engineering design study is the next step to implementation. Due to its interest in anaerobic digestion, the scope of the design should include an analysis of technology options and partnership opportunities with the farm's neighbor, the Lorain County Joint Vocational School. In this context, for example, one of the design options would examine the possibility of LCJVS hosting and operating the digester in tandem with new curricula; ownership could be shared with the Dovins—including financial benefits. Such a partnership could spread the risk sufficiently and therefore satisfy the business interests of the farm, open potential funding pathways heretofore unforeseen, and create a public/private partnership that promotes clean, renewable energy, educational training, and jobs.

Food Processing Waste

According to the U.S. Bureau of Economic Analysis, the State of Ohio ranks 4th in value added food processing production (following California, Illinois, and Texas).[2] Both Jeanty et. al. (2004) and this project have shown the potential for food processing waste as a biomass resource for energy production using extrapolation methodology. This is not adequate. A significant study that pinpoints sources, types, and volumes of food processing waste is recommended.

New Technology

In the 9th Congressional District, Oberlin College and the City of Oberlin have become joint Climate Positive Development Program participants of the William J. Clinton Foundation's Clinton Climate Initiative (CCI) and are searching for long-term, climate positive, carbon-free energy solutions and strategies that will create a successful model of sustainable development that can be widely emulated throughout the U.S. The college has determined its coal-fired, central heating plant should be converted (or replaced) to carbon-neutral technology. The city is on track to meet up to 80% of its power needs from carbon-neutral sources, drastically reducing its carbon footprint but leaving up to a 20% gap filled by non-renewable sources. Both entities are looking to landfill gas to meet the bulk of their carbon-neutral energy needs in the near term. But landfill gas is not a long-term, sustainable solution. Although carbon-neutral, the technology relies on profligate waste continuing to fill up landfills and is perhaps a 30-

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[2] P. Wilner Jeanty, et. al., "Assessing Ohio's Biomass Resources for Energy Potential Using GIS." 2004.

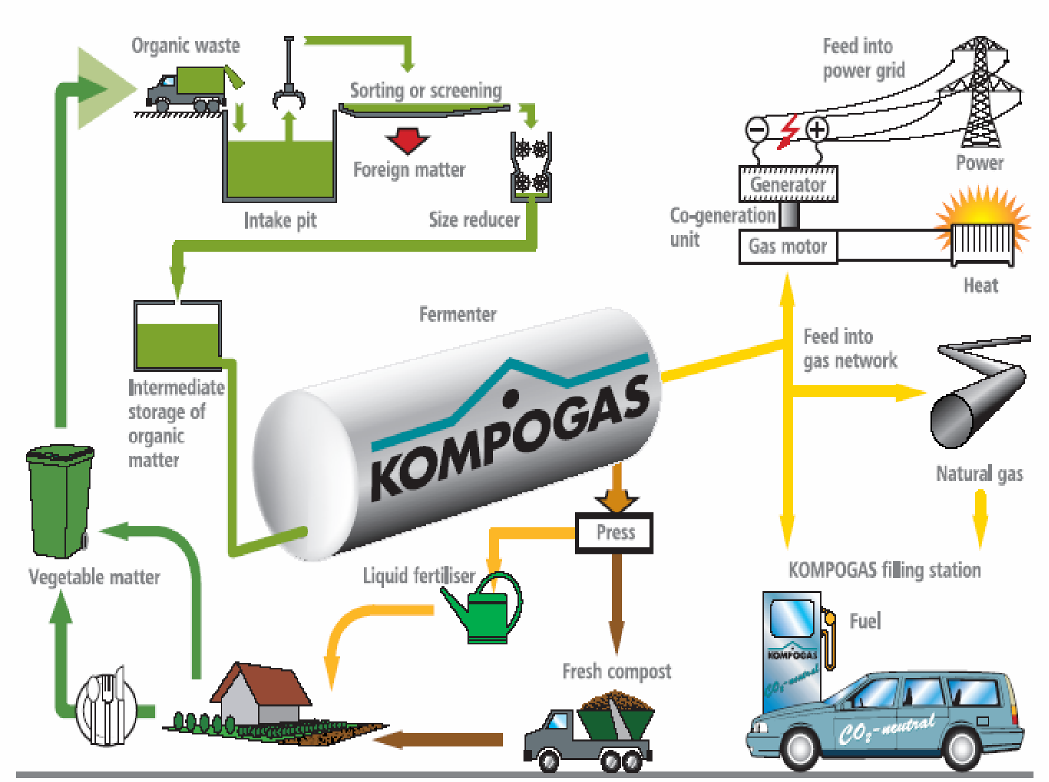
year solution. Two promising options exist to innovate beyond the 'conventional' landfill gas solution.

Dry Anaerobic Digestion

Dry anaerobic digester technologies have been developed and deployed commercially to produce biogas from organic wastes with low moisture content—75% moisture or less. Municipal Solid Waste (MSW) is the largest source of potential biomass to energy in the State of Ohio.[3] In contrast, to crop waste (12%) and manure (1%), MSW represents 68% of the biomass waste stream. The amount of MSW biomass available for energy conversion is staggering in proportion to all other biomass waste resources.

While methane recovery at landfills is becoming more commonplace, diverting waste from the landfill into dry digesters would extend the life of landfills while producing clean energy and jobs. The dry digester approach to carbon-neutral energy production should receive high priority consideration and a feasibility study funded for implementing a system near Oberlin. Ownership scenarios (private, college/city) should be included in the scope of the project.

Figure 7: Kompogas Dry Fermentation Technology



(source: Evergreen Energy Corporation Pty Ltd., "Independent Review of the Kompogas Technology" June 2005.)

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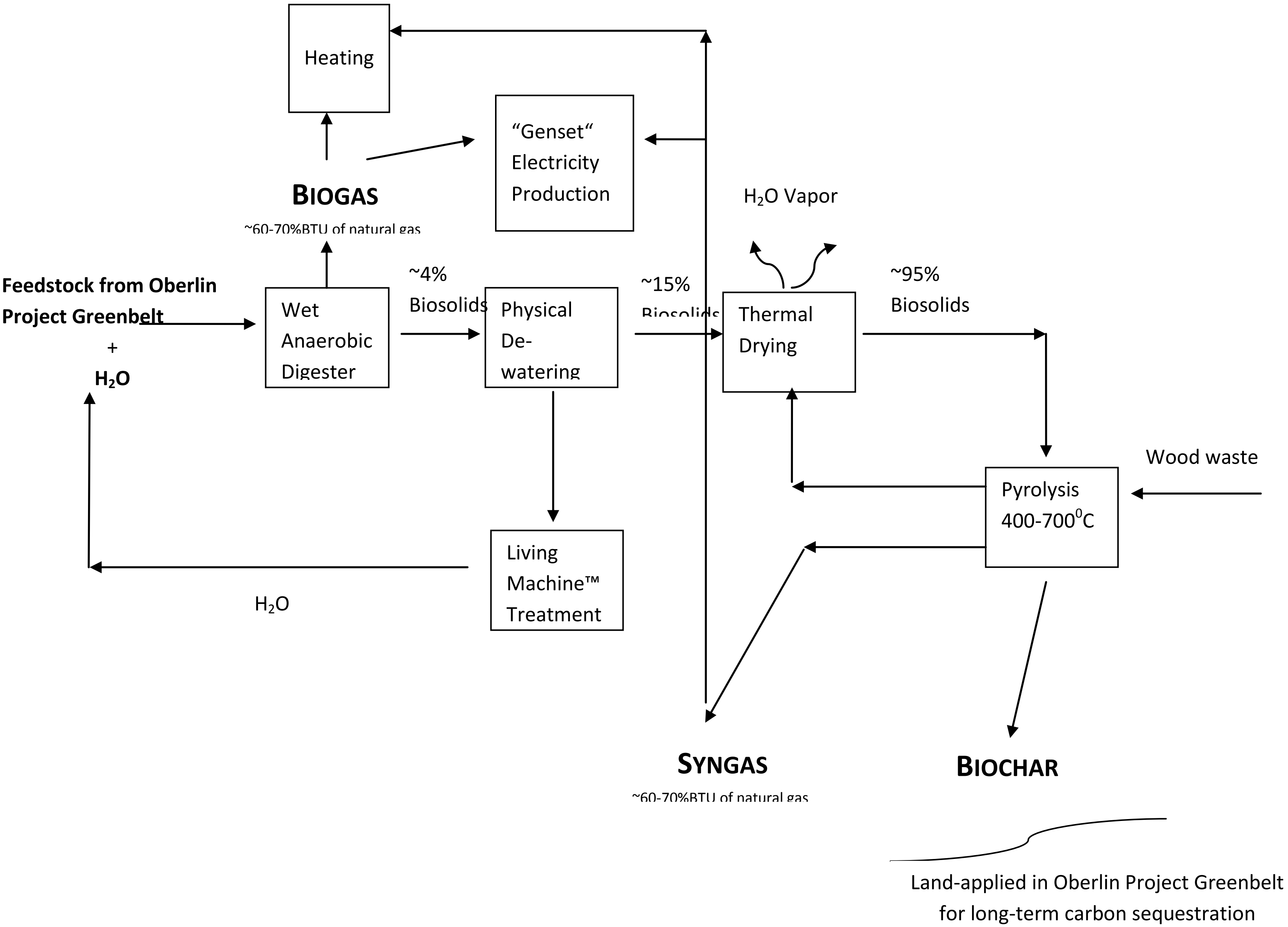
[3] Jeanty, et. al. p. 103.

Anaerobic Digestion and Pyrolysis for Carbon-Negative Energy

Another innovative technology that complements anaerobic digestion is pyrolysis (heating to high temperatures in the absence of oxygen). Pyrolysis of residual biosolids from an anaerobic digester would produce biochar—a carbon sequestering material—and syngas creating a **carbon-negative** energy generation system. If feedstock for the digester were drawn from the Oberlin Project area, with residual biochar being returned to it, a local, closed-loop and sustainable energy generation system would result. This option should receive high priority consideration and a feasibility study funded for implementing a system near Oberlin—either in conjunction with a dry digester or a wet digester at Dovin Dairy Farms, LLC. See Figure 8 for a representative schematic of this system.

Figure 8: Simple schematic for a sustainable, carbon-negative, closed-loop, biogas/biochar energy generation system for Oberlin, Ohio



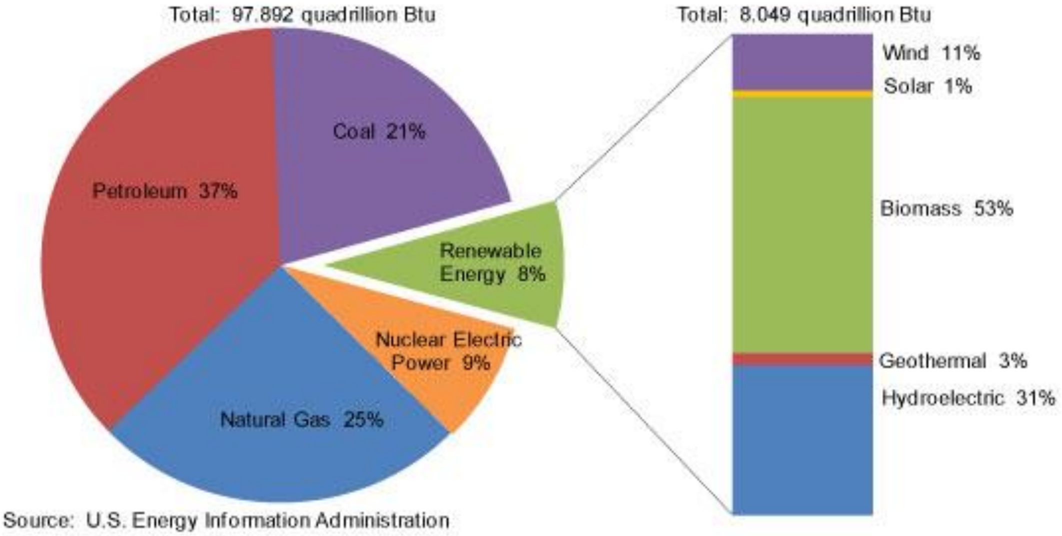
INTRODUCTION AND OVERVIEW

Oberlin College's "Energy Transmission and Infrastructure Northern Ohio" project, funded by the Department of Energy, seeks to identify opportunities for northern Ohio to play a leadership role nationally in the development of an efficient, sustainable, post-fossil fuel energy economy. It provides a context for identifying ways in which communities in Northern Ohio can transition to sustainable energy sources. The overarching objective of the project is to improve the efficiency with which energy is used in the residential, commercial, industrial, agricultural, and transportation sectors and identify potential technology deployment strategies for creating effective regional energy systems. The 9th District Biogas Assessment Project reviewed and evaluated potential utilizations of farm and food processing biomass waste as feedstock for anaerobic digestion with the utilization of the biogas for generating electrical and/or heat energy as well as conditioned biogas for pipeline injection.

Biogas in the Current Energy and Environmental Landscape

Renewable energy in the United States supplies 8% of the total energy consumption. Biomass makes up the largest portion of renewable energy consumed (Figure 1). For the biomass category, more detailed data indicates that wood-derived fuels made up the largest portion of biomass energy in 2010 (46%), followed by biofuels (43%), and waste (11%). Current biogas production from landfills, wastewater treatment facilities, and manure digesters fall into the waste category along with municipal solid waste-to-energy facilities. Thus, the portion of biogas energy from all sources supplied less than one-half of one percent of the total U.S. energy.

Figure 1. Renewable energy consumption in the nation's energy supply, 2010



Source: U.S. Energy Information Administration

Figure 1: Renewable Energy Consumption in the United States, 2010 (preliminary)
www.eia.gov/renewable/annual/preliminary/

The majority of existing biogas is produced using anaerobic digesters, gas-tight high-moisture enclosures that provide a stable environment for methane-producing bacteria to flourish. The raw biogas is collected from the digester and then flared or processed and used in energy applications as a replacement for electricity, natural gas, propane, diesel fuel, or gasoline. The bacterial processes that produce methane from waste occur naturally in many environments where organic-rich material is isolated from oxygen, such as thick wetland sediments, the origin of the term "swamp gas."[4]

In addition to the energy potential of biogas, anaerobic digesters provide other benefits. Specific non-energy benefits from anaerobic digestion of farm manure wastes include,

- Reduced greenhouse gas emissions,
- Reduced odors,
- High quality fertilizer,
- Reduced surface and groundwater contamination,
- Pathogen reduction.[5]

Moreover, anaerobic digesters can aid in the economic development of rural areas (including the 9th Congressional District) by allowing farms to become part of a renewable, distributed energy generation and transmission system, promoting decentralized sustainable energy supply, while creating jobs in rural areas. In this way, they can become part of the process to promote a more vibrant and resilient, sustainable local economy. Use of anaerobic digestion to produce biogas can reduce dependence on out-of-state and foreign energy sources, keep energy dollars invested in Ohio's economy, and create high skill, high value job opportunities for utility and power equipment and agricultural equipment industries.[6]

9th District Biogas Assessment Project Description

In partnership with Marquette University, Milwaukee, WI (College of Engineering—Civil and Environmental Engineering), the Ohio State University, Ohio Agricultural Research Development Center (OARDC), Ohio BioProducts Innovation Center of Columbus (OBIC), and North Coast Initiatives, LTD, of Oberlin, OH, the 9th District Biogas Assessment project reviewed and evaluated potential utilizations of farm and food processing waste for generating electrical or heat energy as well as conditioned biogas for pipeline injection using anaerobic digestion technology. Estimates were derived for the biogas

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[4] "Biogas: Rethinking the Midwest's Potential." Peter Taglia. Clean Wisconsin, June 2010.

[5] EPA AgSTAR Handbook, p. 1-4, http://www.epa.gov/agstar/tools/project-dev/handbook.html.

[6] Jeanty, et. al.(2004)

production potential in the 9th District that can be obtained by anaerobic digestion of animal manure (bovine, swine, poultry), crop residue (corn stover, wheat straw), and food processing waste including calculations for conversion of potential biogas to electrical or heat energy and/or conditioned biogas for pipeline injection.
The study identified policy, regulatory, and financial barriers that impede development of farm-based, biogas generation systems that could be part of a diversified, sustainable and renewable energy system. A case-study analysis of the biogas potential and utilization options at an Oberlin-area dairy farm, including preliminary cost estimates for system deployment was conducted as a representative example for the 9th District.

9th Congressional District

Ohio's 9th Congressional District is composed of Lorain, Lucas, Erie, and Ottawa Counties, which stretch along Ohio's Northern border. This district comprises the majority of Ohio's Lake Erie shoreline, as well as a small state boundary with Michigan. The 10 largest municipalities in this district by population are Toledo, Sandusky, Oregon, Sylvania, Maumee, Amherst, Vermillion, Oberlin, Huron, and Port Clinton. Toledo is by far the largest city, with a population of 313,619 as compared to Sandusky, the second largest, at 27,844.

The total population of the district is 641,387, with an estimated 86% residing in urban areas and only 14% residing rurally. 13.5% of individuals in the district live below the poverty line, and the district has a 10.1% unemployment rate.

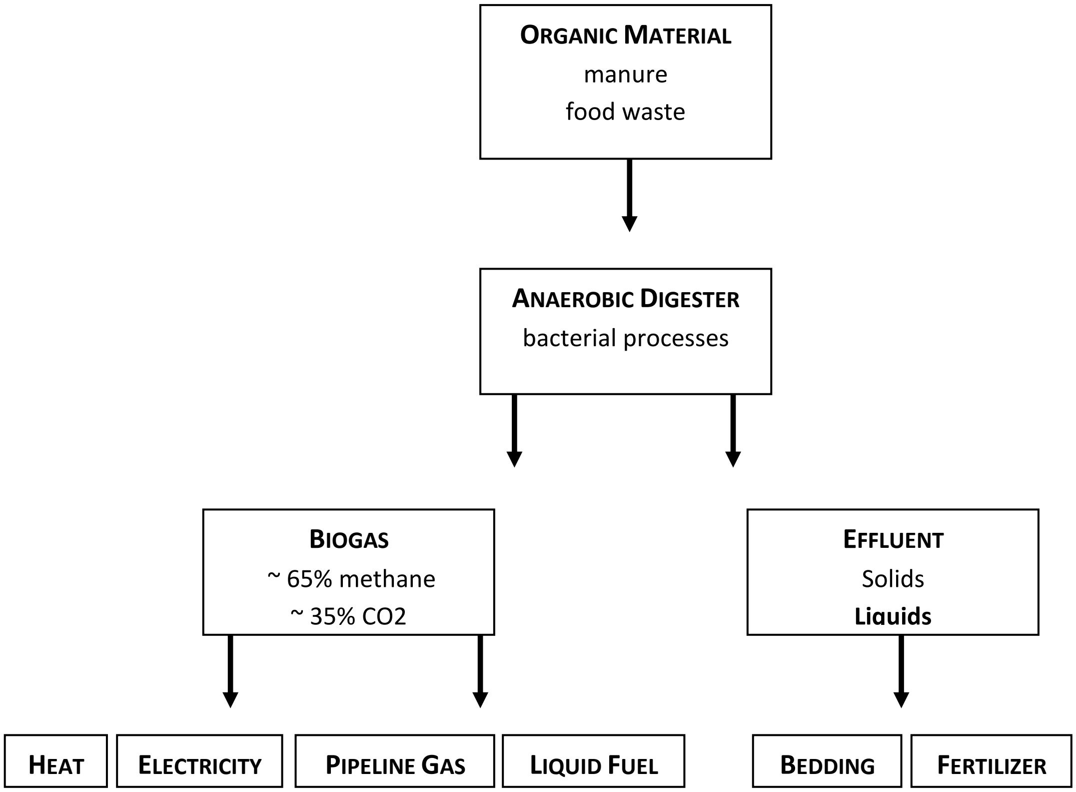
Agriculture is one of the district's primary industries. The district's comparatively flat landscape makes the land ideal for raising crops, making wheat, corn, and soybeans more prevalent in this district than large-scale cattle operations. The farms in the district total 2190, with the average farm size ranging from 142 to 208 acres. Land area of farms totals 378,000; with land area in the district totaling 858,880 acres, this puts 44% of land area under cultivation. In total, the district holds 16,100 head of cattle, 5,400 of which are dairy cows. The vast majority of cattle reside in Lorain County (11,600 cattle total, 4,600 dairy), and Lorain County holds a higher number of farms than any other county (840).

Anaerobic Digestion

Anaerobic digestion is the controlled breakdown of organic wastes in the absence of oxygen. An anaerobic digester is an air tight, oxygen-free container that is fed an organic material, such as animal manure or food scraps. A natural biological process occurs to this mixture to produce gas containing methane, commonly known as biogas, along with an odor-reduced slurry effluent. Microbes break down manure into biogas and a nutrient rich effluent. The product known as “biogas” consists of approximately 65% methane and is a renewable source of fuel. Typical feedstocks for an anaerobic digester are animal and agricultural wastes, wastewater sewage sludge, food waste, municipal waste, and certain types of biomass. Anaerobic digestion of wastes to produce biogas is an off-the-shelf technology that is widely used in agricultural and wastewater treatment facilities to control odor, reduce the volume of solid material, and produce energy. Product biogas can be conditioned and injected into natural gas pipelines, or it can be burned in-situ to produce carbon-neutral heat and electricity by using an engine-generator set—a diesel engine modified to burn biogas combined with an electrical generator—or it can be compressed into a liquid fuel. Biogas is also the fuel for adsorption chillers and fuel cells in addition to engines.

Biogas recovery systems utilizing anaerobic digestion are effective at confined livestock facilities that handle manure as liquids and slurries, typically swine and dairy farms. Anaerobic digester technologies provide enhanced environmental and financial performance when compared to traditional waste management systems such as manure storages and lagoons. They are particularly effective in reducing methane emissions, but also provide other air and water pollution control opportunities.

Figure 2: Anaerobic Digestion Flowchart



(Steve Baertsche, Mary Wicks, OARDC)

Table 1: Types of Digesters

Characteristics	Covered Lagoon	Plug Flow	Complete Mix	Fixed Film
Digestion Vessel	Deep lagoon	Rectangular in-ground	Round/square above or in-ground	Above ground tank
Level of technology	Low	Low	Medium	Medium
Supplemental heat	No	Yes	Yes	No
Total solids	0.5 – 3%	11 – 13%	3 – 10%	3%
Solid characteristics	Fine	Coarse	Coarse	Fine
Retention time	40 – 60 days	15+ days	15+ days	2-3 days
Optimum climate	Temperate & warm	All	All	Temperate & warm

(Source: http://www.epa.gov/agstar/pdf/handbook/chapter1.pdf)

BIOGAS ASSESSMENT OF THE 9TH CONGRESSIONAL DISTRICT

Animal Manure

A 2004 Study of the energy potential of biomass in the State of Ohio estimated that livestock manure could produce 2,393 billion Btu of energy. Lorain, Lucas, Erie, and Ottawa counties could potentially produce 42.2 billion Btu.[7]

Researchers at OARDC/OBIC calculated biogas estimates for the 9th Congressional district following EPA methodology. Data was sourced from the 2007 U.S. Agricultural Census, the Agricultural Waste Management Field Handbook, County Offices for Soil and Water Conservation, and the Ohio Department of Natural Resources. Their findings indicated that there are relatively few larger-scale animal operations left in the district (>$50K sales) for the production of hogs, cattle (including milk cows) and poultry.

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[7] Jeanty, et. al. p, 106.

Table 2: Animal Operations by Sales

	Cattle	Hogs	Poultry
# of operations >$50k sales	31	22	2
# of operations >$1K sales	585	224	270

(Source: OARDC/OBIC, 2011)

Livestock Inventory by County was determined and is represented in Table 7:

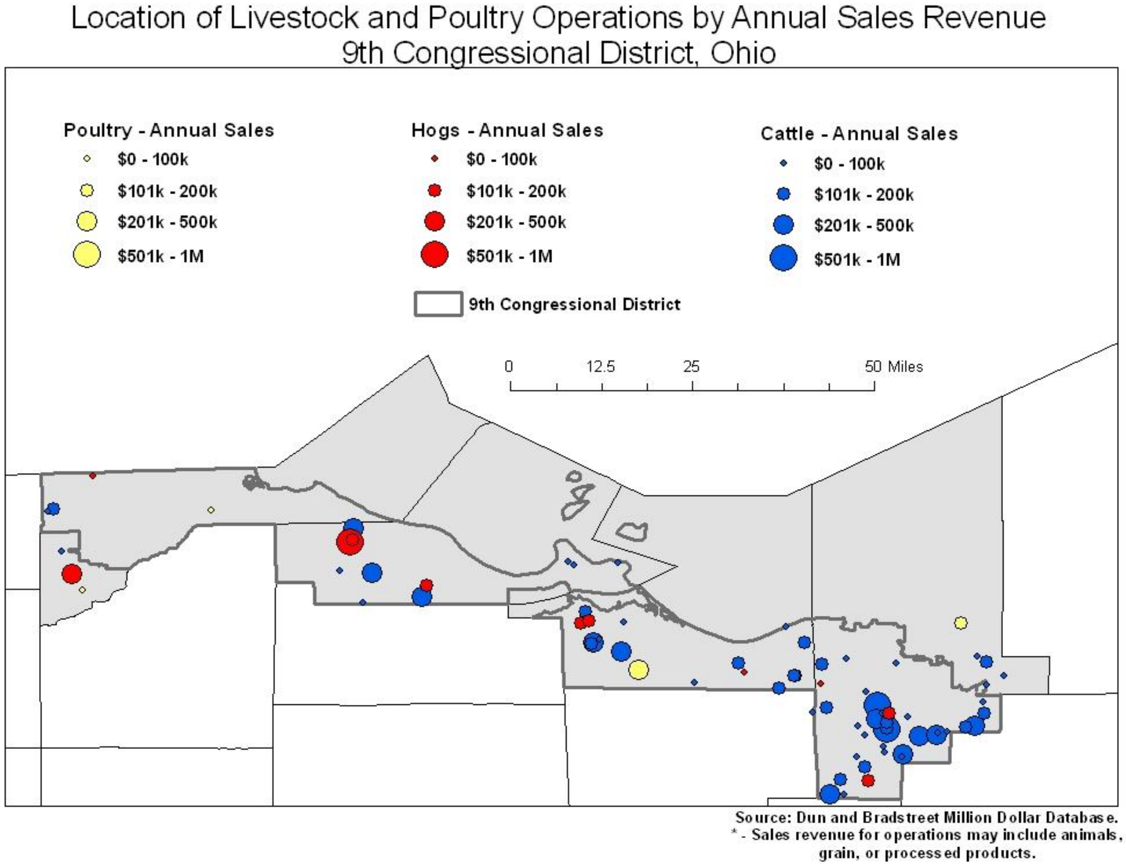
Table 3: Animal Distribution by County

	Ohio	Erie	Lucas	Lorain	Ottawa
Cattle/Calves	1272402	2519	621	11995	1523
Cows w/calves	565695	1237	206	5585	618
Beef Cows	293757	718	206	796	343
Milk Cows	271938	519	N/A	4789	275
Total Hogs & Pigs	1831084	239	4268	5417	3639
Breeders	159764	27	390	N/A	N/A
Layers	27070109	836	565	2874	615
Pullets	6778418	N/A	56	276	59
Broilers	10021948	1592	285	1474	105

(Source: OARDC/OBIC, 2011)

The distribution of farms in the 9th Congressional District was determined and is represented in Figure 3:

Figure 3: Distribution of Animal Operations by County



(Source: OARDC/OBIC, 2011)

Using EPA methodology; the <u>Biogas Utilization Handbook,</u> DOE, 1988; "*Basics of Energy Production through Anaerobic Digestion of Livestock Manure"*, Ileleji et. al., 2008, the biogas and energy potential from this biomass resource was calculated.

Table 4: Potential Animal Biogas and Energy Estimates by County

	Lorain	Lucas	Erie	Ottawa
Biogas (m^3/yr)*	0.79	0.15	0.07	0.16
Pipeline Methane (m^3/yr)*	0.47	0.09	0.04	0.10
Electrical Energy (MWh)	158	30	14	32
Thermal Energy (MWh)	237	45	21	48

*x100,000 (Source: OARDC/OBIC, 2011)

Researchers concluded that Lorain County has the most livestock activity and more operations with >$50K sales than Lucas, Erie, and Ottawa county, though livestock production may be trending downwards for the area. Manure sources in the 9th District are most likely distributed among many small operations that would not currently be collecting manure. There may be a benefit to working with other counties to locate enough manure biomass to make a regional digester economically feasible, but careful attention to distance and transportation costs will be needed.

Crop Residue

Jeanty, et. al. (2004) determined the energy potential of crop residue in the State of Ohio at 53,716.8 billion Btu of energy. Lorain, Lucas, Erie, and Ottawa counties could potentially produce 1,618.1 billion Btu.[8]

To assess the biogas potential from crop residue in the 9th District, a definition of "usable crop residue" was established. The majority of collectable crop residues are limited to corn stover and wheat straw (due to the rapid decomposition of soybean residue). Adjustments for animal use (consumption and bedding), erosion control, harvesting efficiency, moisture content, and storage transportation and loss were determined. Residue was determined by NREL methodology (Residue = yield*weight per bushel*stover-to-grain ratio; Bone dry residue = Residue*(1-percent moisture)*harvest efficiency).

Table 5: Usable Crop Residue by County

	Erie	Lorain	Lucas	Ottawa	4 Counties
Corn Residue (BDT)	27,361.6	27,249.5	17,810.1	26,341.5	98,762.8
Wheat Residue (BDT)	7,924.1	7,389.8	7,920.0	10,663.6	33,897.5

(Source: OARDC/OBIC, 2011)

The distribution of farms in the 9th Congressional District was determined and is represented in Figure 4:

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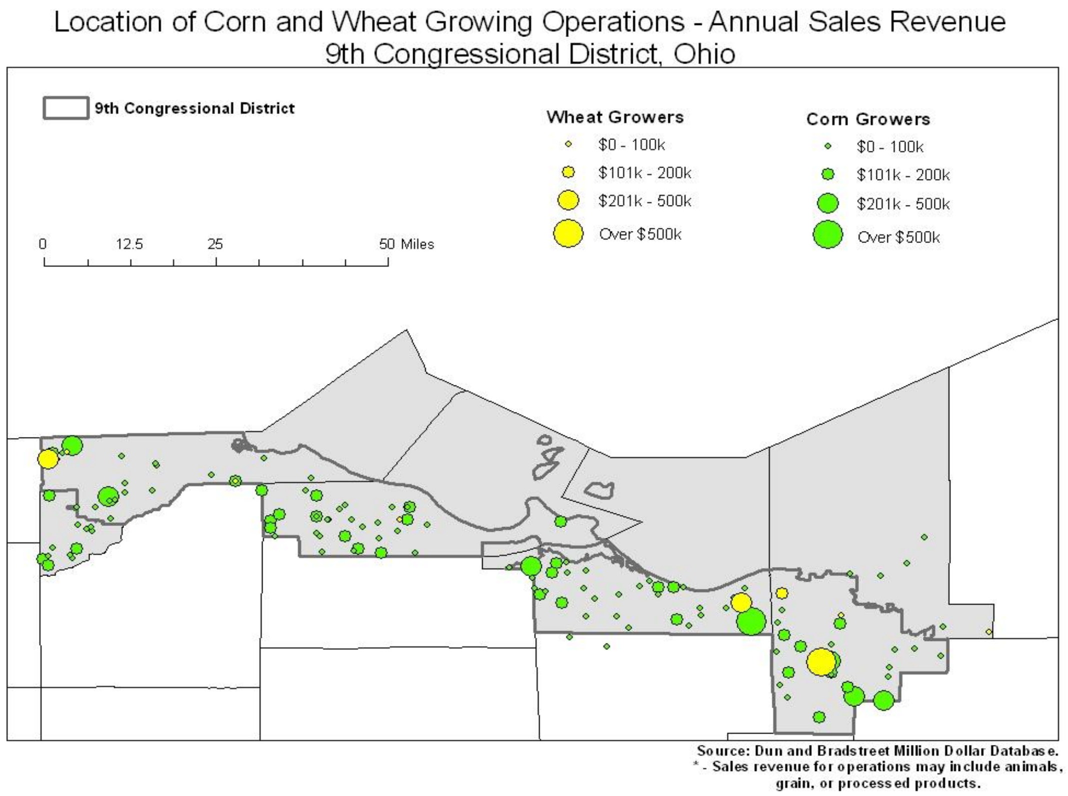
[8] Jeanty, et. al. p, 106.

Figure 4: Distribution of Crop Operations by County



(Source: OARDC/OBIC, 2011)

Using EPA methodology; the Biogas Utilization Handbook, DOE, 1988; "*Basics of Energy Production through Anaerobic Digestion of Livestock Manure*", Ileleji et. al., 2008, the biogas and energy potential from this biomass resource was calculated.

Table 6: Potential Corn Stover Biogas and Energy Estimates by County

	Lorain	Lucas	Erie	Ottawa
Biogas (m^3/yr)*	9.1	5.98	9.2	8.8
Pipeline Methane (m^3/yr)*	5.5	3.6	5.5	5.3
Electrical Energy (MWh)	1820	1196	1840	1760
Thermal Energy (MWh)	2730	1794	2760	2640

*x100,000 (Source: OARDC/OBIC, 2011)

Table 7: Potential Wheat Straw Biogas and Energy Estimates by County

	Lorain	Lucas	Erie	Ottawa
Biogas (m^3/yr)*	1.6	1.7	1.7	2.2
Pipeline Methane (m^3/yr)*	0.96	1.02	1.02	1.32
Electrical Energy (MWh)	320	340	340	440
Thermal Energy (MWh)	480	510	510	660

*x100,000 (Source: OARDC/OBIC, 2011)

Researchers concluded that crop residue sources in the 9th District are likely distributed among many small operations that would not currently be collecting residue. Using crop residue for anaerobic digestion may require a change in current corn stover and wheat straw handling practices and equipment, which probably adds an economic hurdle to smaller operations. Moreover, transportation costs and the chemical makeup of corn stover and wheat straw make them poor candidates (economically) for anaerobic digestion. For example, researchers discussed co-digesting corn stover with manure at an 80:1 ratio of manure to corn stover as a theoretical blend. But, researchers emphasized that at $5/decatherm for biogas, crop residue is probably not economically viable as a feedstock source for anaerobic digesters.

Food Processing Waste

Though the U.S. Bureau of Economic Analysis claims that Ohio ranks 4th in terms of food waste biomass, Jeanty, et. al. (2004) found that no specific data existed regarding the amount and location of food processing waste in the State of Ohio.[9] Food processing waste is a biomass resource for anaerobic digestion in its own right, but in this context it was examined due to its potential as a feedstock for co-digestion.

Co-digestion involves the combination of two or more feedstocks in an anaerobic digester (e.g., dairy manure with meat processing waste). Research has shown that co-digestion can significantly boost biogas production in a digester over the amount produced if only one feedstock is used—depending on the feedstock combinations. Moreover, producers of high quality food processing waste ('high quality' from an anaerobic digestion point of view) are usually willing to pay a tipping fee to have the waste processed in a digester in order to avoid landfill tipping fees which are usually

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[9] Jeanty, et. al. p, 75.

higher. The digester tipping fee, then, becomes an additional revenue stream for the digester operator boosting the economic value of the project.

Researchers used North American Industry Classification System (NAICS) codes to create a database of food processors in the 9th Congressional District. Companies were contacted by phone to gather information on waste type and volume.

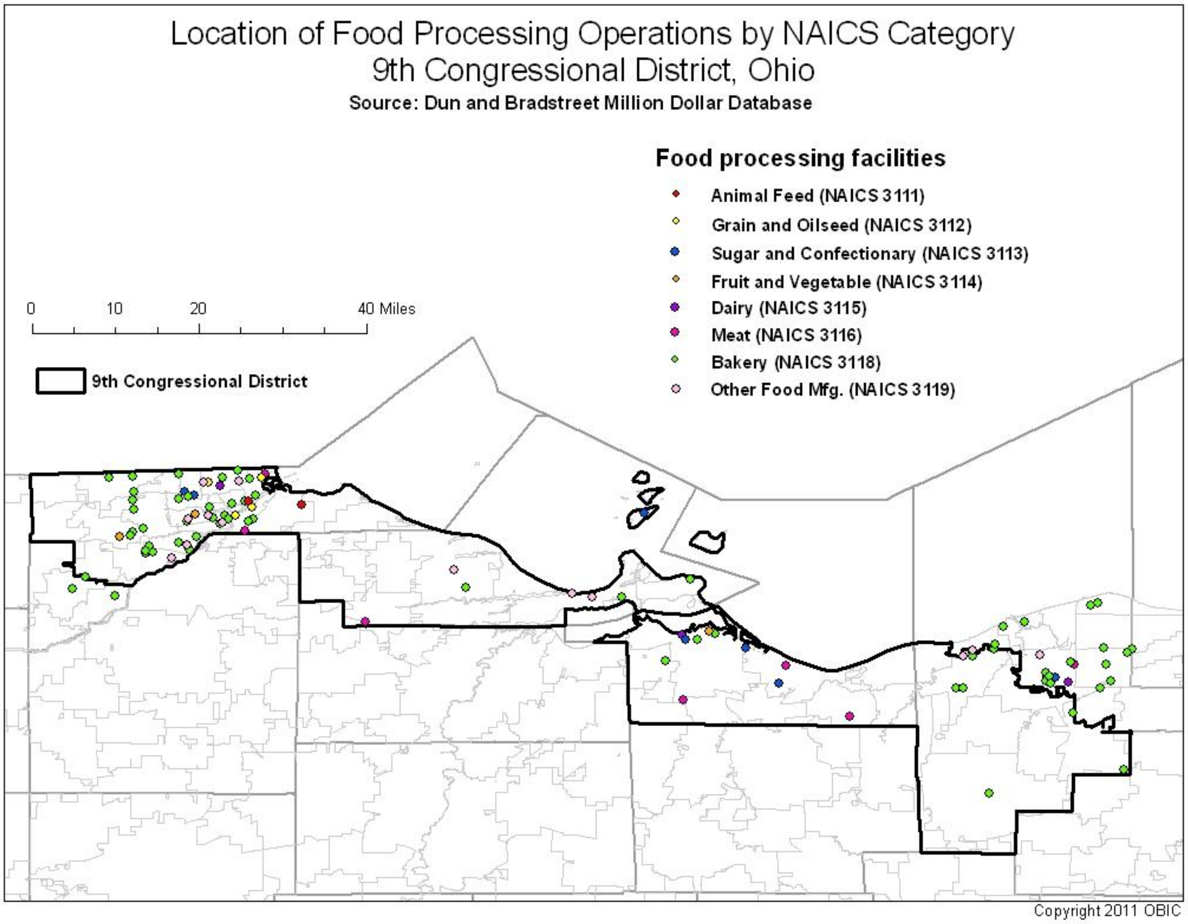
Table 8: Food Processing Producers by County

NAICS	Total	Erie	Lorain	Lucas	Ottawa
Animal Feed	2	N/A	N/A	2	0
Grain and Oilseed	4	N/A	N/A	4	0
Sugar and Confectionery	9	3	1	3	2
Fruit and Vegetable	3	1	N/A	2	1
Dairy	4	1	2	1	N/A
Meat	7	3	1	2	1
Bakery	70	4	25	38	3
Other Food Manufacturing	13	N/A	3	7	3
All	**112**	**12**	**32**	**59**	**9**

(Source: OARDC/OBIC, 2011)

The distribution of food processing operations in the 9th Congressional District was determined and is represented in Figure 5:

Figure 5: Location of Solid Food Processing Operations by County



(Source: OARDC/OBIC, 2011)

Company telephone contact yielded no meaningful response. Researchers developed a secondary source methodology for determining food processing waste types and volumes. While no linear correlation has been shown in previous studies between sales amount and employee information and waste volume, it was determined to be a good indicator based on a review of literature and past studies.

Table 9: Estimation of Solid Food Processing Waste by County (Tons/year)

	Lucas	Ottawa	Erie	Lorain
Animal Feed	355.6			
Grain and Oilseed	716.0			
Sugar and Confectionery	160.0	179.8	397.5	187.6
Fruit and Vegetable	265.7		323.9	
Dairy	319.0		315.2	345.2
Meat	308.0	215.0	207.0	308.0
Bakery	195.6		163.9	193.8
Other Food Manufacturing	207.5	163.9		437.1
All	**2527.4**	**558.7**	**1407.5**	**1163.7**

(Source: OARDC/OBIC, 2011)

Using EPA methodology; the Biogas Utilization Handbook, DOE, 1988; "*Basics of Energy Production through Anaerobic Digestion of Livestock Manure*", Ileleji et. al., 2008, the biogas and energy potential from this biomass resource was calculated.

Table 10: Potential Food Processing Waste Biogas and Energy Estimates by County

	Lorain	Lucas	Erie	Ottawa
Biogas (m^3/yr)*	0.13	0.27	0.15	0.06
Pipeline Methane (m^3/yr)*	0.08	0.16	0.09	0.04
Electrical Energy (MWh)	250.9	544.8	303.4	120.4
Thermal Energy (MWh)	383.8	831.3	462.9	183.8

*x100,000 (Source: OARDC/OBIC 2011)

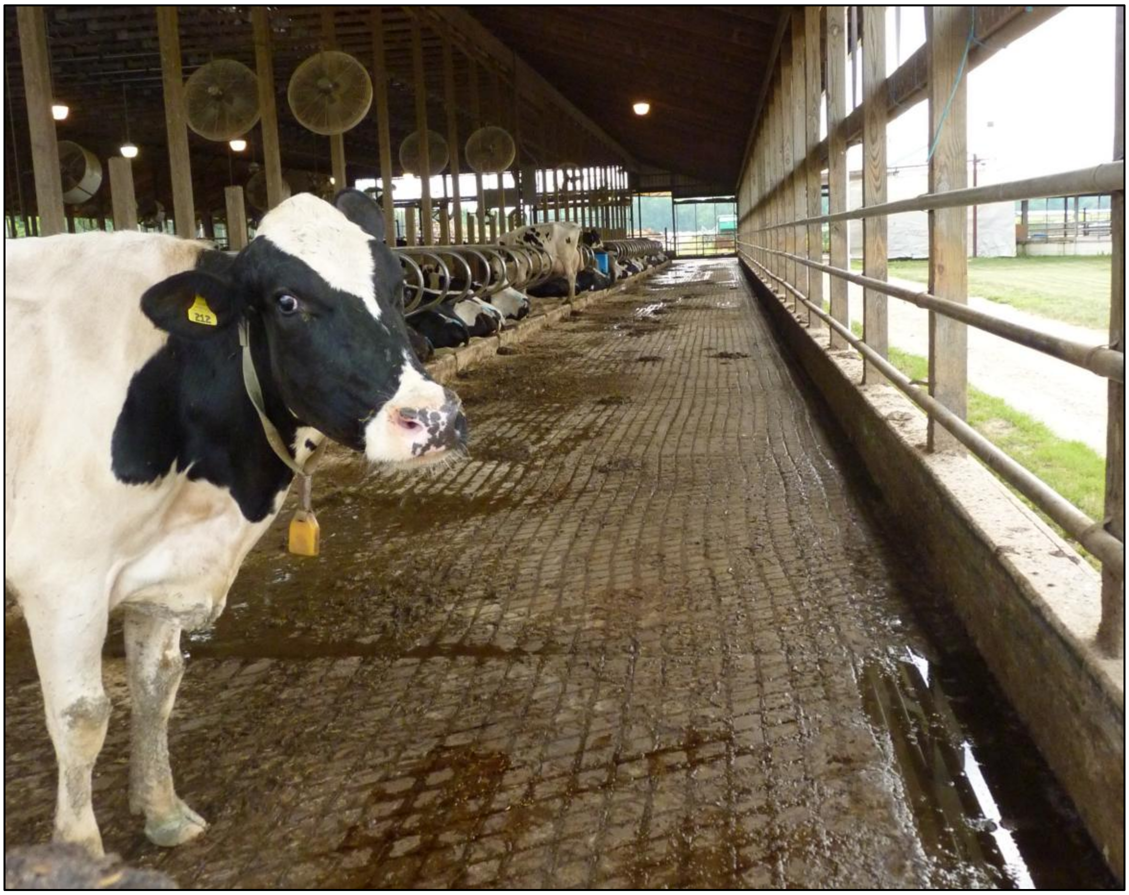
Researchers concluded that the estimated waste volume, and therefore biogas and energy estimates, should be in the correct order of magnitude based on a benchmark validation study involving Class I and Class II composting facilities in the 9th District. In order to garner more accurate data, a long-term study would be needed.

ECONOMIC FEASIBILITY

The economic feasibility of implementing anaerobic digesters on-farm varies widely according to specific conditions (e.g., number of animals, manure management system, prices paid for energy on-farm, etc.). The U.S. EPA has developed the AgSTAR program to support and promote the recovery and use of methane from animal manure (www.epa.gov/agstar) through the use of biogas recovery systems. AgSTAR is a collaborative effort of the EPA, the U.S. Department of Agriculture, and the U.S. Department of Energy. AgSTAR conducts farm digester extension events and conferences, provides "how-to" project development tools and industry listings, conducts performance characterizations for digesters and conventional waste management systems, provides recognition for voluntary environmental initiatives, and collaborates with federal and state renewable energy, agriculture, and environmental programs.

In farm settings where animals are confined and manure is managed as a liquid or slurry, anaerobic digesters can be an economical way to provide enhanced environmental and financial performance when compared to traditional waste management systems such as manure storage and lagoons. They are particularly effective in reducing methane emissions, but also provide other air and water pollution control opportunities. To highlight the potential in the 9th Congressional District, a case study was conducted on a farm near Oberlin, Ohio.

CASE STUDY: IMPLEMENTATION OF A PLUG FLOW ANAEROBIC DIGESTER AT DOVIN DAIRY FARMS, LLC IN OBERLIN, OHIO.



The purpose of this case study is to evaluate the potential benefits of implementing a plug flow anaerobic digester or similar at the Dovin Dairy Farms LLC (Rte 58 site).

Background

Anaerobic digestion is the controlled breakdown of organic wastes in the absence of oxygen. An anaerobic digester is an air tight, oxygen-free container that is fed an organic material, such as animal manure or food scraps. A natural biological process occurs to this mixture to produce gas containing methane, commonly known as biogas, along with an odor-reduced slurry effluent. Microbes break down manure into biogas and a nutrient rich effluent. The product known as "biogas" consists of approximately 65% methane and is a renewable source of fuel. Typical feedstocks for an anaerobic digester are animal and agricultural wastes, wastewater sewage sludge, food waste, municipal waste, and certain types of biomass.

Anaerobic digestion of wastes to produce biogas is an off-the-shelf technology that is widely used in agricultural and wastewater treatment facilities to control odor, reduce the volume of solid material, and produce energy. Product biogas can be conditioned and injected into natural gas pipelines, or it can be burned in-situ to produce relatively carbon-neutral heat and electricity by using an engine-generator set—a diesel engine modified to burn biogas combined with an electrical generator—or it can be compressed into a liquid fuel.

A variety of anaerobic digestion technologies exist for dairy manure, including complete mix bulk fermentation, plug flow, and the covered lagoon. Because they are commonly used in a dairy setting, the technology examined for Dovin Dairy Farms is a plug flow digester. However, a complete-mix bulk fermenter or other process can also be used.

Regardless of the type of technology implemented, anaerobic digestion can produce environmental and financial benefits. On large-scale animal farms, the buildup of animal waste products can present serious environmental management problems. For example, on large-scale dairy farms animal manure is typically collected in lagoons, where the high concentrations of waste produce high levels of odor and release a significant amount of methane, a potent greenhouse gas. When manure is anaerobically digested, odors are substantially reduced and methane is produced, captured, and can be burned to produce energy. This not only reduces the farm's greenhouse gas emissions but also offsets future emissions that would have been produced by burning coal or natural gas to produce energy needed for the farm. Residual heat is also produced by combusting the biogas, which can be used to heat the farm. Thus, a farm's energy costs can be reduced by on-site energy production. Other financial benefits come in the form of selling excess electricity to the local utility, tax breaks, or from the sale of carbon and/or renewable energy credits. Digested biosolids from the digester can be dried and used for bedding material. This can be a cost savings if biosolids replace purchased beding, such as sand.

This case study is only one element in a larger study of the biogas potential of Ohio's 9th congressional district, composed of Ottawa, Lorain, Lucas, and Erie Counties. Researchers at Ohio State's Ohio Agricultural Research and Development Center (OARDC) working through the Ohio Bioproduct Innovation Center (OBIC), have determined the distribution and amount of animal waste biomass (bovine, swine, poultry), usable crop residue (corn stover, wheat straw), and food processing waste in the district. Using this data, OBIC has provided estimates of the biogas energy potential for the district. Researchers at Marquette University have determined the composition of Dovin Dairy Farm's manure and calculated the amount of biogas and thus potential energy that can be produced by a farm this size.

As a part of the larger study, the Dovin Dairy Farms case study will serve as a representative example of how anaerobic digestion technology can be applied effectively in this region to utilize its valuable waste products.

Dovin Dairy Farm

The Dovin Dairy Farm is a family-owned farm located just outside of Oberlin, Ohio on Route 58 housing 700 lactating dairy cows and 400 calves. The farm is currently owned and operated by Dovin Dairy Farms, LLC which operates 5 separate locations, as detailed in the table below. The focus of this case study is on the Route 58 location.

Case Study Table 1: Dovin Dairy Farms, LLC

	lactating dairy cows	dry cows	steers	heifers	calves	total animal equivalents	# lagoons/lagoon capacity
Route 58	700				400	1,145	3; 1M, 1.6M, 4M gal
Quarry Rd/303			200 (1000lb)			200	
Spencer	300					405	1; 1.3Mgal
McConnell			200 (700lb)			140	
Ashland				900		900	1; 4.5Mgal
Other		120	120		50	307	1; 1.5Mgal
Total	1000	120	520	900	450	3097	6

Manure Management

Current manure management practices at Dovin Dairy Farms follow the USDA's Comprehensive Nutrient Management Plan. Though the smaller size of this operation exempts it from any regulations pertaining to nutrient levels or soil or water quality, following this conservation plan aids the farm in being attentive to these areas of concern and has led to responsible manure application practices. Under this plan, Dovin Dairy Farms uses a scrape and lagoon manure collection system and deploys dragline manure application, in which liquid manure is injected directly into the soil. This allows for a more controlled method of manure application that lessens the damage from soil erosion and runoff while also significantly reducing odor.

Manure Lagoon at Dovin Dairy Farm

Dragline Manure Application

http://www.mda.state.mn.us/protecting/conservation/practices/manuremgmt.aspx

Odor Control

Currently in Ohio there are no formal regulations requiring farmers to meet odor control standards if their farms are not registered as Concentrated Animal Feeding Operations (CAFOs,). CAFOs, which are defined by the number of animals present, fall under the jurisdiction of EPA regulations (administered by the State of Ohio EPA), which maintains strict regulations on odor control and manure management practices. Though a farm may be determined a CAFO if it has only 200 dairy cattle, only the largest CAFOs with upwards of 1000 cattle are subject to full Ohio EPA regulations. None of the operations run through Dovin Dairy Farms are currently large enough to fall under Ohio EPA jurisdiction. However, at Dovin Dairy Farms several courtesy practices are used to manage odor. These practices include pumping manure onto the fields very close to the ground rather than spraying it into the air, and communicating with those in the community so even this low-odor form of manure spreading will not conflict with community events.

Bedding

Rather than using straw or sawdust bedding, Dovin Dairy Farms uses sand and some straw to bed its cows. According to Mr. Dovin, this practice has lowered the number of mastitis infections by 75%. Mastitis is caused by pathogens that often thrive in organic bedding. Sand also creates a comfortable bed for the cows and provides traction on the slippery concrete floors, reducing rates of injuries resulting from falls.

Manure Analysis and Energy Calculations

Samples were taken and sent to the Water Quality Center at Marquette University for analysis. Results for Total Solids (TS), Volatile Solids (VS), Chemical Oxygen Demand (COD), Total Kjeldahl Nitrogen (TKN), metals, and biochemical methanogenic potential (BMP) are below:

Case Study Table 2: Marquette University Water Quality Center Data

Sample	TS (g TS/g sample)	VS (g VS/g sample)	COD (g/Kg)	NH-N (mg/Kg)	TKN (mg/Kg)	PO4 (mg/Kg)
						soluble/total
Lactating Barn Manure	0.153	0.105	171	4170	7870	2450 / 6020

Cadmium	Chromium	Cobalt	Copper	Lead	Nickel	Zinc	Iron	Mn	As	Se	Silver
in ug/Kg wet weight											
75.2	421	914	8678	313	1496	25930	297000	31720	134	137	16.2

Molybdenum	Mercury	Beryllium	Calcium	Sodium	Potassium	Magnesium
				in mg/Kg wet weight		
481	ND	ND	2786	573	1183	984

Biochemical Methanogenic Potential Results					
	1	2	3	Average	Std dev
BMP (ml-methane/g-COD added)	166	145	140	150	14
BMP (ml-methane/g-VS added)	271	238	229	246	22

Based on the above analysis, Marquette University used the data and determined the following energy potential for Dovin Dairy Farm manure:

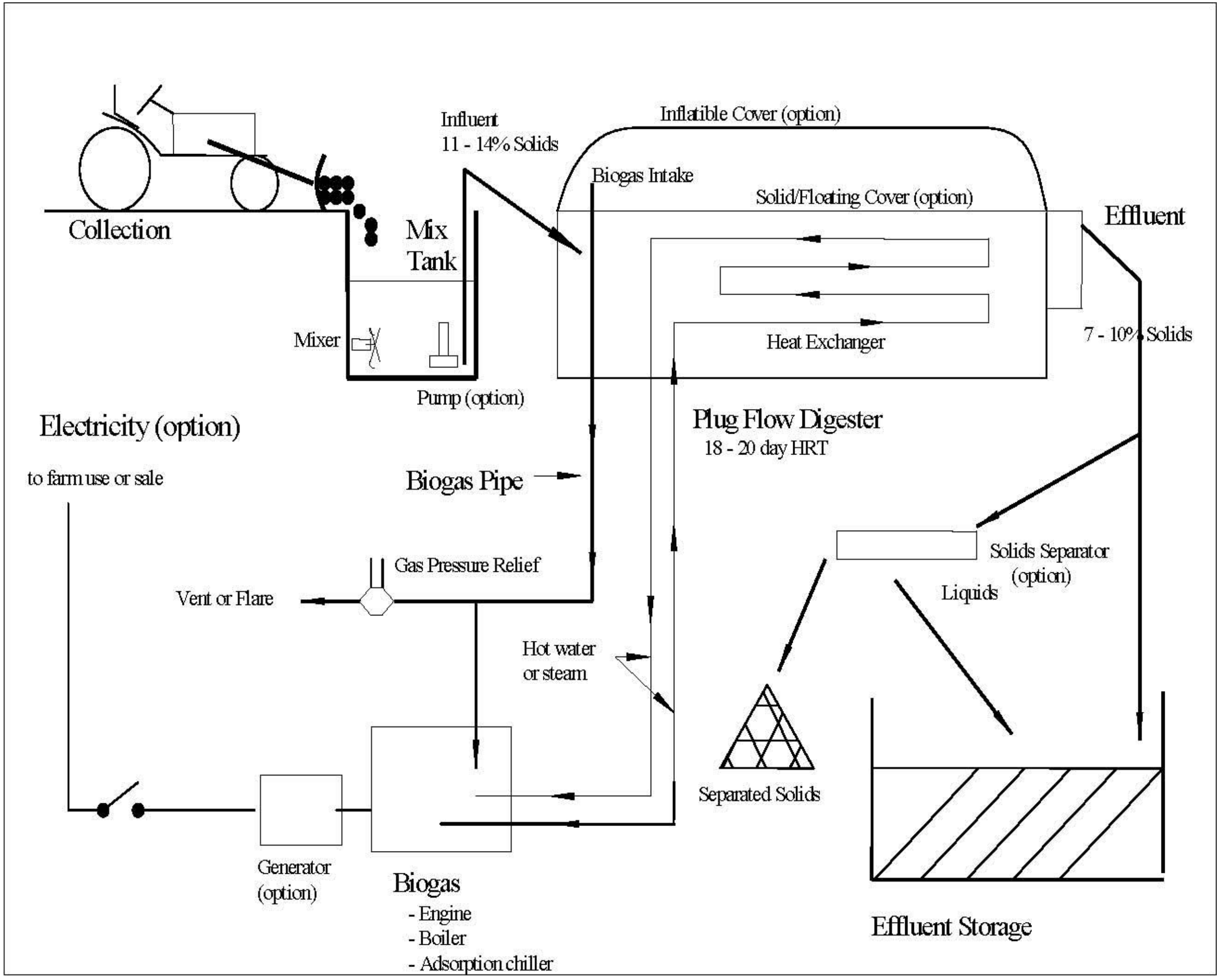
1. Animal Equivalents (ae): 1,145ae,
2. Estimated Manure Production: 17,800wet tons/year,
3. Volatile Solids (VS): 11,800lbVS/day,
4. Estimated Methane: 41,300ft3 methane/day; 15,074,500ft3 methane/year,
5. Estimated Biogas: 63,600ft3 biogas/day; 23,214,000ft3 biogas/year,
6. Estimated Electricity Production Potential: 3,700kWh/day; 1,350,500kWh/year,
7. Estimated Power Rating: 150kW,
8. Estimated Waste Heat: 8,954,253,000BTU waste heat/year,
9. AE/kW: 7.6ae/kW.

Also, electric generation from biogas at five dairy anaerobic digestion facilities in Wisconsin was reviewed (Wisconsin Agricultural Biogas Casebook, 2008). Heard size ranged from 800 to 2500 ae, and electricity production averaged 0.16 kW/ae (6.3 ae/kW), which is within 20% of the value estimated herein.

Plug Flow Digester Assessment

A plug flow digester was used in this case study since this technology is often used in dairy farm sites. Plug Flow refers to a covered rectangular in-ground concrete structure in which the feedstock is fed into one end and as more feedstock is added the substance already in the digester (the plug) slowly moves through. Biogas is collected as it rises to the top of the digester, and the digestate end products move to the far end. This is a comparatively simple technology for an anaerobic digester, and it often requires supplemental heat for optimum digestion. The heat can be generated by burning a portion of the biogas, or from excess heat from internal combustion engines (e.g., a genset). It is an appropriate technology to use for the scrape manure systems seen on most dairy farms, and is typically used in situations where the waste has a higher solid content (11-13% total solids by mass). However, other technologies, such as a complete-mix bulk fermenter, have also been successfully employed for dairy manure digestion.

Case Study Figure 1: Plug Flow Digester System



(Diagram courtesy of RCM Digesters)

Plug Flow Digester (Source: http://www.plugflowdigester.com/)

Economic Feasibility Analysis

A high-level feasibility analysis for implementing a plug flow digester and genset at the Dovin Farm was conducted using EPA's AgStar FarmWare 3.5 software with the following economic assumptions:

1. 20 year project life,
2. 20 percent down payment,
3. 25% implementation grant (e.g., Rural Energy for America Program REAP),
4. 8 percent loan interest rate,
5. 10 year loan term,
6. 10 percent project discount rate,
7. 15 percent marginal tax rate,
8. Modified Accelerated Cost Recovery System 7yr. depreciation method,
9. 3 percent annual inflation.

The assumptions in FarmWare analysis #1 should be seen as 'conventional': waste is processed in a digester and electricity is sold to the local utility (Lorain Medina Rural Electric Cooperative, Inc.) on a net-metering basis at the same average rate as is charged the farm ($0.08/kWh). In this scenario, FarmWare predicts that the unit will produce more electricity than the farm uses on an annual basis, creating a net-positive cash flow from the sale of electricity. And, the approximate annual cost of sand for bedding $56,000 is eliminated from the farm budget due to the switch from purchased sand to use of dried digester solids for bedding. In analysis #1 there are no assumed auxiliary financial benefits from the sale of renewable energy credits (RECs) or carbon credits.

The project shows a simple payback of 5 years and a net present value of $43,650 (*See* full report in Case Study Appendix A).

Case Study Table 3: "Conventional" FarmWare Assessment

Financial Estimates	Estimated Value
Capital Investment	$936,000
Annual revenue from the recovery and use of biogas	$125,700 / year
>>> Revenue received from the sale of biogas	$54,200 / year
>>> Revenue derived from on-site use of biogas	$71,500 / year
Total Annual Cost	$74,800 / year
Simple payback	5 years
Estimated average annual net income before taxes (loss)	$106,800 / year
Net present value	$43,600

FarmWare was re-run using the same economic assumptions, but revenue from the sale of RECs and carbon credits (*See* Carbon Credits below) were added. In this scenario the project shows a simple payback of 4 years and a net present value of $417,500 (*See* full report in Case Study Appendix B).

Case Study Table 4: FarmWare Assessment with REC and Carbon Credit Revenue

Financial Estimates	Estimated Value
Capital Investment	$936,000
Annual revenue from the recovery and use of biogas	$125,700 / year
>>> Revenue received from the sale of biogas	$54,200 / year
>>> Revenue derived from on-site use of biogas	$71,500 / year
Total Annual Cost	$74,800 / year
Simple payback	4 years
Estimated average annual net income before taxes (loss)	$146,800 / year
Net present value	$417,500

FarmWare was run a third time using the same economic assumptions, adding revenue from sale of RECs and carbon credits, and a feed-in-tariff price support of $0.12/kWh for the electricity sold on a net metering basis. In this scenario, the project shows a simple payback of 3 years and a net present value of $666,500 (*See* full report in Case Study Appendix C).

Case Study Table 5: FarmWare Assessment with REC, Carbon Credit, and Feed-in Tariff of $0.12/kWh

Financial Estimates	Estimated Value
Capital Investment	$936,000
Annual revenue from the recovery and use of biogas	$152,900 / year
>>> Revenue received from the sale of biogas	$81,400 / year
>>> Revenue derived from on-site use of biogas	$71,500 / year
Total Annual Cost	$74,800 / year
Simple payback	3 years
Estimated average annual net income before taxes (loss)	$174,000 / year
Net present value	$666,500

We also conducted a bottom line cash flow assessment using Modified Accelerated Cost-Recovery System (MACRS) + Bonus Depreciation (2008-2012), a federal program, (http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US06F) and the simple payback dropped to between 1 and 2 years. This clearly shows the value of current economic incentives which are set to expire soon.

Benefits of Anaerobic Digestion

Odor Control

Anaerobic digestion has been proven to drastically reduce odors, which is a significant benefit for many farms. However, odor reduction is not a significant economic benefit for this particular case because of the lack of comprehensive odor regulations in Ohio for farms the size of Dovin Dairy Farms and because the farm already manages its manure application practices to minimize odor.

Waste Management

Utilizing anaerobic digestion would also consume and eliminate a large amount of the farm's waste products. This is not a significant economic factor, however, as all of the manure produced on the farm is already being utilized and spread in the fields. With no enforced limits on nutrient spreading for farms of this size and no unused waste product to eliminate, there remains little incentive to pursue anaerobic digestion from the simple economic perspective of waste elimination.

Usable Fertilizer and Bedding

Anaerobic digestion also produces materials useable by the farm. The end product of the digestion process can be used as bedding for the cows. Pathogens are reduced through anaerobic digestion of manure, and successful applications using dried, digested biosolids for bedding material currently exist. Some research has shown that the occurrence of mastitis is not higher when using dried biosolids compared to conventional bedding, such as straw or sand. A farm's bedding management practices, stall size and configuration also contribute to pathogen control whatever bedding is used. The farm is currently spending $56,000 a year on sand, a cost that could be eliminated by switching to a bedding material that is produced on-site for no additional cost. Additionally, the nutrient-rich slurry of digested biosolids produced by anaerobic digestion can be utilized or sold as liquid fertilizer with readily available nitrogen.

Energy Production

The farm may benefit directly from the energy produced by the anaerobic digester. The electricity produced is projected to meet and exceed farm needs**.** Therefore, Dovin Farm would be able to benefit from net metering and the sale of energy to the local utility. Net metering refers to the process whereby a renewable energy producer can receive a credit on their utility bill for extra electricity produced on-site that flows back into the grid. In this way, the excess clean energy produced by the digester not used on-site would be utilized and would also provide a financial benefit to the farm. With the price of electricity in the study area ($0.08/kWh) the economics of energy sales are not as attractive for digesters as if the price per kWh approached rates seen in other regions of the U.S. (e.g., Northeast and Mid-Atlantic commercial rates can average $0.14-$0.15). This does not mean that the economics of a digester on the Dovin Farm (Rte. 58) are not necessarily unfavorable, but they would be stronger with better prices earned per kWh.

Renewable Energy Credits

Renewable energy credits: An emerging market for Renewable Energy Credits (RECs) has faltered in the State of Ohio and elsewhere. A REC represents the property rights to the environmental, social, and other non-power qualities of renewable electricity generation. A REC can be sold separately from the underlying physical electricity associated with a renewable-based generation source. One REC is created for every 1000 kilowatt-hours (or 1 megawatt-hour) of electricity placed on the grid. In the case of the Dovin Farm, the annual RECs that could be produced would be approximately 1,350/year. At an average retail price of $50/REC, this would represent additional income of $67,525.

Carbon Credits

Because an anaerobic digester would reduce the methane output of the Dovin Farm, a monetary value can be estimated for the avoided greenhouse gas. The farm might be able to convert the methane reduction to carbon credits to be sold in a carbon credit market. Organizations such as the Climate Action Reserve (www.climateactionreserve.org) have been established to independently verify and certify the carbon credits produced by a project, which can facilitate their sale in available markets (e.g., California). Verification costs can be substantial, and monitoring costs are ongoing. A rule-of-thumb for determining carbon credits shows a yield of 2,100 at the Dovin site. At current market prices of $8/credit, this represents additional potential revenue of approximately $16,800/year. A stronger carbon market, of course, would mean a better price.[10]

In general terms, implementing an anaerobic digester will address larger environmental problems by greatly reducing the farm's greenhouse gas emissions.

Considerations

Numerous financial and environmental benefits to implementing anaerobic digestion technology at Dovin Dairy Farm have been highlighted. Other considerations remain.

Manure Management

Whether a digester would alter the nutrient management plan for the farm needs further study.

Change in Bedding Practices

Utilizing dairy manure for anaerobic digestion typically requires that the bedding be switched from sand and straw to an organic, digestible product due to the destructive nature of sand on pump seals and other mechanical equipment. Or, sand separating technology could be implemented; however the technology may be cost-prohibitive. The end product of anaerobic digestion (dried biosolids) can be used as bedding, thereby providing an inexpensive alternative bedding source. Control of pathogens is a primary concern for udder health and milk production. Careful management of bedding seems to be critically important to pathogen reduction no matter what material is used (organic or inorganic). For possible comparative information, Bridgewater Dairy in Northwest, Ohio (4,200 cows) may be bedding about half its herd on digested solids, and the other half on sand, www.bridgewaterdairy.com. In addition, *See* "Reinfold Farm Case Study" performed by Penn State University Department of Agricultural and Biological Engineering, 2009. A copy can be found in Case Study Appendix D, as well as here: http://www.biogas.psu.edu/casestudies.html

Capital Costs

The initial capital costs for anaerobic digestion may present a financial barrier. An analysis of the Dovin Dairy Farm, LLC balance sheet and finances was not performed as part of this case study. From the results of the FarmWare feasibility analysis, however, it appears as if the capital costs could be manageable.

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[10] Interview with Environmental Credit Corporation, 2011.

Odor Control

Due to its size, the Dovin Dairy Farm is not required to control odor. However, most U.S. dairy producers are primarily attracted to anaerobic digestion because of the odor control benefit.

Preliminary Design

A next step in the process of considering an anaerobic digester at the Dovin Farm might be to contract with a provider to prepare a preliminary engineering design. The USDA Rural Energy for America Program (REAP) provides grants to assist with the cost of renewable energy feasibility studies, and may fund a preliminary design. More information can be found at http://www.rurdev.usda.gov/rbs/busp/REAPFEAS.htm

The US EPA's AgSTAR program provides a comprehensive "how to" handbook for project development: http://www.epa.gov/agstar/tools/project-dev/handbook.html

Partnerships

The Lorain County Joint Vocational School is an immediate neighbor to the Dovin Dairy Farm Rte 58. Senior staff expressed an interest in some form of partnership with Dovin Dairy Farm in the operation of an anaerobic digester. As an educational resource, an anaerobic digester located on LCJVS property, utilizing feedstock from the Dovin operation, could provide new curricular opportunities for the school to train students in technology-based, renewable energy systems. With the close proximity, transportation of manure to a digester located at LCJVS would not be cost prohibitive. This opportunity requires further study and investigation with the mutual agreement of both parties.

CASE STUDY APPENDIX A: FarmWare 3.5 Assessment #1 “Conventional”

Dovin Dairy Farms, LLC
Oberlin, OH

NOTICE

This assessment is provided as a first step in evaluating the technical and financial feasibility of biogas production for use as a source of energy at **Dovin Dairy Farms, LLC**. This assessment should be considered preliminary and only be used as input for determining whether to proceed with a more rigorous assessment. It is imperative that a detailed feasibility assessment be performed by a qualified engineer prior to commencing facility design or construction activities. Please consult the AgSTAR Handbook for additional references and guidance (http://www.epa.gov/agstar/tools/project-dev/FarmWare.html).

EXECUTIVE SUMMARY

This FarmWare Assessment was prepared for **Dovin Dairy Farms, LLC**, an existing dairy farm located in Oberlin, OH. **Dovin Dairy Farms, LLC** has 1,100 dairy cattle confined in a freestall scraped barn. Scraped manure and milking center wastewater is currently discharged into a conventional storage pond for storage. This assessment evaluated the costs and benefits of installing a Plug Flow Digester and capturing methane, which will be used to generate electricity using an internal combustion engine-generator set, and using the recoverable heat produced from the engine-generator to replace heat requirements on the farm.

Table ES-1 summarizes the results of a financial feasibility analysis of this modification of the existing manure management system. Table ES-2 provides estimates of the expected biogas production and the potential to generate electricity or replace fuel oil or liquefied petroleum gas (LPG).

Table ES-1
Financial Feasibility of Modifying the Conventional Manure Management System to Capture and Utilize Biogas

Financial Estimates	Estimated Value	
Capital investment	$936,035	
Annual revenue from the recovery and use of biogas	$125,772	/ year
>>> Revenue received from the sale of biogas	$54,258	/ year
>>> Revenue derived from on-site use of biogas	$71,514	/ year
Total Annual Cost	$74,883	/ year
Simple payback	5	years
Estimated average annual net income before taxes (loss)	$106,889	/ year
Net present value	$43,649	

Table ES-2
Summary of Biogas System Performance Estimates

	Estimated Potential
Biogas production	28,886,290 cu ft/year
Electricity generation	1,257,717 kWh/year

Table ES-3
Environmental Performance Comparison

	Conventional System	Biogas System
Parameter	**Storage Pond (1)**	**Plug Flow Digester with Effluent Storage (2)**
Air Quality Parameters		
Methane emissions pounds/year	41,964	Approximately 0
Ammonia Loss (%)	12%	8%
Water Quality Parameters		
COD (%) reduction from influent	3%	42%

(1) Tanks and ponds data are adapted from two dairies.

(2) Plug flow digester data are adapted from two dairies.

(3) Substantial reductions in the pathogen-indicator organisms suggest that significant reductions in other pathogens also occurred.

1.0 INTRODUCTION

This report summarizes the results of a preliminary assessment of the technical and economic feasibility of modifying the existing manure management system at **Dovin Dairy Farms, LLC** by the addition of a Plug Flow Digester and capturing methane, which will be used to generate electricity using an internal combustion engine-generator set, and using the recoverable heat produced from the engine-generator to replace heat requirements on the farm. The report is divided into five sections:

Section 2.0 User Inputs

Section 3.0 Technical Feasibility

Section 4.0 Economic Feasibility

Section 5.0 Environmental Performance

Section 6.0 Warnings

SECTION 2.0 USER INPUTS

Section 2 presents a summary of the information provided for this assessment of the technical and economic feasibility of modifying the current manure management system at Dovin Dairy Farm, LLC by adding a Plug Flow Digester and capturing methane that will be used to generate electricity using an internal combustion engine-generator set, and using the recoverable heat produced from the engine-generator to replace heat requirements on the farm. It is important to check the accuracy of this information to insure the accuracy of the assessment

Table 2-1
Summary of General Information Provided by the User

Farm name and address	Dovin Dairy Farm, LLC Oberlin, OH
Type of farm	Dairy
Confinement facilities and manure collection	Scrape Barn for Dairy Cow: Lactating
Current waste management system	Manure and milking center wastewater is discharged to a conventional Storage Pond
Proposed modification	Plug Flow Digester Addition of an engine-generator set, associated interconnection equipment, and heat recovery.

Table 2-2
Standing Animal Populations and Time Spent in Housing (Hours)

	Dairy Cow: Lactating	Dairy Calf
Number of Animals	700	400
Barn	24	
Pasture		24
Milking Center		

Table 2-3
Record of Energy Use in the Most Recent 12 Months

	Electricity		Fuel Oil		Propane (LPG)	
Month	**kWh**	**Cost ($*)**	**gal/month**	**Cost ($)**	**gal/month**	**Cost ($)**
January	52,640	3,917	0	0	668	861
February	51,280	3,610	0	0	618	797
March	45,280	3,503	0	0	917	1,183
April	63,280	5,137	0	0	497	731
May	71,120	5,983	0	0	500	735
June	105,440	8,150	0	0	437	696
July	103,840	8,412	0	0	259	391
August	109,120	8,050	0	0	410	651
September	101,280	7,889	0	0	635	971
October	75,600	6,796	0	0	1,615	2,471
November	63,040	5,708	0	0	575	879
December	52,000	4,389	0	0	1,630	2,495
Total	893,920	$71,544	0	$0	8,761	$12,861

* Excluding demand and fixed charges.

Table 2-4
Estimates of Water Use and Waste Flow through Housing

Type of Housing	Fresh Water (GPD)	Recycled Water (GPD)	Total Manure (lbs/day)
Milking Center	5,000	0	0
Barn	0	0	103,600
Pasture	0	0	10,800
Total:	5,000	0	114,400

SECTION 3.0 TECHNICAL FEASIBILITY

Table 3-1 lists the monthly biogas, methane, and Btu production potentials for **Dovin Dairy Farm, LLC** based on the information provided and summarized in Tables 2-1 through 2-4. These estimates are based on the user inputs summarized in Table 3-2.

Table 3-1
Monthly Estimates of Biogas, Methane, and Btu Production Potential

	Biogas (ft^3/month)	**Methane (ft^3/month)**	**Btu (Btu/month)**
January	2,453,356	1,410,680	1,302,057,000
February	2,215,935	1,274,162	1,176,052,000
March	2,453,356	1,410,680	1,302,057,000
April	2,374,216	1,365,174	1,260,056,000
May	2,453,356	1,410,680	1,302,057,000
June	2,374,216	1,365,174	1,260,056,000
July	2,453,356	1,410,680	1,302,057,000
August	2,453,356	1,410,680	1,302,057,000
September	2,374,216	1,365,174	1,260,056,000
October	2,453,356	1,410,680	1,302,057,000
November	2,374,216	1,365,174	1,260,056,000
December	2,453,356	1,410,680	1,302,057,000
Total	28,886,291	16,609,618	15,330,675,000

Table 3-2
Design Assumptions Used for Estimates Provided in Table 3-1

Metric	Value	
Type of biogas production system	Plug Flow Digester	
Collectable manure	90,276	lb/day
Collectable total solids	13,300	lb/day
Collectable total volatile solids	11,200	lb/day
Digester volume	33,205	ft^3
Hydraulic retention time	20	days
Surface area	3,321	ft^2

Table 3-3 lists monthly estimates of the potential use of biogas at **Dovin Dairy Farm, LLC** to generate electricity or replace fuel oil or liquefied petroleum gas. Table 3-4 compares these estimates with historical use patterns.

Table 3-3
Monthly Estimates of the Potential of Using Biogas to Generate Electricity

Month	Electricity (kWh/month)	Gallons of LPG Saved by Using Recoverable Heat
January	133,525	45
February	120,603	40
March	133,525	45
April	129,218	43
May	133,525	45
June	129,218	43
July	133,525	45
August	133,525	45
September	129,218	43
October	133,525	45
November	129,218	43
December	133,525	45

Table 3-4
Energy Balance for Net Metering

Month	Historical Use (kWh)	Biogas Electricity Generation Potential (kWh)	For Net Metering: End of Month Balance*
January	52,640	133,525	80,885
February	51,280	120,603	150,208
March	45,280	133,525	238,452
April	63,280	129,218	304,390
May	71,120	133,525	366,795
June	105,440	129,218	390,572
July	103,840	133,525	420,257
August	109,120	133,525	444,662
September	101,280	129,218	472,599
October	75,600	133,525	530,524
November	63,040	129,218	596,702
December	52,000	133,525	678,226
Total	893,920	1,572,146	4,674,272

*Based on the assumptions that there is: (1) no carryover of the December kWh balance to the next January with the biogas producer receiving payment for the kWh balance at the end of December and (2) no deletion from the end of the month kWh balance to off-set demand or other changes or both.

4.0 ECONOMIC FEASIBILITY

Table 4-1 presents the capital costs of the digester system and the assumptions used to estimate the potential gross income realized from biogas utilization. Table 4-2 presents a monthly cash flow analysis based on the values in Table 4-1.

Table 4-1
Financial Factors

Financial Factor	Value
Capital Cost of Digester System[1]	$936,035
Project Lifetime	20 Years
Down Payment Percentage	20 Percent
Loan Interest Rate	8 Percent
Loan Term	10 Years
Project Discount Rate	10 Percent
Marginal Tax Rate	15 Percent
Depreciation Method	MACRS7
General Annual Inflation Rate	3.00 Percent

1. Cost breakout is approximately 10% for engineering, 50% for digester installation, and 40% for engine generator set.

Table 4-2
Estimate of Net Income or Loss Associated with Biogas Production and Utilization

Month	Future Energy Cost ($)	Value of Energy, Derived from Biogas, Used Onsite ($)	Value of Energy, Derived from Biogas, Delivered to Grid ($)	Costs Associated with Generating Energy Derived From Biogas ($)	Saved Energy Expense ($)
January	4,211	4,211	0	2,340	1,871
February	4,102	4,102	0	2,340	1,762
March	3,622	3,622	0	2,340	1,282
April	5,062	5,062	0	2,340	2,722
May	5,690	5,690	0	2,340	3,350
June	8,435	8,435	0	2,340	6,095
July	8,307	8,307	0	2,340	5,967
August	8,730	8,730	0	2,340	6,390
September	8,102	8,102	0	2,340	5,762
October	6,048	6,048	0	2,340	3,708
November	5,043	5,043	0	2,340	2,703
December	4,160	4,160	54,258	2,340	1,820
Total	$71,514	$71,514	$54,258	$28,081	$43,433

5.0 ENVIRONMENTAL PERFORMANCE

Table 5-1
Environmental Performance Comparison

	Conventional System	Biogas System
Parameter	**Storage Pond (1)**	**Plug Flow Digester with Effluent Storage (2)**
Air Quality		
Methane emissions pounds/year	41,964	Approximately 0
Hydrogen Sulfide reduction	No reduction	Notable reduction
Odor Control	None	Digesters produce substantially less odor than conventional systems due to reductions in emissions of hydrogen sulfide and various VOCs such as mercaptans and skatole
Ammonia Loss (%)	12%	8%
Water Quality Parameters		
COD (%) reduction from influent	3%	42%
Total Nitrogen (%) reduction from influent	9%	5%
Total Phosphorus (%) reduction from influent	No reduction	No reduction
Fecal Coliforms (3), Log10 CFU reduction from influent	0.7	Digester: 2.8 Storage: +1.2 (regrowth)
Pathogens, Log10 CFU reduction from influent	+ 0.04 (M. avium paratuberculosis)	Digester: 2.1 Storage: No data (M. avium paratuberculosis)

(1) Tanks and ponds data are adapted from two dairies.

(2) Plug flow digester data are adapted from two dairies.

(3) Substantial reductions in the pathogen-indicator organisms suggest that significant reductions in other pathogens also occurred.

6.0 WARNINGS

1.

There were no warnings generated for this assessment.

CASE STUDY APPENDIX B: FarmWare 3.5 Assessment #2, with REC and Carbon Credit Revenue

Dovin Dairy Farms, LLC
Oberlin, OH

NOTICE

This assessment is provided as a first step in evaluating the technical and financial feasibility of biogas production for use as a source of energy at **Dovin Dairy Farms, LLC**. This assessment should be considered preliminary and only be used as input for determining whether to proceed with a more rigorous assessment. It is imperative that a detailed feasibility assessment be performed by a qualified engineer prior to commencing facility design or construction activities. Please consult the AgSTAR Handbook for additional references and guidance (http://www.epa.gov/agstar/tools/project-dev/FarmWare.html).

EXECUTIVE SUMMARY

This FarmWare Assessment was prepared for **Dovin Dairy Farms, LLC**, an existing dairy farm located in Oberlin, OH. **Dovin Dairy Farms, LLC** has 1,100 dairy cattle confined in a freestall scraped barn. Scraped manure and milking center wastewater is currently discharged into a conventional storage pond for storage. This assessment evaluated the costs and benefits of installing a Plug Flow Digester and capturing methane, which will be used to generate electricity using an internal combustion engine-generator set, and using the recoverable heat produced from the engine-generator to replace heat requirements on the farm.

Table ES-1 summarizes the results of a financial feasibility analysis of this modification of the existing manure management system. Table ES-2 provides estimates of the expected biogas production and the potential to generate electricity or replace fuel oil or liquefied petroleum gas (LPG).

Table ES-1
Financial Feasibility of Modifying the Conventional Manure Management System to Capture and Utilize Biogas

Financial Estimates	Estimated Value	
Capital investment	$936,035	
Annual revenue from the recovery and use of biogas	$125,772	/ year
>>> Revenue received from the sale of biogas	$54,258	/ year
>>> Revenue derived from on-site use of biogas	$71,514	/ year
Total Annual Cost	$74,883	/ year
Simple payback	4	years
Estimated average annual net income before taxes (loss)	$146,889	/ year
Net present value	$417,465	

Table ES-2
Summary of Biogas System Performance Estimates

	Estimated Potential
Biogas production	28,886,290 cu ft/year
Electricity generation	1,257,717 kWh/year

Table ES-3
Environmental Performance Comparison

	Conventional System	Biogas System
Parameter	**Storage Pond (1)**	**Plug Flow Digester with Effluent Storage (2)**
Air Quality Parameters		
Methane emissions pounds/year	41,964	Approximately 0
Ammonia Loss (%)	12%	8%
Water Quality Parameters		
COD (%) reduction from influent	3%	42%

(1) Tanks and ponds data are adapted from two dairies.

(2) Plug flow digester data are adapted from two dairies.

(3) Substantial reductions in the pathogen-indicator organisms suggest that significant reductions in other pathogens also occurred.

1.0 INTRODUCTION

This report summarizes the results of a preliminary assessment of the technical and economic feasibility of modifying the existing manure management system at **Dovin Dairy Farms, LLC** by the addition of a Plug Flow Digester and capturing methane, which will be used to generate electricity using an internal combustion engine-generator set, and using the recoverable heat produced from the engine-generator to replace heat requirements on the farm. The report is divided into five sections:

Section 2.0 User Inputs

Section 3.0 Technical Feasibility

Section 4.0 Economic Feasibility

Section 5.0 Environmental Performance

Section 6.0 Warnings

SECTION 2.0 USER INPUTS

Section 2 presents a summary of the information provided for this assessment of the technical and economic feasibility of modifying the current manure management system at Dovin Dairy Farm, LLC by adding a Plug Flow Digester and capturing methane that will be used to generate electricity using an internal combustion engine-generator set, and using the recoverable heat produced from the engine-generator to replace heat requirements on the farm. It is important to check the accuracy of this information to insure the accuracy of the assessment.

Table 2-1
Summary of General Information Provided by the User

Farm name and address	Dovin Dairy Farm, LLC Oberlin, OH
Type of farm	Dairy
Confinement facilities and manure collection	Scrape Barn for Dairy Cow: Lactating
Current waste management system	Manure and milking center wastewater is discharged to a conventional Storage Pond
Proposed modification	Plug Flow Digester Addition of an engine-generator set, associated interconnection equipment, and heat recovery.

Table 2-2
Standing Animal Populations and Time Spent in Housing (Hours)

	Dairy Cow: Lactating	**Dairy Calf**
Number of Animals	700	400
Barn	24	
Pasture		24
Milking Center		

Table 2-3
Record of Energy Use in the Most Recent 12 Months

	Electricity		Fuel Oil		Propane (LPG)	
Month	**kWh**	**Cost ($*)**	**gal/month**	**Cost ($)**	**gal/month**	**Cost ($)**
January	52,640	3,917	0	0	668	861
February	51,280	3,610	0	0	618	797
March	45,280	3,503	0	0	917	1,183
April	63,280	5,137	0	0	497	731
May	71,120	5,983	0	0	500	735
June	105,440	8,150	0	0	437	696
July	103,840	8,412	0	0	259	391
August	109,120	8,050	0	0	410	651
September	101,280	7,889	0	0	635	971
October	75,600	6,796	0	0	1,615	2,471
November	63,040	5,708	0	0	575	879
December	52,000	4,389	0	0	1,630	2,495
Total	893,920	$71,544	0	$0	8,761	$12,861

* Excluding demand and fixed charges.

Table 2-4
Estimates of Water Use and Waste Flow through Housing

Type of Housing	Fresh Water (GPD)	Recycled Water (GPD)	Total Manure (lbs/day)
Milking Center	5,000	0	0
Barn	0	0	103,600
Pasture	0	0	10,800
Total:	5,000	0	114,400

SECTION 3.0 TECHNICAL FEASIBILITY

Table 3-1 lists the monthly biogas, methane, and Btu production potentials for **Dovin Dairy Farm, LLC** based on the information provided and summarized in Tables 2-1 through 2-4. These estimates are based on the user inputs summarized in Table 3-2.

Table 3-1
Monthly Estimates of Biogas, Methane, and Btu Production Potential

	Biogas (ft^3/month)	Methane (ft^3/month)	Btu (Btu/month)
January	2,453,356	1,410,680	1,302,057,000
February	2,215,935	1,274,162	1,176,052,000
March	2,453,356	1,410,680	1,302,057,000
April	2,374,216	1,365,174	1,260,056,000
May	2,453,356	1,410,680	1,302,057,000
June	2,374,216	1,365,174	1,260,056,000
July	2,453,356	1,410,680	1,302,057,000
August	2,453,356	1,410,680	1,302,057,000
September	2,374,216	1,365,174	1,260,056,000
October	2,453,356	1,410,680	1,302,057,000
November	2,374,216	1,365,174	1,260,056,000
December	2,453,356	1,410,680	1,302,057,000
Total	28,886,291	16,609,618	15,330,675,000

Table 3-2
Design Assumptions Used for Estimates Provided in Table 3-1

Metric	Value	
Type of biogas production system	Plug Flow Digester	
Collectable manure	90,276	lb/day
Collectable total solids	13,300	lb/day
Collectable total volatile solids	11,200	lb/day
Digester volume	33,205	ft^3
Hydraulic retention time	20	days
Surface area	3,321	ft^2

Table 3-3 lists monthly estimates of the potential use of biogas at **Dovin Dairy Farm, LLC** to generate electricity or replace fuel oil or liquefied petroleum gas. Table 3-4 compares these estimates with historical use patterns.

Table 3-3
Monthly Estimates of the Potential of Using Biogas to Generate Electricity

Month	Electricity (kWh/month)	Gallons of LPG Saved by Using Recoverable Heat
January	133,525	45
February	120,603	40
March	133,525	45
April	129,218	43
May	133,525	45
June	129,218	43
July	133,525	45
August	133,525	45
September	129,218	43
October	133,525	45
November	129,218	43
December	133,525	45

Table 3-4
Energy Balance for Net Metering

Month	Historical Use (kWh)	Biogas Electricity Generation Potential (kWh)	For Net Metering: End of Month Balance*
January	52,640	133,525	80,885
February	51,280	120,603	150,208
March	45,280	133,525	238,452
April	63,280	129,218	304,390
May	71,120	133,525	366,795
June	105,440	129,218	390,572
July	103,840	133,525	420,257
August	109,120	133,525	444,662
September	101,280	129,218	472,599
October	75,600	133,525	530,524
November	63,040	129,218	596,702
December	52,000	133,525	678,226
Total	893,920	1,572,146	4,674,272

*Based on the assumptions that there is: (1) no carryover of the December kWh balance to the next January with the biogas producer receiving payment for the kWh balance at the end of December and (2) no deletion from the end of the month kWh balance to off-set demand or other changes or both.

4.0 ECONOMIC FEASIBILITY

Table 4-1 presents the capital costs of the digester system and the assumptions used to estimate the potential gross income realized from biogas utilization. Table 4-2 presents a monthly cash flow analysis based on the values in Table 4-1.

Table 4-1
Financial Factors

Financial Factor	Value
Capital Cost of Digester System[1]	$936,035
Project Lifetime	20 Years
Down Payment Percentage	20 Percent
Loan Interest Rate	8 Percent
Loan Term	10 Years
Project Discount Rate	10 Percent
Marginal Tax Rate	15 Percent
Depreciation Method	MACRS7
General Annual Inflation Rate	3.00 Percent

1. Cost breakout is approximately 10% for engineering, 50% for digester installation, and 40% for engine generator set.

Table 4-2
Estimate of Net Income or Loss Associated with Biogas Production and Utilization

Month	Future Energy Cost ($)	Value of Energy, Derived from Biogas, Used Onsite ($)	Value of Energy, Derived from Biogas, Delivered to Grid ($)	Costs Associated with Generating Energy Derived From Biogas ($)	Saved Energy Expense ($)
January	4,211	4,211	0	2,340	1,871
February	4,102	4,102	0	2,340	1,762
March	3,622	3,622	0	2,340	1,282
April	5,062	5,062	0	2,340	2,722
May	5,690	5,690	0	2,340	3,350
June	8,435	8,435	0	2,340	6,095
July	8,307	8,307	0	2,340	5,967
August	8,730	8,730	0	2,340	6,390
September	8,102	8,102	0	2,340	5,762
October	6,048	6,048	0	2,340	3,708
November	5,043	5,043	0	2,340	2,703
December	4,160	4,160	54,258	2,340	1,820
Total	$71,514	$71,514	$54,258	$28,081	$43,433

5.0 ENVIRONMENTAL PERFORMANCE

Table 5-1
Environmental Performance Comparison

	Conventional System	Biogas System
Parameter	**Storage Pond (1)**	**Plug Flow Digester with Effluent Storage (2)**
Air Quality		
Methane emissions pounds/year	41,964	Approximately 0
Hydrogen Sulfide reduction	No reduction	Notable reduction
Odor Control	None	Digesters produce substantially less odor than conventional systems due to reductions in emissions of hydrogen sulfide and various VOCs such as mercaptans and skatole
Ammonia Loss (%)	12%	8%
Water Quality Parameters		
COD (%) reduction from influent	3%	42%
Total Nitrogen (%) reduction from influent	9%	5%
Total Phosphorus (%) reduction from influent	No reduction	No reduction
Fecal Coliforms (3), Log10 CFU reduction from influent	0.7	Digester: 2.8 Storage: +1.2 (regrowth)
Pathogens, Log10 CFU reduction from influent	+ 0.04 (M. avium paratuberculosis)	Digester: 2.1 Storage: No data (M. avium paratuberculosis)

(1) Tanks and ponds data are adapted from two dairies.

(2) Plug flow digester data are adapted from two dairies.

(3) Substantial reductions in the pathogen-indicator organisms suggest that significant reductions in other pathogens also occurred.

6.0 WARNINGS

1.

There were no warnings generated for this assessment.

CASE STUDY APPENDIX C: FarmWare 3.5 Assessment #3 with REC, Carbon Credit, and Feed-In-Tariff Revenue

Dovin Dairy Farms, LLC
Oberlin, OH

NOTICE

This assessment is provided as a first step in evaluating the technical and financial feasibility of biogas production for use as a source of energy at **Dovin Dairy Farms, LLC**. This assessment should be considered preliminary and only be used as input for determining whether to proceed with a more rigorous assessment. It is imperative that a detailed feasibility assessment be performed by a qualified engineer prior to commencing facility design or construction activities. Please consult the AgSTAR Handbook for additional references and guidance (http://www.epa.gov/agstar/tools/project-dev/FarmWare.html).

EXECUTIVE SUMMARY

This FarmWare Assessment was prepared for **Dovin Dairy Farms, LLC**, an existing dairy farm located in Oberlin, OH. **Dovin Dairy Farms, LLC** has 1,100 dairy cattle confined in a freestall scraped barn. Scraped manure and milking center wastewater is currently discharged into a conventional storage pond for storage. This assessment evaluated the costs and benefits of installing a Plug Flow Digester and capturing methane, which will be used to generate electricity using an internal combustion engine-generator set, and using the recoverable heat produced from the engine-generator to replace heat requirements on the farm.

Table ES-1 summarizes the results of a financial feasibility analysis of this modification of the existing manure management system. Table ES-2 provides estimates of the expected biogas production and the potential to generate electricity or replace fuel oil or liquefied petroleum gas (LPG).

Table ES-1
Financial Feasibility of Modifying the Conventional Manure Management System to Capture and Utilize Biogas

Financial Estimates	Estimated Value	
Capital investment	$936,035	
Annual revenue from the recovery and use of biogas	$152,901	/ year
>>> Revenue received from the sale of biogas	$81,387	/ year
>>> Revenue derived from on-site use of biogas	$71,514	/ year
Total Annual Cost	$74,883	/ year
Simple payback	3	years
Estimated average annual net income before taxes (loss)	$174,018	/ year
Net present value	$666,531	

Table ES-2
Summary of Biogas System Performance Estimates

	Estimated Potential
Biogas production	28,886,290 cu ft/year
Electricity generation	1,257,717 kWh/year

Table ES-3
Environmental Performance Comparison

	Conventional System	Biogas System
Parameter	**Storage Pond (1)**	**Plug Flow Digester with Effluent Storage (2)**
Air Quality Parameters		
Methane emissions pounds/year	41,964	Approximately 0
Ammonia Loss (%)	12%	8%
Water Quality Parameters		
COD (%) reduction from influent	3%	42%

(1) Tanks and ponds data are adapted from two dairies.

(2) Plug flow digester data are adapted from two dairies.

(3) Substantial reductions in the pathogen-indicator organisms suggest that significant reductions in other pathogens also occurred.

1.0 INTRODUCTION

This report summarizes the results of a preliminary assessment of the technical and economic feasibility of modifying the existing manure management system at **Dovin Dairy Farms, LLC** by the addition of a Plug Flow Digester and capturing methane, which will be used to generate electricity using an internal combustion engine-generator set, and using the recoverable heat produced from the engine-generator to replace heat requirements on the farm. The report is divided into five sections:

Section 2.0 User Inputs

Section 3.0 Technical Feasibility

Section 4.0 Economic Feasibility

Section 5.0 Environmental Performance

Section 6.0 Warnings

SECTION 2.0 USER INPUTS

Section 2 presents a summary of the information provided for this assessment of the technical and economic feasibility of modifying the current manure management system at Dovin Dairy Farm, LLC by adding a Plug Flow Digester and capturing methane that will be used to generate electricity using an internal combustion engine-generator set, and using the recoverable heat produced from the engine-generator to replace heat requirements on the farm. It is important to check the accuracy of this information to insure the accuracy of the assessment

Table 2-1
Summary of General Information Provided by the User

Farm name and address	Dovin Dairy Farm, LLC Oberlin, OH
Type of farm	Dairy
Confinement facilities and manure collection	Scrape Barn for Dairy Cow: Lactating
Current waste management system	Manure and milking center wastewater is discharged to a conventional Storage Pond
Proposed modification	Plug Flow Digester Addition of an engine-generator set, associated interconnection equipment, and heat recovery.

Table 2-2
Standing Animal Populations and Time Spent in Housing (Hours)

	Dairy Cow: Lactating	Dairy Calf
Number of Animals	700	400
Barn	24	
Pasture		24
Milking Center		

Table 2-3
Record of Energy Use in the Most Recent 12 Months

	Electricity		Fuel Oil		Propane (LPG)	
Month	**kWh**	**Cost ($*)**	**gal/month**	**Cost ($)**	**gal/month**	**Cost ($)**
January	52,640	3,917	0	0	668	861
February	51,280	3,610	0	0	618	797
March	45,280	3,503	0	0	917	1,183
April	63,280	5,137	0	0	497	731
May	71,120	5,983	0	0	500	735
June	105,440	8,150	0	0	437	696
July	103,840	8,412	0	0	259	391
August	109,120	8,050	0	0	410	651
September	101,280	7,889	0	0	635	971
October	75,600	6,796	0	0	1,615	2,471
November	63,040	5,708	0	0	575	879
December	52,000	4,389	0	0	1,630	2,495
Total	893,920	$71,544	0	$0	8,761	$12,861

* Excluding demand and fixed charges.

Table 2-4
Estimates of Water Use and Waste Flow through Housing

Type of Housing	Fresh Water (GPD)	Recycled Water (GPD)	Total Manure (lbs/day)
Milking Center	5,000	0	0
Barn	0	0	103,600
Pasture	0	0	10,800
Total:	5,000	0	114,400

SECTION 3.0 TECHNICAL FEASIBILITY

Table 3-1 lists the monthly biogas, methane, and Btu production potentials for **Dovin Dairy Farm, LLC** based on the information provided and summarized in Tables 2-1 through 2-4. These estimates are based on the user inputs summarized in Table 3-2.

Table 3-1
Monthly Estimates of Biogas, Methane, and Btu Production Potential

	Biogas (ft^3/month)	**Methane (ft^3/month)**	**Btu (Btu/month)**
January	2,453,356	1,410,680	1,302,057,000
February	2,215,935	1,274,162	1,176,052,000
March	2,453,356	1,410,680	1,302,057,000
April	2,374,216	1,365,174	1,260,056,000
May	2,453,356	1,410,680	1,302,057,000
June	2,374,216	1,365,174	1,260,056,000
July	2,453,356	1,410,680	1,302,057,000
August	2,453,356	1,410,680	1,302,057,000
September	2,374,216	1,365,174	1,260,056,000
October	2,453,356	1,410,680	1,302,057,000
November	2,374,216	1,365,174	1,260,056,000
December	2,453,356	1,410,680	1,302,057,000
Total	28,886,291	16,609,618	15,330,675,000

Table 3-2
Design Assumptions Used for Estimates Provided in Table 3-1

Metric	Value	
Type of biogas production system	Plug Flow Digester	
Collectable manure	90,276	lb/day
Collectable total solids	13,300	lb/day
Collectable total volatile solids	11,200	lb/day
Digester volume	33,205	ft^3
Hydraulic retention time	20	days
Surface area	3,321	ft^2

Table 3-3 lists monthly estimates of the potential use of biogas at **Dovin Dairy Farm, LLC** to generate electricity or replace fuel oil or liquefied petroleum gas. Table 3-4 compares these estimates with historical use patterns.

Table 3-3
Monthly Estimates of the Potential of Using Biogas to Generate Electricity

Month	Electricity (kWh/month)	Gallons of LPG Saved by Using Recoverable Heat
January	133,525	45
February	120,603	40
March	133,525	45
April	129,218	43
May	133,525	45
June	129,218	43
July	133,525	45
August	133,525	45
September	129,218	43
October	133,525	45
November	129,218	43
December	133,525	45

Table 3-4
Energy Balance for Net Metering

Month	Historical Use (kWh)	Biogas Electricity Generation Potential (kWh)	For Net Metering: End of Month Balance*
January	52,640	133,525	80,885
February	51,280	120,603	150,208
March	45,280	133,525	238,452
April	63,280	129,218	304,390
May	71,120	133,525	366,795
June	105,440	129,218	390,572
July	103,840	133,525	420,257
August	109,120	133,525	444,662
September	101,280	129,218	472,599
October	75,600	133,525	530,524
November	63,040	129,218	596,702
December	52,000	133,525	678,226
Total	893,920	1,572,146	4,674,272

*Based on the assumptions that there is: (1) no carryover of the December kWh balance to the next January with the biogas producer receiving payment for the kWh balance at the end of December and (2) no deletion from the end of the month kWh balance to off-set demand or other changes or both.

4.0 ECONOMIC FEASIBILITY

Table 4-1 presents the capital costs of the digester system and the assumptions used to estimate the potential gross income realized from biogas utilization. Table 4-2 presents a monthly cash flow analysis based on the values in Table 4-1.

Table 4-1
Financial Factors

Financial Factor	Value
Capital Cost of Digester System[1]	$936,035
Project Lifetime	20 Years
Down Payment Percentage	20 Percent
Loan Interest Rate	8 Percent
Loan Term	10 Years
Project Discount Rate	10 Percent
Marginal Tax Rate	15 Percent
Depreciation Method	MACRS7
General Annual Inflation Rate	3.00 Percent

[1] Cost breakout is approximately 10% for engineering, 50% for digester installation, and 40% for engine generator set.

Table 4-2
Estimate of Net Income or Loss Associated with Biogas Production and Utilization

Month	Future Energy Cost ($)	Value of Energy, Derived from Biogas, Used Onsite ($)	Value of Energy, Derived from Biogas, Delivered to Grid ($)	Costs Associated with Generating Energy Derived From Biogas ($)	Saved Energy Expense ($)
January	4,211	4,211	0	2,340	1,871
February	4,102	4,102	0	2,340	1,762
March	3,622	3,622	0	2,340	1,282
April	5,062	5,062	0	2,340	2,722
May	5,690	5,690	0	2,340	3,350
June	8,435	8,435	0	2,340	6,095
July	8,307	8,307	0	2,340	5,967
August	8,730	8,730	0	2,340	6,390
September	8,102	8,102	0	2,340	5,762
October	6,048	6,048	0	2,340	3,708
November	5,043	5,043	0	2,340	2,703
December	4,160	4,160	81,387	2,340	1,820
Total	$71,514	$71,514	$81,387	$28,081	$43,433

5.0 ENVIRONMENTAL PERFORMANCE

Table 5-1
Environmental Performance Comparison

	Conventional System	Biogas System
Parameter	**Storage Pond (1)**	**Plug Flow Digester with Effluent Storage (2)**
Air Quality		
Methane emissions pounds/year	41,964	Approximately 0
Hydrogen Sulfide reduction	No reduction	Notable reduction
Odor Control	None	Digesters produce substantially less odor than conventional systems due to reductions in emissions of hydrogen sulfide and various VOCs such as mercaptans and skatole
Ammonia Loss (%)	12%	8%
Water Quality Parameters		
COD (%) reduction from influent	3%	42%
Total Nitrogen (%) reduction from influent	9%	5%
Total Phosphorus (%) reduction from influent	No reduction	No reduction
Fecal Coliforms (3), Log10 CFU reduction from influent	0.7	Digester: 2.8 Storage: +1.2 (regrowth)
Pathogens, Log10 CFU reduction from influent	+ 0.04 (M. avium paratuberculosis)	Digester: 2.1 Storage: No data (M. avium paratuberculosis)

(1) Tanks and ponds data are adapted from two dairies.

(2) Plug flow digester data are adapted from two dairies.

(3) Substantial reductions in the pathogen-indicator organisms suggest that significant reductions in other pathogens also occurred.

6.0 WARNINGS

1.

There were no warnings generated for this assessment.

CASE STUDY APPENDIX D: REINFOLD FARM CASE STUDY, 2009

PENNSTATE

Department of Agricultural
and Biological Engineering

Reinfold Farm

Type of farm: Dairy

Name of farm: Reinford Farm

County: Juniata

Anaerobic digester operator: Drew Reinford

Digester designer: RCM Digesters Berkeley, CA

Digester Installer: Reinford Farm acted as the general contractor

Construction start date: August 2007

Date Digester became operational: February 2008

Number of animals contributing to the digester: 470, milking and dry

Type of Barn: freestall

Manure handling system: continuous alley scraped

Type of Bedding: separated, digested manure solids

Type of digester: Complete Mix

Digester cover: flexible

Digester temperature: mesophilic 100°F

Biogas uses: operate the CHP unit to produce electricity and heat

Biogas utilization equipment: Caterpillar 342 engine with a 130kW single phase 220 volt generator, auto flare

Recovered heat utilization: engine generator water and exhaust jackets to heat digester,

hot water for milking parlor, heat to milking parlor, calf milk pasteurizer, house, domestic hot water and shop floor heat; engine radiator hot air provides supplemental heat for grain drying.

Power Purchase Agreement: Yes

2009 July Status of Digester: operational

www.biogas.psu.edu 246 Agricultural Engineering Building, University Park, PA 16802 (814) 863-7960

Introduction:

Reinford Farm is located in Juniata County, Pennsylvania. The dairy farm was purchased in 1991, starting out with 57 dairy cows and 144 acres. Currently the farm consists of 440 milking cows, 30 dry cows and 180 acres. A total of 900 acres are farmed and heifers are raised on another farm. Plans are in motion to bring all the heifers to the main farm. In 2003 the family thought about putting in an anaerobic digester; mainly for odor control, but also for a planned farm expansion and power production to reduce or totally eliminate the purchase of electrical power from the local utility, Pennsylvania Power and Light (PPL). Son, Brett led the way in gathering anaerobic digester information. The Reinford's visited other farms with anaerobic digesters and attended various meetings on the topic. One such meeting was The Dairy Summit, at which they found the designer for their digester project. The Reinford's are very innovative and progressive in how they upgrade and operate their farm. They have not only put in the anaerobic digester for odor reduction and power production, but also have installed a calf milk pasteurizer and grain drier that utilizes rejected heat from the gen-set. The Reinford Farm was the first farm East of the Mississippi to have a Westfalia Carousel milking parlor and the first anaerobic digester on the East Coast to have a RCM, Inc. H2S scrubber installed. Expansion is planned, for a new 500 cow freestall barn, but has been temporarily placed on hold. The family farm has received the Dairy of Distinction Award and Dairy Quality Award.

The digester currently receives manure from 470 cows of which 440 are milking and 30 dry cows. The manure from the dry cows, heifers and calves on another farm just down the road does not enter the digester. Drew Reinford is the digester operator.

Digester Information:

RCM Digesters from Berkeley, CA designed the Reinford digester. Team Ag Inc. from Ephrata, Pennsylvania provided the Professional Engineering services for the project. Reinford Farm acted as the General Contractor and hired a Project Manager to oversee all construction. Construction for the complete mix digester started the first week of August 2007 with a February 2008 start-up. The digester is designed for 1000 cows and an operating mesophilic temperature of 100oF. Currently the digester is operating at the designed 100oF, with the manure from 470 cows. Continuous alley scrapers are used to remove the manure from the freestall barn and daily scrape from the dry cow barn to a concrete holding tank, where gravity flow moves the manure through a 30 inch pipe to the 20' L x 20' W x 12' D influent tank. Reinford's received additional feedstock, spent brewers yeast, during the first few months of operation; 6,000 gallon loads were put into the manure influent tank with each yeast delivery. A Houle 10 hp mixer is used in the influent tank to mix the manure. The total amount of manure introduced into the digester each day is 11,000 gallons. The influent pump to the digester is a 5 hp Houle piston pump which starts and runs 12 minutes every 4 hours. Three Houle 20 hp (two 10 hp motors) mixers are used to mix the digester tank. The complete mix digester is a m circular, heated, mostly below ground tank sized at 80' in diameter x 16' deep and has a non-expanding flexible cover. The manure capacity of the digester is 526,000 gallons (70,370ft3) when two feet of freeboard is maintained. Recovered hot water from the CHP unit is circulated through internal heating pipes inside the digester. Two inches of insulation surrounds the outside of the digester with four inches of insulation covering the top to help maintain the 100oF temperature. The heated, complete mix digester is designed for a hydraulic retention time (HRT) of 21 - 24 days at 10 – 12% solids, and is currently operating at about 48 day HRT with about 14% solids. Biogas is produced and collected under the non-expanding flexible cover. The digester cover is a black plastic 60 mil thick material. All milking parlor waste water and copper sulfate foot bath waste by-pass the digester.

Complete Mix digester with non-expandable flexible cover.

Manure influent, effluent and digester temperatures are recorded daily from probes within the digester. Influent and effluent, manure total and volatile solids and nutrients are analyzed twice per year. In the summer of 2008, with yeast waste added to the digester influent, the total solids reduction was 10.3% with volatile solids reduction of 9.6%.

Biogas System:

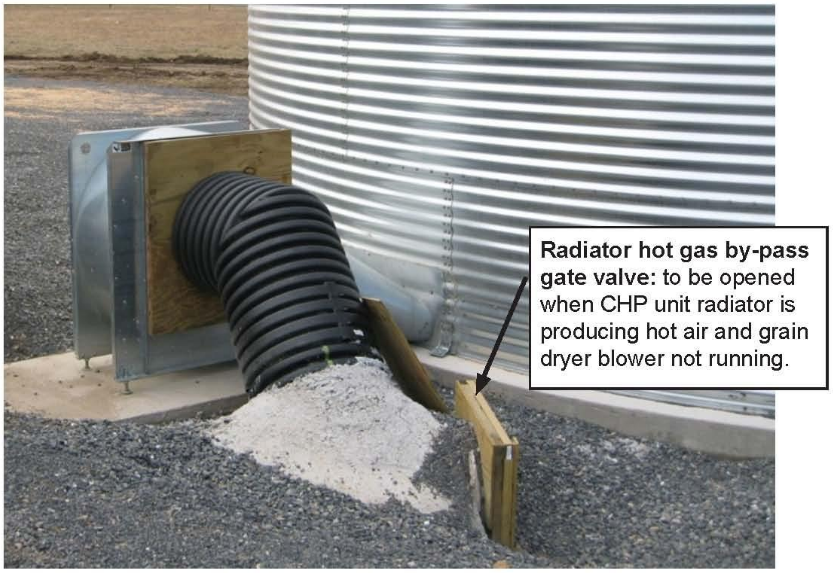
Biogas is piped underground through PVC pipe to the engine generator set. A hydrogen sulfide removal system is also used to pre-treat the biogas before it enters the engine. Biogas production measured on the Fox Thermal Instrument gas meter averages 50,000 to 60,000 ft3/day. An auto flare burns any excess biogas not consumed by the engine generator set. A Bacharach Fyrite® Gas Analyzer is used to manually measure the CO2 concentration in the biogas and is typically 36%; the calculated methane concentration is 64%. The hydrogen sulfide content in the untreated biogas measures in the range of 2500 ppm.

Combined heat and power unit (CHP):

The biogas is piped to a reconditioned, 1200 rpm Caterpillar G342 engine coupled to a 250 volt AC, 60 hertz, single phase 130kW generator purchased from Martin Machinery Inc. of Ephrata, PA. Heat recovered from the engine water jacket heats water for the digester, milking parlor, a calf milk pasteurizer, farmhouse heat and domestic hot water. This hot water is also used as radiant heat in the floor of the work shed and office space. A grain bin installed in November 2008 uses the waste heat from the radiator of the engine to dry the grain. The CHP unit runs 24/7/365 days a year except during maintenance. All power is sold to the local utility. Brad Penn engine lubrication oil is being used and changed every 400 hours of operation. Engine oil analysis is performed after each oil change and the results are reviewed by Martin Machinery Inc.

Waste heat recovered from the engine water jacket heats hot water to pasteurize milk for the new born calves in this pasteurizer.

Capturing and sending the heat from the engine radiator over to the grain drier.


Radiator hot gas by-pass gate valve: to be opened when CHP unit radiator is producing hot air and grain dryer blower not running.

Waste heat from the engine radiator entering the circulating fan for the grain drier.

G342 Caterpillar, 1200 rpm engine with 250 Volt, 1 phase generator.

Power purchase agreement:

Reinford Farm has a power purchase agreement with Pennsylvania Power & Light (PPL) Electric Utilities Corporation. Daily power production averages 95 kWh/day. The farm has a commercial electric service with all power produced being sold to the grid at 13.0 cent per kWh. Electricity used on the farm is bought back at a residential rate of 8.9 cent per kWh. Use of rejected heat from the CHP unit to heat the farmhouse has saved $3,000.00 in electric heating cost when compared to 2007 electric rates.

Digester effluent:

The nearly odorless digested manure flows to an effluent storage pit measuring 20' L x 20' W x 12' D. A Houle (Baldor Farm Duty Motor) 7.5 hp pump directs the effluent to the solids separation building. The solid/liquid separation room is above the separated solids storage bay. A Cri Man manure separator, distributed by Alpha Bio Systems, Inc., with a 5 hp motor is used. The solids fall directly into the digested solids storage bay. These separated solids are then used as bedding for the cows. Only half of the separated solids are needed for use on the farm, the remaining 50% is sold to nearby farms. The herd somatic cell count has had a continuous lowering trend since the use of separated solids for bedding. Counts now range between 120,000 – 150,000. The separated liquid effluent gravity flows to the 2.5 million gallon storage pond. The effluent is stored and applied by both drag hose and tanker haul twice a year to crop fields.

Cri-Man solid/liquid manure separator distributed by Alpha-Bio Systems, Inc.

Appling separated solids as bedding.

Project costs:

The digester project cost $1.1 million. A feasibility study was first preformed for the farm at a cost of $12,000. RCM Digesters helped the Reinford Farm apply for grants for the anaerobic digester system. The Reinford's received funding for the project from the Pennsylvania Department of Environmental Protection (PADEP), receiving an Energy Harvest Grant of $285,000, a Pennsylvania Department of Agriculture's Machinery and Equipment Loan Fund (MELF) for $135,000, Resource Enhancement and Protection Tax Credit Program (REAP) $90,000, a United States Department of Agriculture (USDA) Grant for $203,600 and the USDA Environmental Quality Incentives Program (EQUIP) provided $40,000. The farm borrowed the remaining amount needed for the project. The carbon credits generated by the destruction of the methane are banked through the Chicago Climate Exchange through a broker.

Lessons learned:

A knowledgeable project manager is essential and must be on the construction site everyday during the digester project.

Specific items:

- ensure piping is configured to direct raw manure away from the digester during maintenance
- configure the digester effluent piping to allow by-pass of the solids/liquid separation system and go directly into the lagoon
- add manways to allow access to cleanouts where manure solids may cause piping obstructions Note: ensure manways have the proper signage: "Confined Space: entry requirements must be followed".
- since biogas bypasses the biogas flow meter when using the flare – either a separate biogas flow meter needs to be installed or the flare needs to be moved. Currently if biogas is destroyed by the flare the biogas cannot be measured for carbon credit calculations.

Would you install a digester again? Yes

*Please see the digester system schematic and log sheet on the following two pages.

The information obtained in this case study was collected by Penn State researchers, Deborah Topper and Patrick Topper during farm tours, observations, farmer completed questionnaire and interviews at the Reinford Farm in 2008 & 2009.

The content of this case study is not meant to be all inclusive or intended to delete any entity, or constitute an endorsement of a company or individual or to be a product endorsement of a company.

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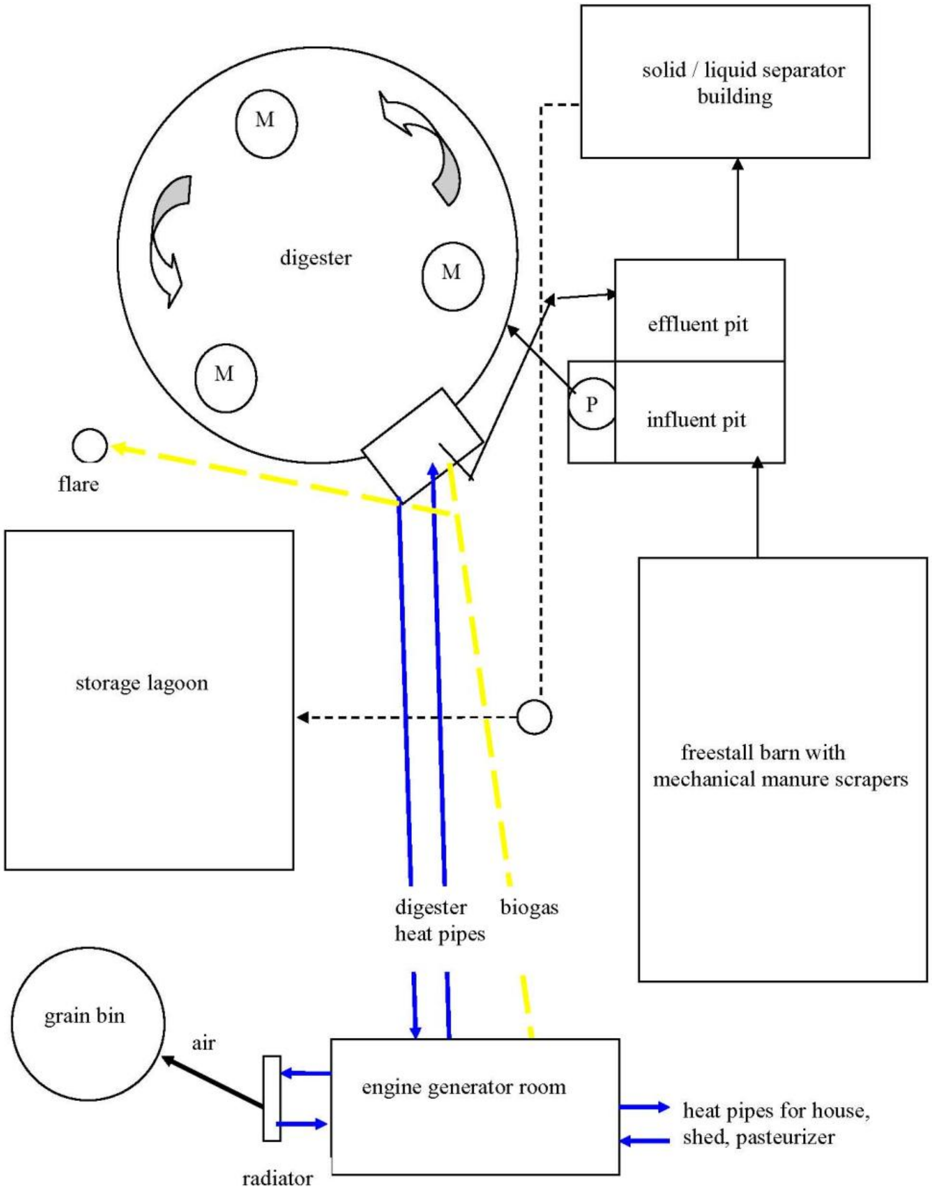
Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture

Pennsylvania State University, Department of Agricultural and Biological Engineering, College of Agricultural Sciences.

Reinford digester system schematic



Community Digester Feasibility

The 9th Congressional District contains a number of small to medium animal farms, as opposed to other areas of the State and Country where large farms dominate. There are no CAFOs according to EPA's list of permitted operations in Ohio, and few large scale operations (>$50K sales) for production of hogs, cattle (including milk cows) and poultry. With few large farms that would have concentrated sources of manure for biogas production, team members wondered if a 'regional' digester that accepts waste from multiple sources might be feasible. A cost/benefit analysis was created for a 0.5MW digester that would be operated as an independent business, accepting or purchasing manure and other wastes as feedstock. Several scenarios were run. Approximately 3,700ae (2,750 cows) are needed to operate a 0.5MW digester. In this scenario, a digester would be located on and operated in partnership with an existing dairy farm of 1,145ae. An additional 2,245ae of manure would be hauled to the site. Other simple assumptions,

- Manure cost: $1/wet ton for additional manure from other farms,
- Manure is hauled 10 miles to the digester,
- Electricity price: $0.12/kWh (average Toledo and Ohio Edison price retail),
- More 'conservative' digester system capital cost (meaning, higher price than EPA estimates),
- Project financing includes 25% REAP grant, 20% equity, 55% loan @ 8% for 10 years.

Table 11: 0.5MW Regional Digester, Electricity Sold at Retail

Capital Costs	$3,000,000
Operating Costs	$400,000
Total Electricity Production (kWh)	4,500,000
Annual Electricity Revenue ($0.12)	$540,000
Bedding/Fertilizer Sales	$165,000
Net Revenue/Savings	$306,000
Simple Payback Period (yrs.)	**10**

The scenario was re-run with manure hauled 20 miles to the site. The economics shift dramatically.

Table 12: 0.5MW Regional Digester, Electricity Sold at Retail, Manure Hauled 30 Miles

Capital Costs	$3,000,000
Operating Costs	$560,000
Total Electricity Production (kWh)	4,500,000
Annual Electricity Revenue ($.12)	$540,000
Bedding/Fertilizer Sales	$164,250
Net Revenue/Savings	$136,000
Simple Payback Period (yrs.)	**21**

The 10 mile scenario was re-run, adding potential revenue streams from Renewable Energy Credits (RECs), Carbon Credits.

Table 13: 0.5MW Regional Digester, Electricity Sold at Retail, with Potential REC and Carbon Credit Revenue

Capital Costs	$3,000,000
Operating Costs	$400,000
Total Electricity Production (kWh)	4,500,000
Annual Electricity Revenue ($.12)	$540,000
Bedding/Fertilizer Sales	$164,250
REC Sales	$90,000
Carbon Credit Sales[11]	$65,000
Net Revenue/Savings	$450,500
Simple Payback Period (yrs.)	**6.5**

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[11] REC and Carbon Credit markets are extremely volatile. The markets for these items vary widely from state to state and they are in a condition of dynamic flux. It seems that this is due to the absence of federal legislation requiring Clean Energy Portfolio or Renewable Energy Portfolio Standards. REC prices are based on $20/REC. Carbon Credits for methane avoidance are based on # of lactating cows * 3 (tons) * $8/ton.

The 20 mile scenario was re-run, adding potential revenue streams from Renewable Energy Credits (RECs), Carbon Credits. The economics shift dramatically.

Table 14: 0.5MW Regional Digester, Electricity Sold at Retail, with Potential REC and Carbon Credit Revenue

Capital Costs	$3,000,000
Operating Costs	$560,000
Total Electricity Production (kWh)	4,500,000
Annual Electricity Revenue ($0.12)	$540,000
Bedding/Fertilizer Sales	$164,250
REC Sales	$90,000
Carbon Credit Sales[12]	$65,000
Net Revenue/Savings	$300,000
Simple Payback Period (yrs.)	**10**

The 10-mile scenario was run to determine Net Present Value.

Table 15: 0.5MW Regional Digester, Electricity Sold at Retail, Net Present Value

Capital Costs	$3,000,000
Accelerated Depreciation	$2,500,000
25% Grant	$750,000
Annual Electricity Revenue ($0.12)	$540,000
Bedding/Fertilizer Sales	$164,250
Discount Factor	10%
Net Present Value (7 yrs.)	**$1,800,000**

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[12] REC and Carbon Credit markets are extremely volatile. The markets for these items vary widely from state to state and they are in a condition of dynamic flux. It seems that this is due to the absence of federal legislation requiring Clean Energy Portfolio or Renewable Energy Portfolio Standards. REC prices are based on $20/REC. Carbon Credits for methane avoidance are based on # of lactating cows * 3 (tons) * $8/ton.

The 10-mile scenario was run to calculate Net Present Value without the accelerated depreciation (set to expire after 2012) or the 25% grant support. The economics shift dramatically.

Table 16: 0.5MW Regional Digester, Electricity Sold at Retail, Standard Depreciation and No Grant, Net Present Value

Capital Costs	$3,000,000
7 yr. Depreciation	$430,000
Grant	$0
Annual Electricity Revenue ($0.12)	$540,000
Bedding/Fertilizer Sales	$164,250
Discount Factor	10%
Net Present Value (7 yrs.)	**$875,000**

The 10-mile scenario was run to calculate Net Present Value with accelerated depreciation, a 25% REAP grant, and revenues from REC and Carbon Credit sales.

Table 17: 0.5MW Regional Digester, Electricity Sold at Retail, Accelerated Depreciation, 25% Grant, Potential REC and Carbon Credit Sales Net Present Value

Capital Costs	**$3,000,000**
Accelerated Depreciation	$2,500,000
25% Grant	$750,000
Annual Electricity Revenue ($0.12)	$540,000
Bedding/Fertilizer Sales	$164,250
REC Sales	$90,000
Carbon Credit Sales	$65,000
Discount Factor	10%
Net Present Value (7 yrs.)	**$2,500,000**

As part of this feasibility exercise, scenarios were created for the 0.5MW digester to produce and condition biogas for pipeline injection. Due to the additional capital costs of biogas conditioning equipment and attendant operating and maintenance costs, and the relatively low price of natural gas ($0.4920/ccf), the scenarios showed a modest net present value in the range of slightly more than $2.3M; however, simple payback periods were negative (even with projected carbon credit sales). At $1.2374/ccf, the simple payback rose to 35 years.

POLICY CONSIDERATIONS

A thorough review and analysis of federal and state policies that bear on biogas production and distribution is beyond the scope of this brief study. However, the economic analyses above illustrate the impact of various policies on the economic feasibility of biogas production. A comprehensive biogas policy analysis was undertaken by the Great Plains Institute, a 501(c)(3) nonprofit organization that brings together key public and private leaders from across the northern plains to accelerate the transition to a renewable and low-carbon energy system by mid-century. Serving the greater Upper Midwest (Illinois, Indiana, Iowa, Manitoba, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin, the organization has successfully crafted and implemented policies, technologies, and practices for over twelve years. Their report, "Spotlight on Biogas: Policies for Utilization and Deployment in the Midwest, 2010"[13] is a thorough analysis of existing, proposed, and needed policy to support the development of biogas as a renewable resource. Their federal policy research is summarized here.

Based on interviews with biogas industry stakeholders, the Institute concludes that future policy should level the playing field between direct incentives and grants for biogas production that produces electricity, renewable natural gas, or other utilization options (e.g., compressed liquid fuel). At present, policy seems weighted to electricity generation. Policies should, instead, provide the right framework for project developers to determine the highest and best use for the biogas produced and not limit the technology applications for producing biogas or biogas utilization options. The simple economic analysis above showing utilization of biogas for electricity vs. production of biogas for pipeline injection underscores this point. Since the scope of this project encompasses on the 9th Congressional District, the summary below focuses on federal policy only. It should be noted that the Great Plains Institute report is comprehensive and covers policy at all levels.

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[13] "Spotlight on Biogas: Policies for Utilization and Deployment in the Midwest." The Great Plains Institute, August 2010.

Table 18: Existing "Best in Class" Policies

Policy	Description
Environmental Quality Incentives Program (EQIP)	Cost share program authorized by the Farm Bill. Agricultural producers can receive cost-share assistance for constructing manure management and storage equipment—part of a biogas system. Some states NRCS offices can offer this assistance for anaerobic digesters.
Rural Energy for America Program (REAP)	Provides grants and loans to agricultural producers and rural small business to implement renewable energy and energy efficiency projects on a competitive basis.
Business and Industry Guaranteed Loans	USDA program providing guaranteed loans for rural cooperative organizations that process value-added agricultural commodities. (**Obstacle**: Biogas projects seeking a guaranteed loan must have a traditional lender in-hand. New businesses proposing projects do not have access to balance sheets from previous years in order to secure a lender.)
Business Energy Investment Tax Credit (ITC)	This program has traditionally supported renewable electricity generation projects, which include anaerobic digesters that produce electricity. It has not supported renewable gas generation projects.
Renewable Electricity Production Tax Credit (PTC)	A federal tax credit with intermittent availability. Stakeholders recommend that the federal government extend the time period PTC is available to give investors financial assurance and to allow for extended project permitting; allow non-electrical producing projects to qualify; and offset the tax liability or accelerate depreciation to make the credit more workable for farmer-owned biogas projects.
U.S. Department of Treasury, Section 160B	Provides a grant for up to 30% of construction and installation costs in lieu of tax credits. The current program excludes open-loop biomass and projects of 150kW or less. It is set to expire in 2011.

Table 19: Proposed Policies that "Need a Push"

Policy	Description
Biogas Production Incentive Act (S. 306, H.R. 1158)	The proposed legislation would provide an incentive for the production, sale, or use of biogas derived by processing a qualified feedstock in an anaerobic digester. Recently proposed changes to the original legislation would include criteria for high-and low BTU gas. An emphasis on high- BTU gas would make this policy less workable for farm-based systems. Overall, the policy should focus on BTU output and not gas quality in order to be applicable to the greatest number of potential projects.
Federal Cap on Carbon Emissions	A federal cap on carbon emissions would create an enormous opportunity to generate and sell carbon credits to a regulated entity to help meet the cap. A federal climate policy capping electric sector or economy-wide carbon emissions that includes a robust carbon credit trading program could provide an additional revenue stream, depending on the offset price, to drive significant biogas project development. The voluntary carbon market has been able to provide a small economic sweetener for biogas projects, but on its own has not pulled biogas projects into the market. The House passed American Clean Energy and Security Act will need to be reconciled with a yet-to-be-passed Senate version. The timing of a possible Senate bill addressing carbon emissions is unclear.
Federal Renewable Electricity Standard (RES)	Would create a uniform, minimum standard across the United States and would provide reasonable assurance to potential projects of a market for renewable electricity. A federal RES should not preempt established state programs that require a higher percentage of renewable electricity than a federal program. A federal RES would also create a national REC market and the national market should treat RECs as a fungible resource, allowing credits to pass across state lines. This would open the door for biogas-to-electricity projects in one region of the country to sell RECs to an electric utility in another part of the country to help the utility meet the federal requirement.
Investment Tax Credit for Biomethane Projects	Legislative proposal by Representative Ron Kind (D-WI) that would provide a 30 percent credit for biogas projects producing gas at least 52 percent methane and utilizing the gas as a fuel. This proposal mirrors the current investment tax credit available for open-loop biomass projects producing electricity. Making a credit available to biogas projects producing electricity or renewable gas will allows project developers to determine the highest and best use for the gas.

Table 20: A Few Promising New Policies that Need a Champion

Policy	Description
National Nutrient Trading Program	Modeled after a program in Pennsylvania could begin to monetize the value of water quality benefits from farm-based biogas projects. In a final statement on water quality trading policy, the Environmental Protection Agency stated, "market-based approaches such as water quality trading provide greater flexibility and have potential to achieve water quality and environmental benefits greater than would otherwise be achieved under more traditional regulatory approaches," (EPA , 2003). A possible vehicle for this policy could be the 2012 Farm Bill.
Rural Infrastructure Development Fund	Established at the national level to provide assistance to individual project developers and rural electric utilities to upgrade electric distribution infrastructure. Inadequate electrical lines to carry renewable electricity produced from an agricultural site are a limiting economic and technical factor for biogas projects. Current developers that decide to upgrade electric service to a project site shoulder the cost associated with upgrading distribution infrastructure. A funding pool in the form of grants, loans, or tax credits could be established to provide financial assistance to share the costs of updating electric distribution infrastructure in rural America.
Tradable Tax Credits	Could supplement the buyback rate offered by an electric or natural gas utility. The project owner could sell the credit to a utility or another entity to use the credits and, in turn, provide an extra investment for the project owner to finance a project.

Table 21: A Few “Other Ideas”

Policy	Description
Carbon Credit Certification Assistance	Would provide the opportunity for smaller biogas projects to defray certification costs, which are essentially the same for large or small projects, and sell or trade carbon credits in a voluntary or mandatory market. A cost-share assistance program could be administered through USDA, carbon credit aggregators could provide package discounts to multiple smaller biogas projects in a geographic location, or livestock organizations or farmer cooperatives could provide assistance as a service to their members. Options to provide assistance for carbon credit certification to smaller projects is an area needing further discussion and examination, especially if a federal cap-and trade program is put in place.
Closed-loop Projects	These present an opportunity for future biogas projects because the biogas created at the project site can either be used on-site or by a nearby customer. Closed-loop projects would avoid the step of needing to market biogas produced into the electric or natural gas distribution infrastructure. Financing mechanisms or potential incentives for closed-loop projects should be examined closely. Many existing incentives are tied to energy production or utilization of the gas. A possible area of financing for closed loop projects could be electric or natural gas utility conservation programs.
Integrate Existing USDA Programs	Currently, agricultural producers who are interested in implementing a biogas project must use a patchwork of grant or cost-share programs to reduce the project’s capital investment. Most programs are available through USDA and an agricultural producer is the eligible applicant. USDA could provide guidance to potential applicants by dedicating available programs to different aspects of a project. For instance, the Environmental Quality Incentives Program (EQIP) could pay for manure storage and handling, the Rural Energy for America Program (REAP) could cover electrical generation equipment and the Biomass Crop Assistance Program (BCAP) could be used to incent the production of feedstocks for a project. USDA should examine all current programs that can be used to provide financial project assistance and issue guidance to potential applicants about which programs can be used to fund portions of a project.

(Source: Great Plains Institute. “Spotlight on Biogas: Policies for Utilization and Deployment in the Midwest, 2010”)

State of Ohio policy was researched by Policy Matters Ohio, a non-profit policy research organization founded in 2000. Their research found a number of barriers to implementation of anaerobic digesters on farms.[14] A summary of particularly potent Ohio policies is below.

1. Ohio electricity prices are artificially low, making the case for anaerobic digestion projects more difficult. There are several factors contributing to low electricity prices in Ohio.
    a. *Existing coal plants in Ohio are old, with their assets largely paid for (but very inefficient).* Ohio's outdated electrical grid system hasn't been upgraded in decades. With roughly 30% efficiency rates, more energy is lost during generation and transmission than actually reaches the end user of electricity. These inefficiencies directly translate into the levels of emissions produced in Ohio and cheap electricity for consumers.
    b. *External costs of electricity not internalized by the utility*.[15] Coal is a relatively cheap source of energy. Approximately 87% of Ohio electricity is generated from coal. However, the price of coal-fired power doesn't reflect its true cost. Electricity generation produces a significant amount of greenhouse gases and other pollutants. The hidden costs of these emissions— increased rates of asthma or climate change—are born by the society generally. Because the costs from pollution are not born by the utility, they are not reflected in the price charged to consumers, causing the price of electricity to be artificially low.
    c. *Industrial rates for electricity are low because they are cross-subsidized by residential and small commercial sectors*. The industrial sector in Ohio pays an average $.0557 per kilowatt-hour. Commercial and residential pay $.104 and $.113 respectively (approximately double the industrial sector rate).[16] The higher prices in the residential and commercial sectors subsidize the industrial sector to reduce the cost of its electricity.
        i. Recommendation: Require electric utility companies to bear the full cost of generating electricity by increasing standards for efficiency, technology, and emissions and require them to upgrade the electricity grid.
2. Cost share and incentive programs
    a. The Ohio Advanced Energy Fund has provided grants, low-interest loans, and incentive payment for clean energy projects. The mechanism for collecting

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[14] Policy Brief on Anaerobic Digestion in Ohio, by Amanda Woodrum, Policy Matters Ohio. A complete copy of the report can be found in Appendix D.

[15] National Academy of Sciences, *Hidden Costs of Energy* at http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=12794

[16] http://www.eia.gov/state/state-energy-profiles-data.cfm?sid=OH#Prices

revenues for this program was allowed to expire in December 2010, putting the program at risk.

    i. Recommendation: Extend and expand the program.

b. *Ohio Renewable Energy and Advanced Energy Project Property Tax Exemption.*[17] Prior to SB232, a renewable energy facility that sold electricity to a 3rd party was considered a "public utility" for tax purposes. SB232 exempts qualified energy projects, including anaerobic digestion, from personal and real property taxes. Qualified projects that are 250kw or less are not subject to payments in lieu of property taxes. Qualified projects greater than 250kw, will be required to make payments in lieu of property taxes based on the size and type of facility, and the number of Ohio-based employees. They must also be placed in service by January of 2015 (unless it is a cogeneration facility then has until 2019), meet certain job-creation criteria, and offer to sell the RECs to Ohio's electric utilities. Projects larger than 5 MW require approval by county commissioners to receive the property tax exemption, must pay for road repairs necessary, and provide training. Projects greater than 2MW must establish partnerships with universities.

    i. Recommendation[18]: Remove the property tax or payments in lieu of on renewable and advanced energy projects.

CONCLUSIONS AND POTENTIAL NEXT STEPS

In a conventional context when considering energy generation options, the biogas potential from anaerobic digestion in the 9th Congressional District involving the agricultural manure feedstocks examined is moderate. Usable crop residue potential is much higher, but the economics of harvesting crop residue and the poor quality of the feedstock itself are significant barriers to development of this resource. Given the potential for biogas to energy from food processing waste, however, a more detailed study is warranted.

However, if the context shifts from conventional energy considerations to examining anaerobic digestion as one of many decentralized renewable energy options needed in the transition from a heavily fossil-based energy system to a post-fossil fuel, carbon neutral system the conclusions are different. With moderate grant and incentive support, the technology appears to be economically feasible on a relatively small scale. This could be good news in a region that has struggled to maintain its agricultural base.

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[17] http://dsireusa.org/incentives/incentive.cfm?Incentive_Code=OH60F&re=1&ee=1

[18] This recommendation is by the author, not Policy Matters Ohio.

For example, providing farmers an additional means to generate income, while supplying their own electrical energy with local, carbon-neutral sources, is an interesting combination of positive economic forces.

Our high-level economic feasibility exercise for deploying a 0.5MW digester with REC and Carbon Credit revenue assumptions shows the positive impact these two revenue streams can have. This point is not to be understated. Federal policy that drives REC and Carbon prices into market is essential. Other federal policy options are also important: integration of USDA programs to make it easier for busy farmers to navigate the complex system of grants, cost-share, and loan programs to implement digester projects; a federal renewable energy or clean energy standard; extension of the accelerated depreciation for renewable energy projects; and, continuation of the 30% Treasury Department grant program. Without these basic policies, anaerobic digestion to produce energy is significantly challenged. These policies seem to make good economic sense: they create clean energy jobs and support the rural backbone of the country.

Dovin Dairy Farm LLC

The case study at Dovin Dairy Farms suggests that a digester would be economically feasible and provide other benefits. A preliminary engineering design study is the next step to implementation. Due to its interest in anaerobic digestion, the scope of the design should include an analysis of technology options and partnership opportunities with the farm's neighbor, the Lorain County Joint Vocational School. In this context, for example, one of the design options would examine the possibility of LCJVS hosting and operating the digester in tandem with new curricula; ownership could be shared with the Dovins—including financial benefits. Such a partnership could spread the risk sufficiently and therefore satisfy the business interests of the farm, open potential funding pathways heretofore unforeseen, and create a public/private partnership that promotes clean, renewable energy, educational training, and jobs.

Food Processing Waste

According to the U.S. Bureau of Economic Analysis, the State of Ohio ranks 4th in value added food processing production (following California, Illinois, and Texas).[19] Both Jeanty et. al. and this project have shown the potential for food processing waste as a biomass resource for energy production using extrapolation methodology. This is not adequate. A significant study that pinpoints sources and varieties of food processing waste is needed.

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[19] Jeanty, et. al.

New Technology Emerging: Dry Digesters and Pyrolysis

Anaerobic digestion of waste biomass is a rapidly changing technology. Traditional anaerobic digesters utilize wet wastes (e.g., slurry manure and food processing waste). Dry anaerobic digester technologies have been developed and deployed commercially to produce biogas from organic wastes with low moisture content—75% moisture or less.

Jeanty et. al. (2004) discovered that Municipal Solid Waste (MSW) is the largest source of potential biomass to energy in the State of Ohio. [20] In contrast, to crop waste (12%) and manure (1%), MSW represents 68% of the biomass waste stream. The amount of MSW biomass resource available for energy conversion is huge in proportion to all other biomass waste resources.

Table 22: Municipal Solid Waste Estimates Based on Active Landfills

	Tons
Lorain	845,000 – 1,100,000
Lucas	180,000 – 350,000
Ottawa	400,000 – 640,000
Erie	12,000 – 156,000

(Source: Jeanty et. al., 2004)

In the 9th Congressional District, Oberlin College and the City of Oberlin have become joint Climate Positive Development Program participants of the William J. Clinton Foundation's Clinton Climate Initiative (CCI) and are searching for long-term, climate positive, carbon-free energy solutions and strategies that will create a successful model of sustainable development that can be widely emulated throughout the U.S. The college has determined its coal-fired, central heating plant should be converted (or replaced) to carbon-neutral technology. The city is on track to meet up to 80% of its power needs from carbon-neutral sources, drastically reducing its carbon footprint but leaving up to a 20% gap filled by non-renewable sources. Both entities are looking to landfill gas to meet the bulk of their carbon-neutral energy needs in the near term. But landfill gas is not a long-term, sustainable solution. Although carbon-neutral, the technology relies on profligate waste continuing to fill up landfills and is perhaps a 30-

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[20] Jeanty, et. al. p. 103.

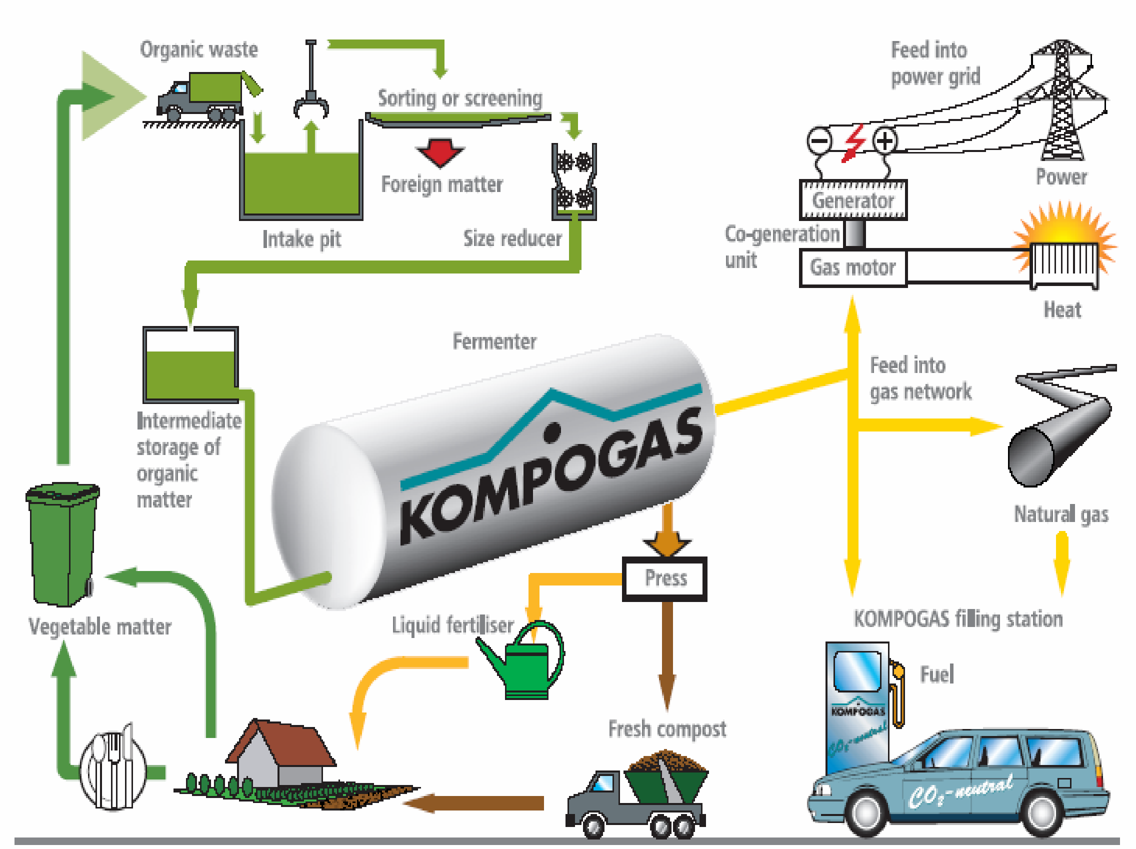
year solution. Two promising options exist to innovate beyond the ‘conventional’ landfill gas solution.

While methane recovery at landfills is becoming more commonplace, diverting waste from the landfill into dry digesters would extend the life of landfills while producing clean energy and jobs. The dry digester approach to carbon-neutral energy production should receive high priority consideration and a feasibility study funded for implementing a system near Oberlin. Ownership scenarios (private, college/city) should be included in the scope of the project.

Figure 6: **Dry Fermentation Digester**

(Source: BioFerm Energy Systems)

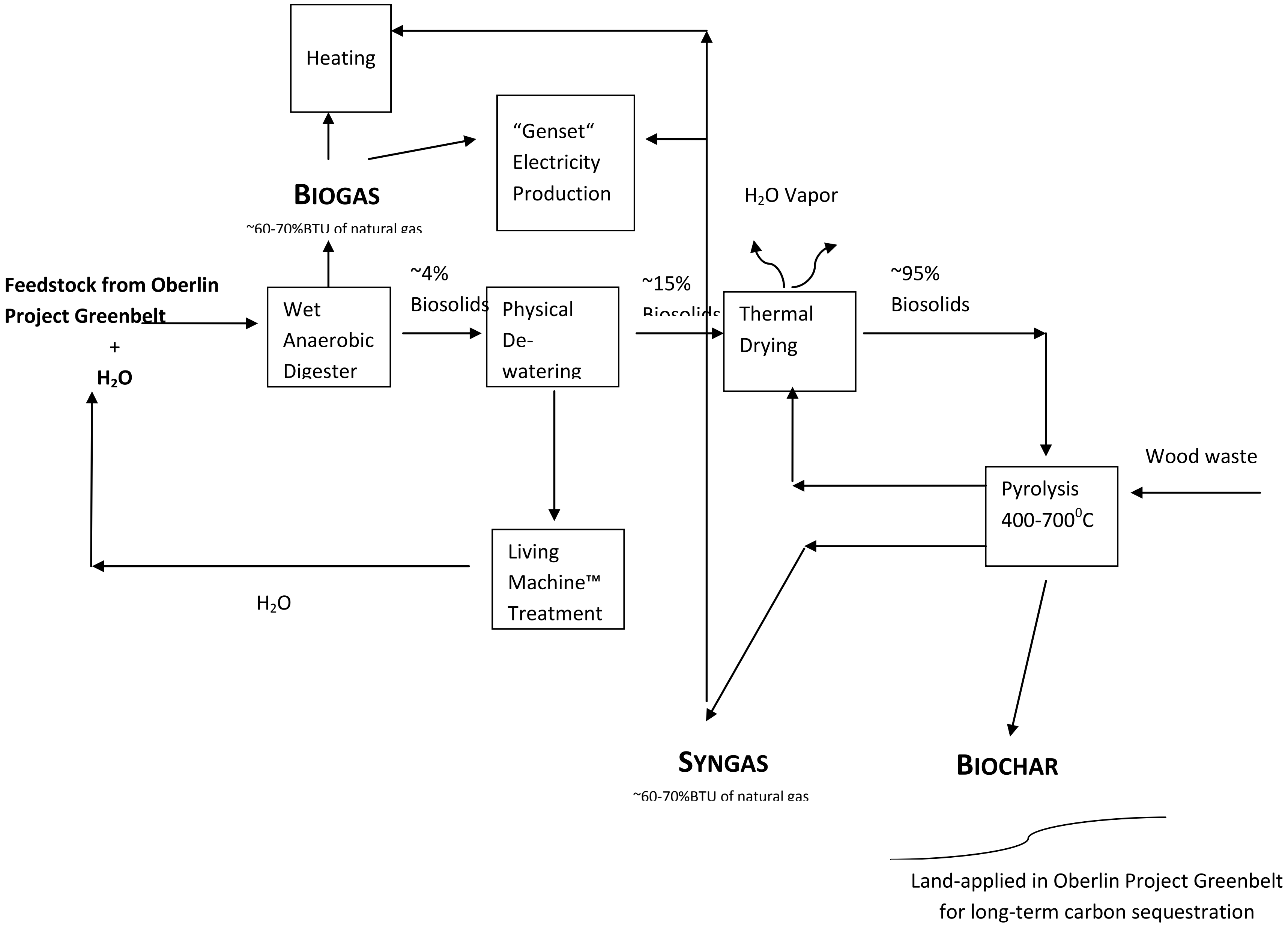
Figure 7: Kompogas Dry Fermentation Technology



(source: Evergreen Energy Corporation Pty Ltd., "Independent Review of the Kompogas Technology" June 2005.)

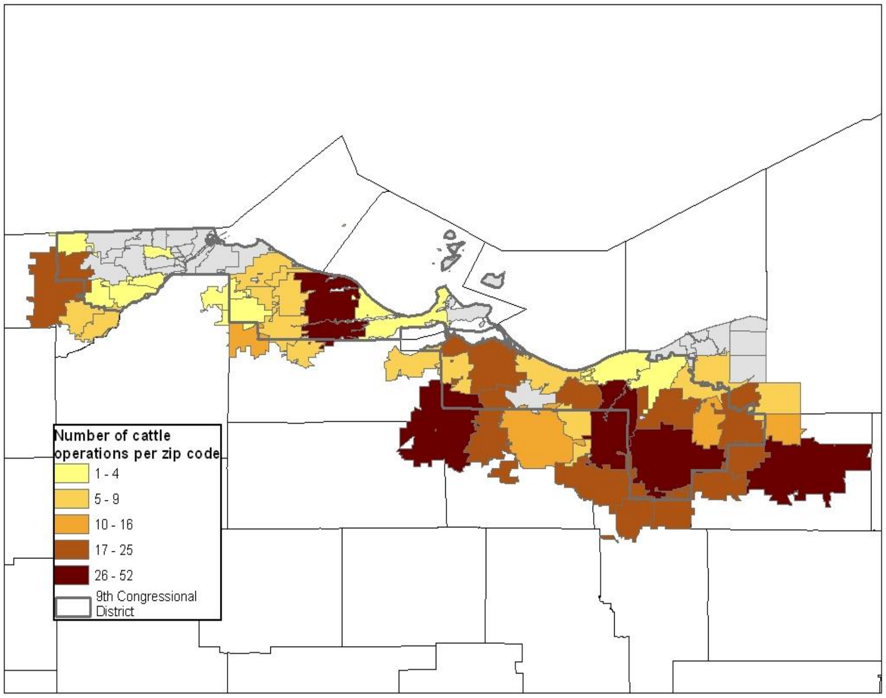
Another innovative technology that complements anaerobic digestion is pyrolysis (heating to high temperatures in the absence of oxygen). Pyrolysis of residual biosolids from an anaerobic digester would produce biochar—a carbon sequestering material—and syngas creating a **carbon-negative** energy generation system. If feedstock for the digester were drawn from the Oberlin Project area, with residual biochar being returned to it, a local, closed-loop and sustainable energy generation system would result. This option should receive high priority consideration and a feasibility study funded for implementing a system near Oberlin—either in conjunction with a dry digester or a wet digester at Dovin Dairy Farms, LLC. See Figure 8 for a representative schematic of this system.

Figure 8: Simple schematic for a sustainable, carbon-negative, closed-loop, biogas/biochar energy generation system for Oberlin, Ohio

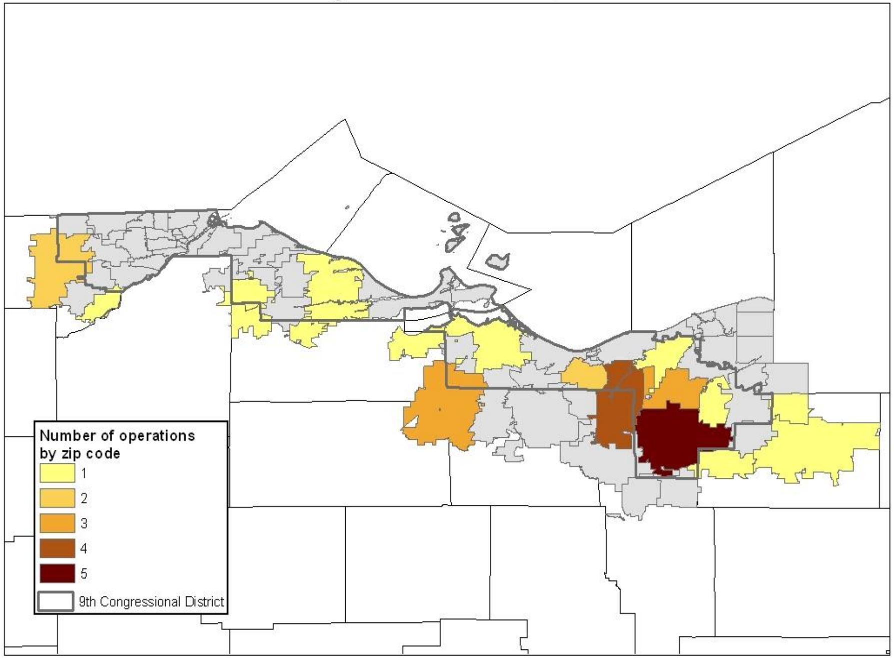


APPENDIX A: Manure Waste Data (Source: OARDC/OBIC, 2011).

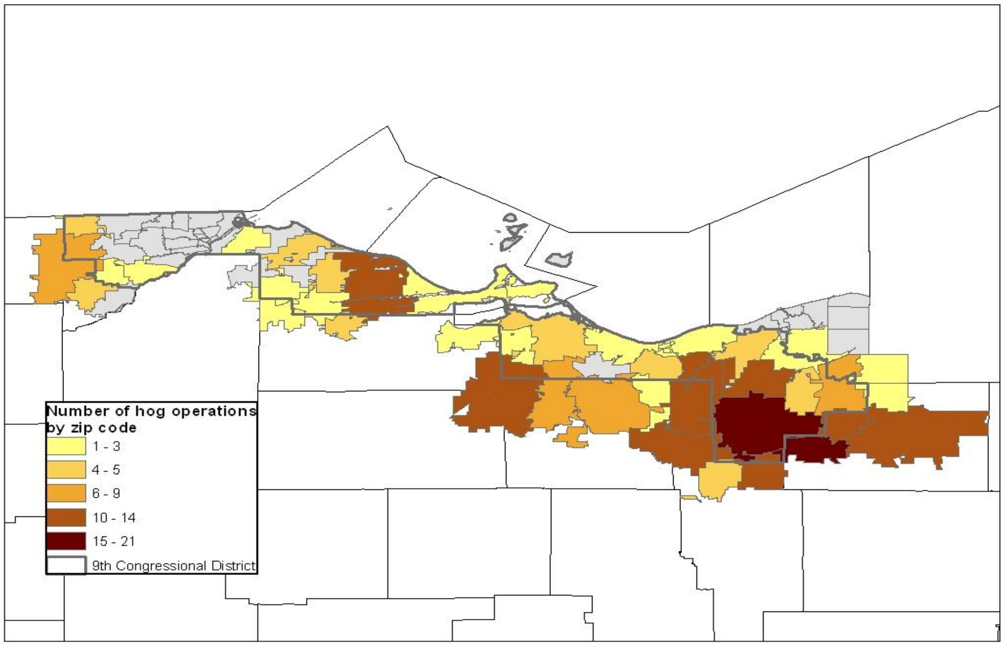
Cattle Operations: 9th Congressional District, Ohio



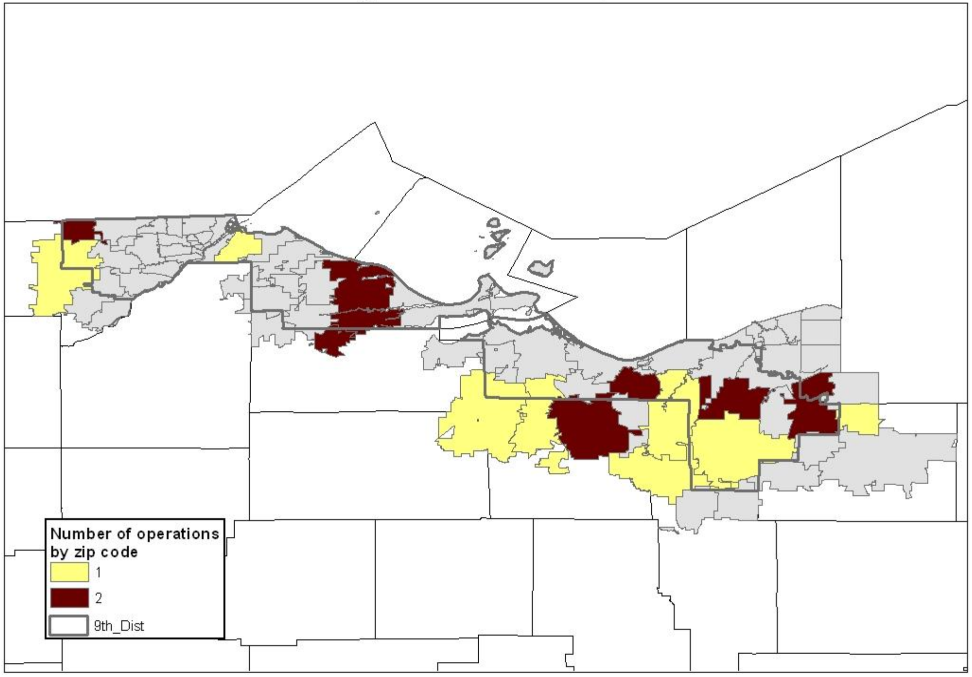
Cattle operations with annual sales exceeding $50,000:
9th Congressional District, Ohio



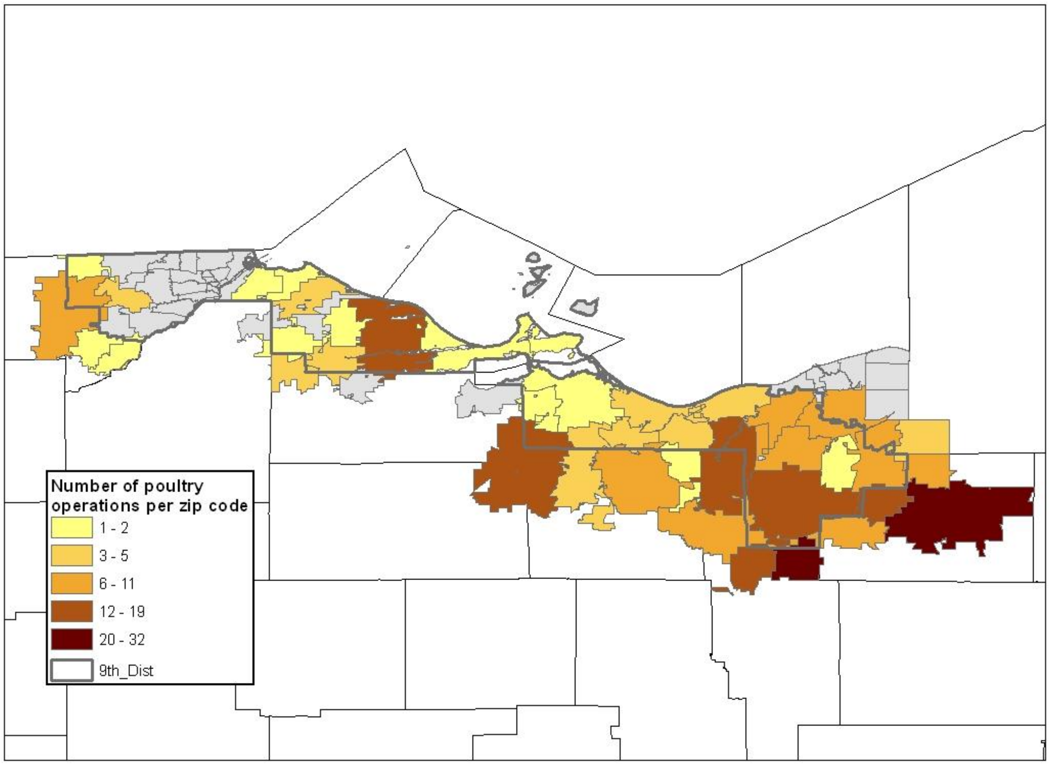
Hog Operations: 9th Congressional District, Ohio



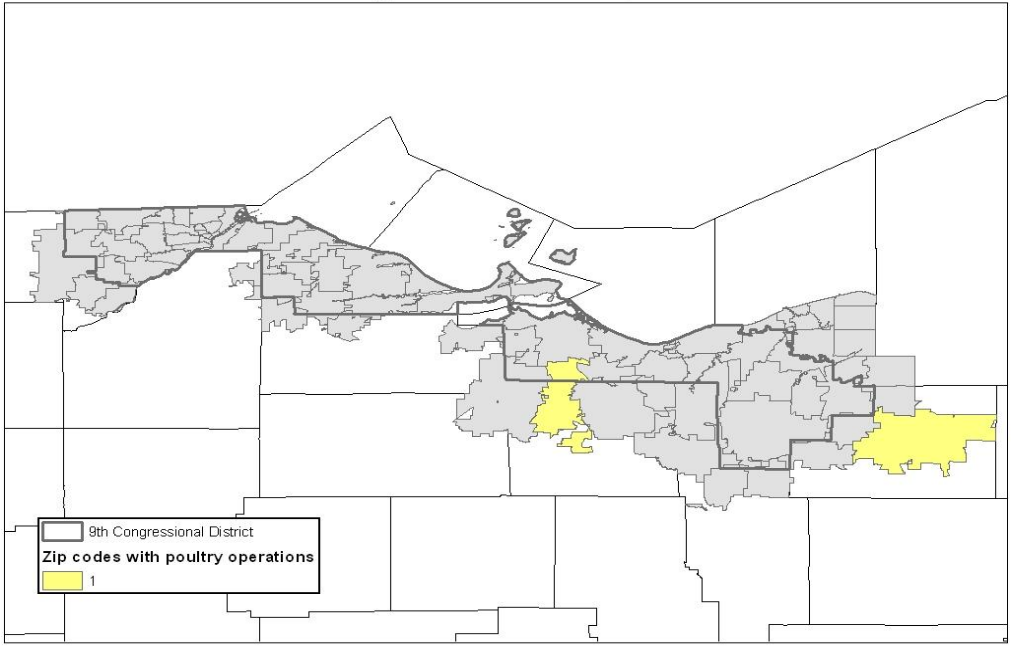
Hog operations with annual sales exceeding $50,000:
9th Congressional District, Ohio



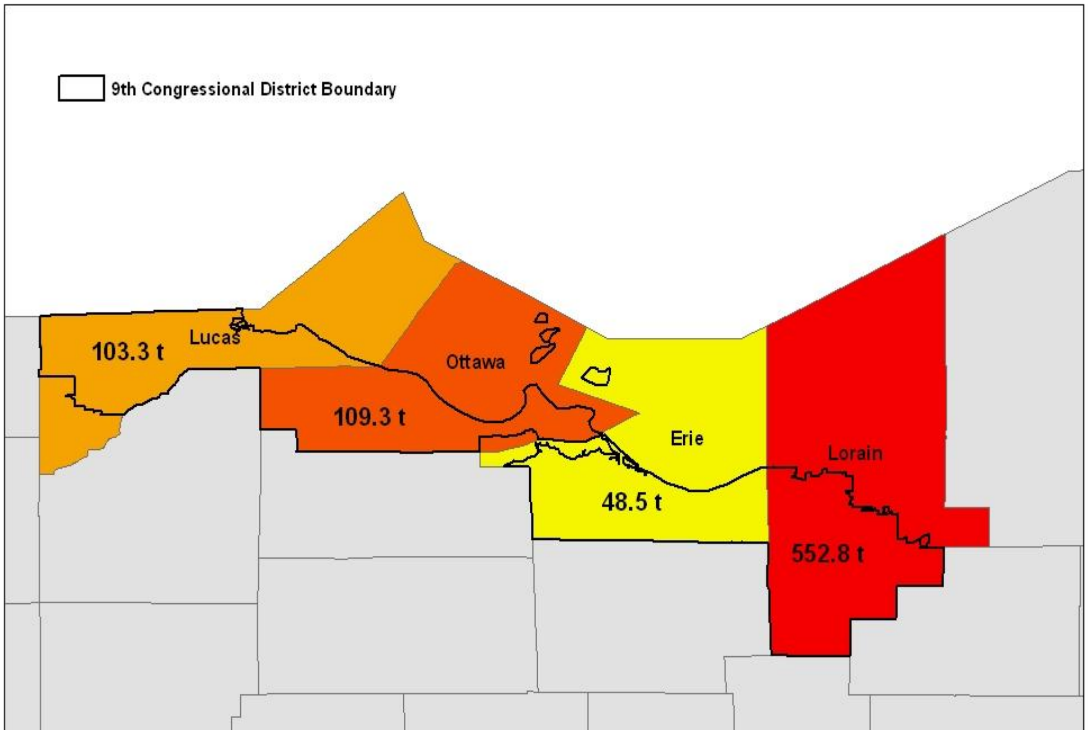
Poultry Operations: 9th Congressional District, Ohio



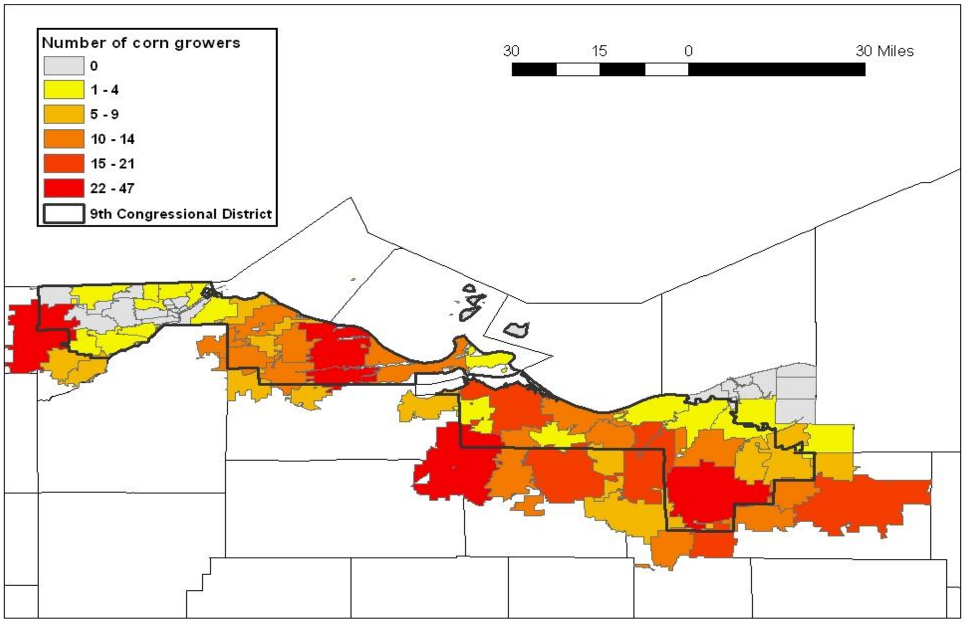
Poultry operations with annual sales exceeding $50,000:
9th Congressional District, Ohio



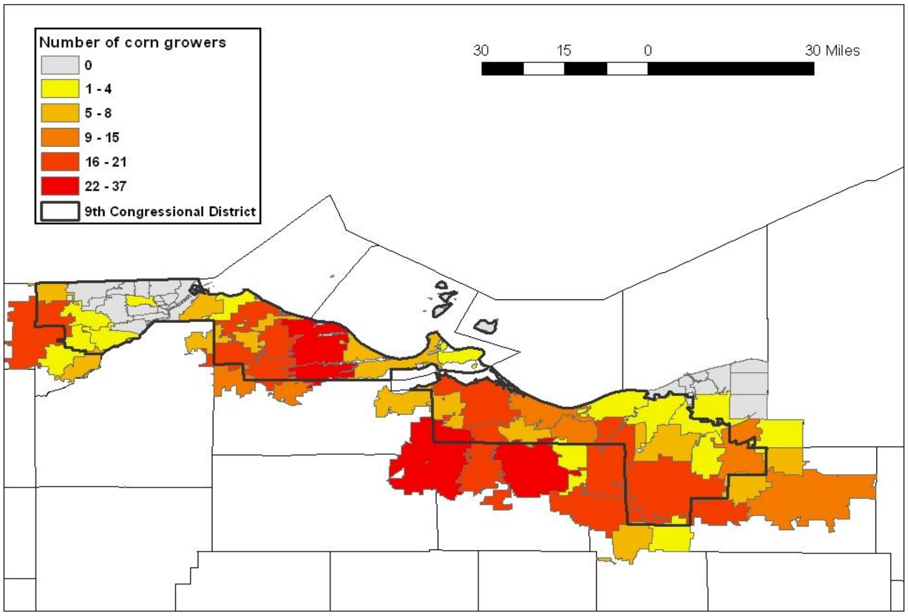
Potential Methane Production by County: 9th Congressional District, Ohio
Methane listed in tons per year



APPENDIX B: Crop Residue Waste Data (Source: OARDC/OBIC, 2011)

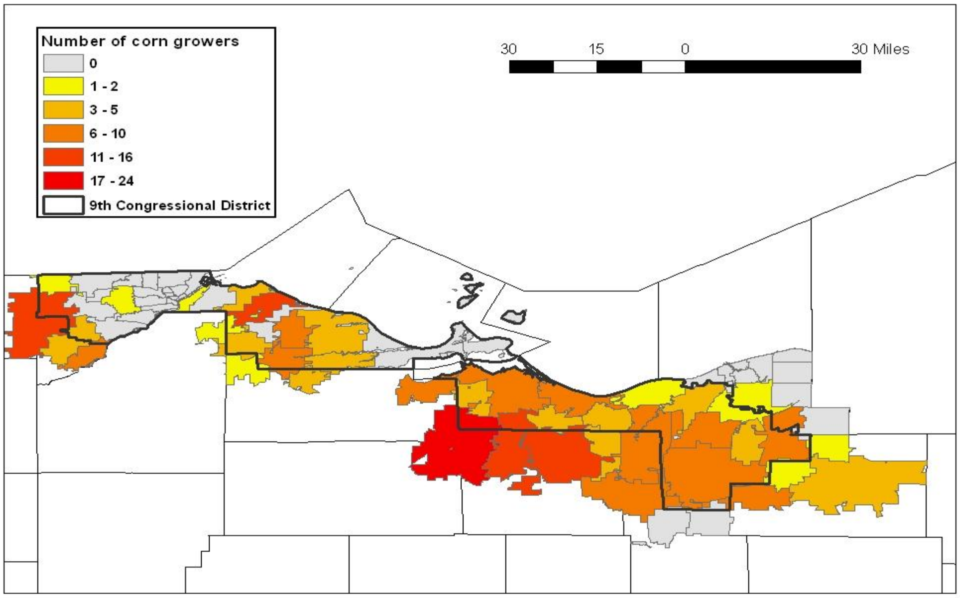


Number of Corn Growing Operations by Zip Code, Under 50 Acres
9th Congressional District, Ohio

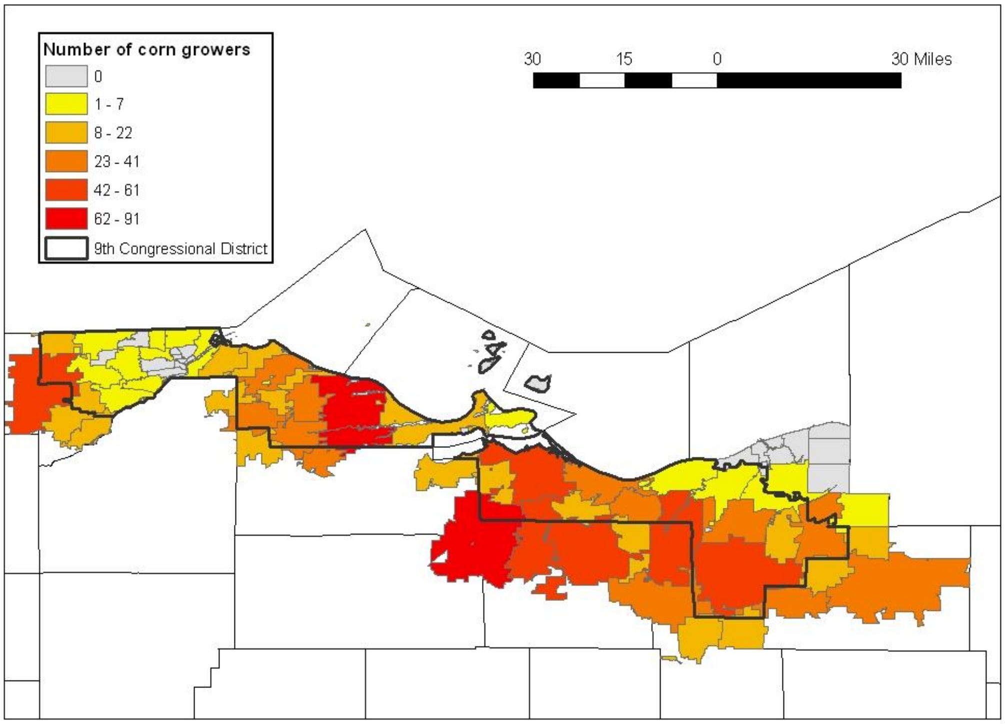


Number of Corn Growing Operations by Zip Code, 50 to 250 Acres
9th Congressional District, Ohio

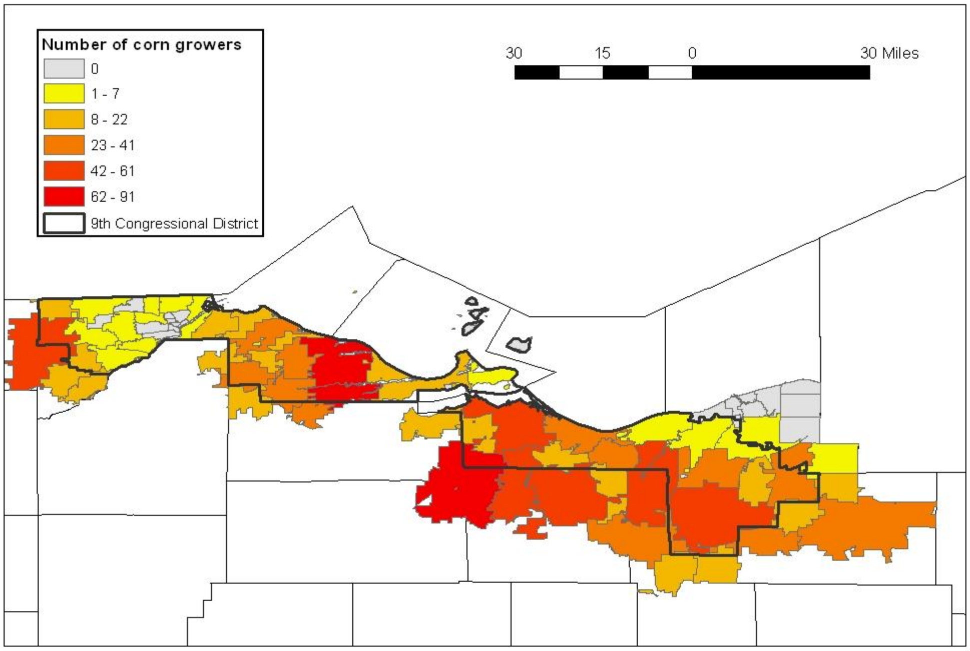
Number of Corn Growing Operations by Zip Code, Over 250 Acres
9th Congressional District, Ohio



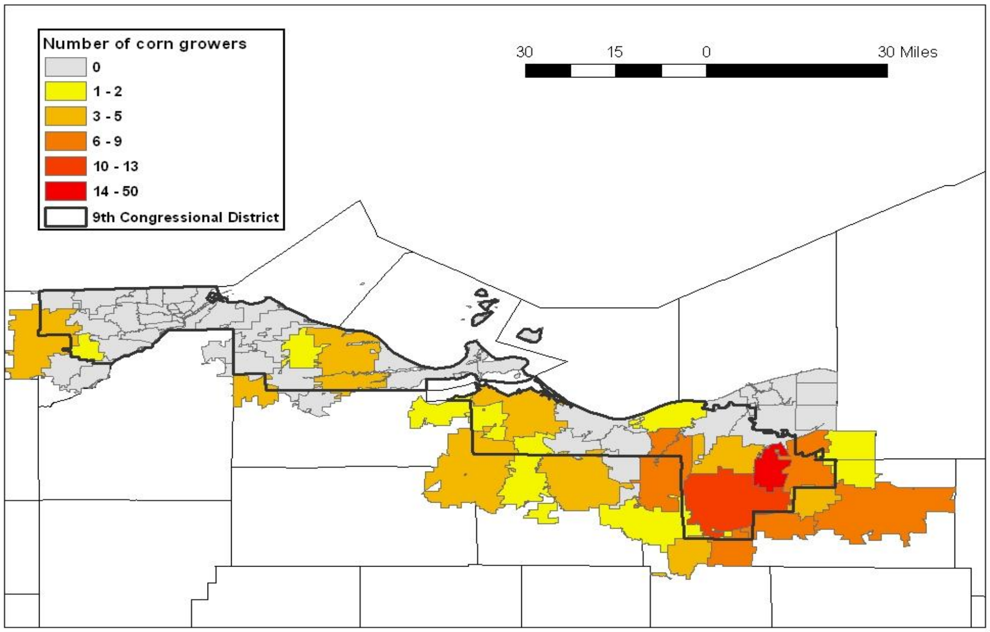
Number of Corn Growing Operations by Zip Code, Any Acreage
9th Congressional District, Ohio



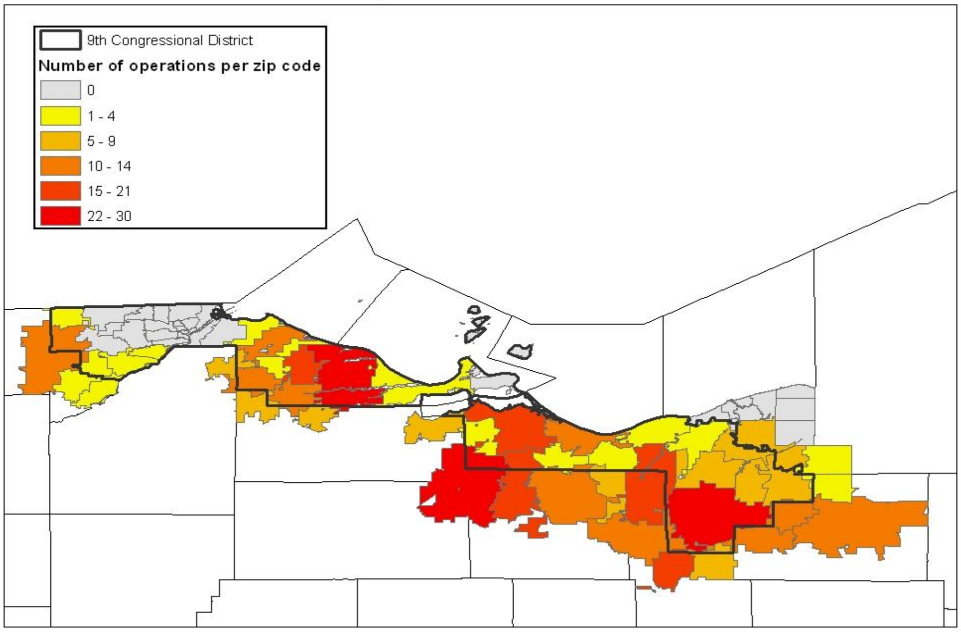
Number of Corn Growing Operations by Zip Code, Any Acreage
9th Congressional District, Ohio



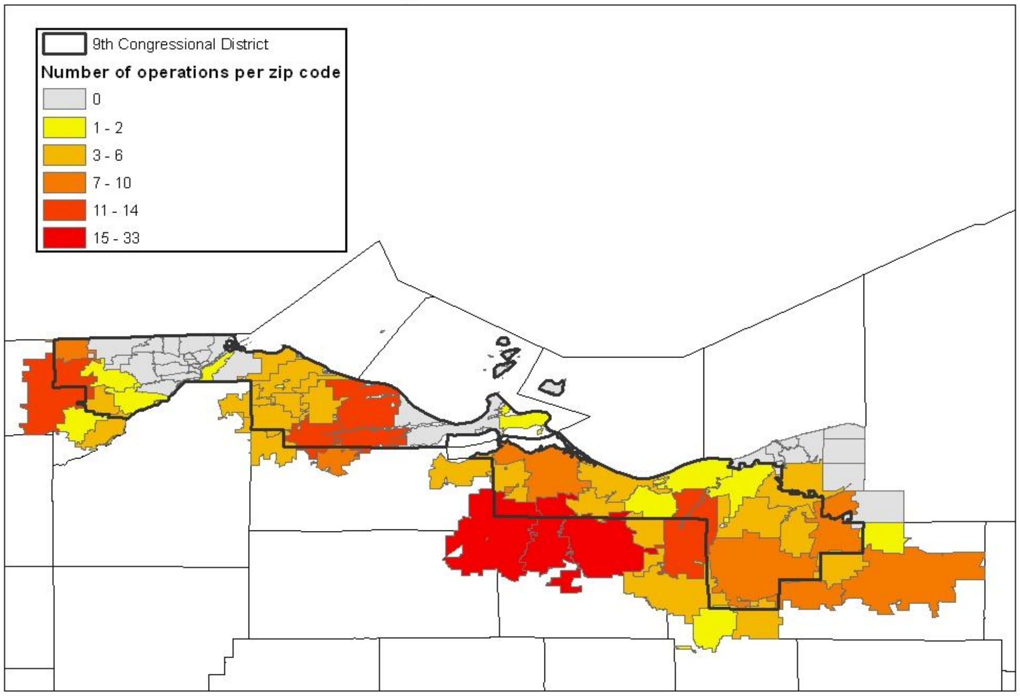
Number of Corn Growing Operations by Zip Code, Silage Only
9th Congressional District, Ohio



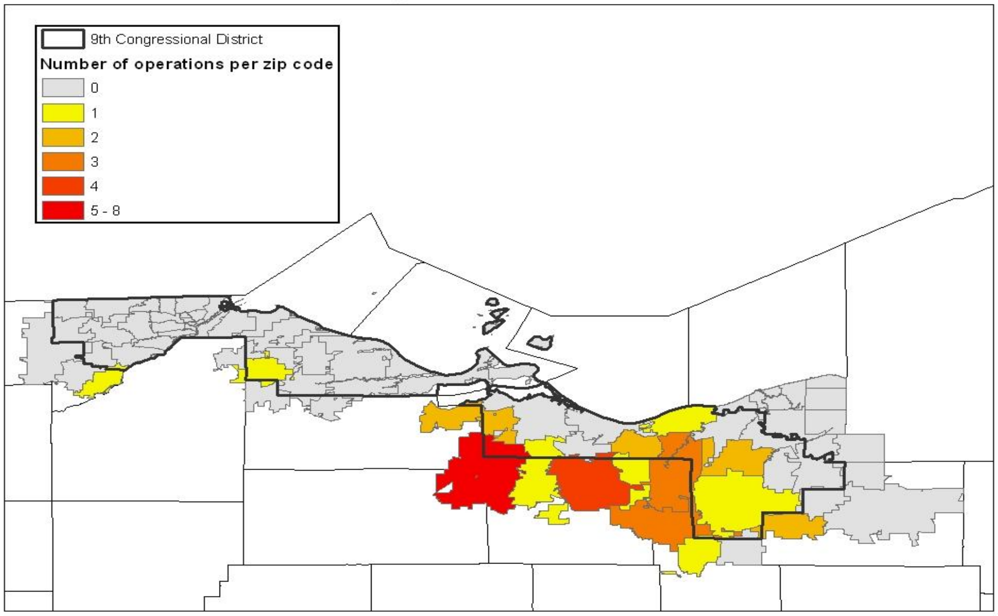
Wheat Growing Operations, 50 Acres or Less
9th Congressional District, Ohio



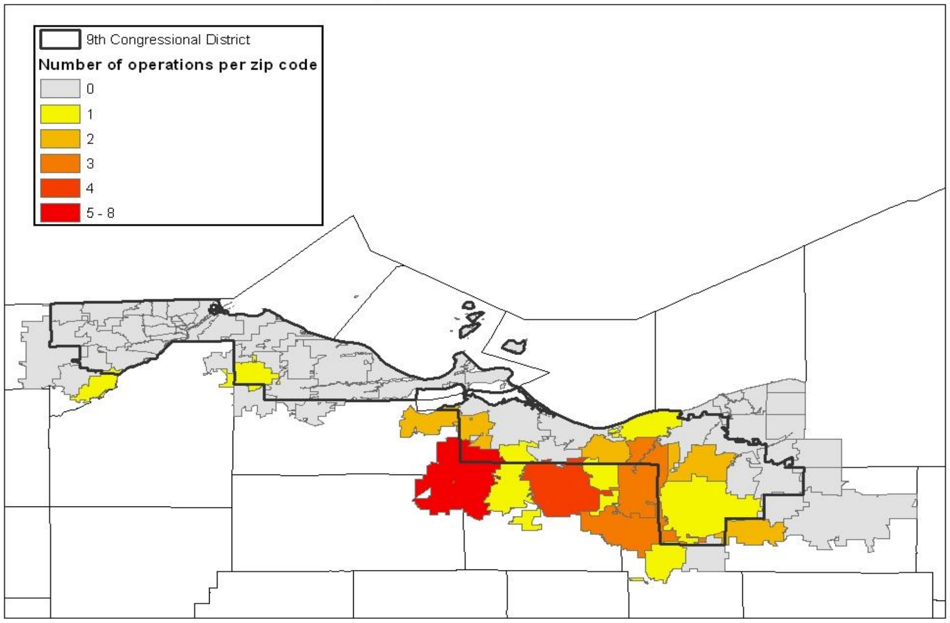
Wheat Growing Operations, 50 to 250 Acres
9th Congressional District, Ohio



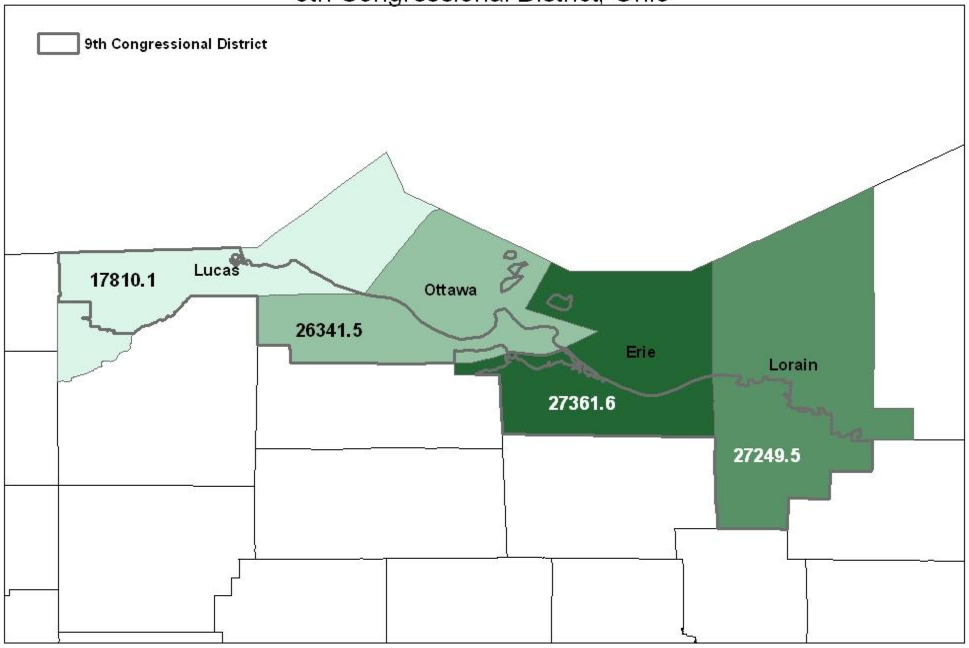
Wheat Growing Operations, Over 250 Acres
9th Congressional District, Ohio



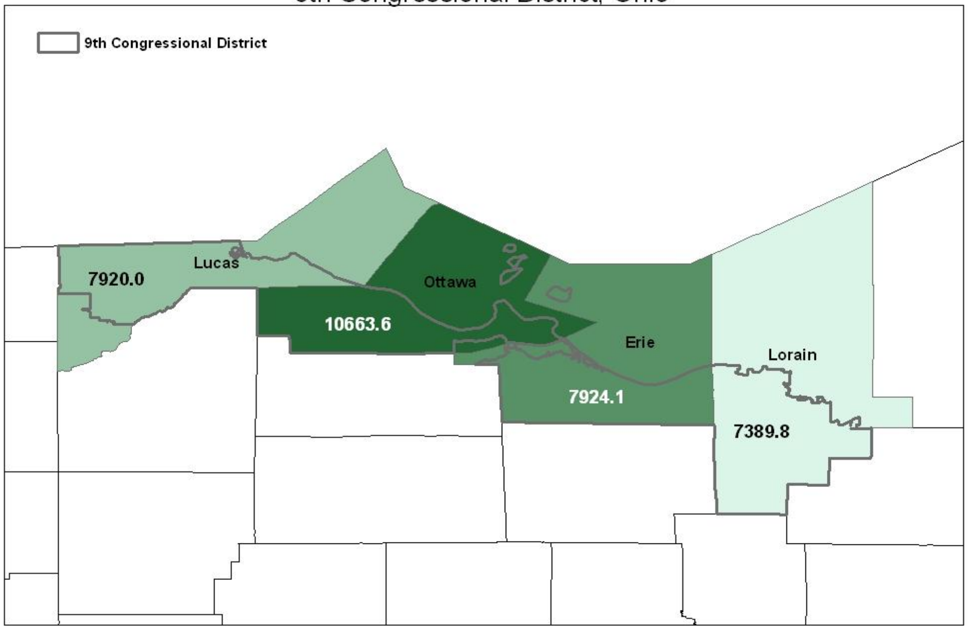
Wheat Growing Operations, Over 250 Acres
9th Congressional District, Ohio



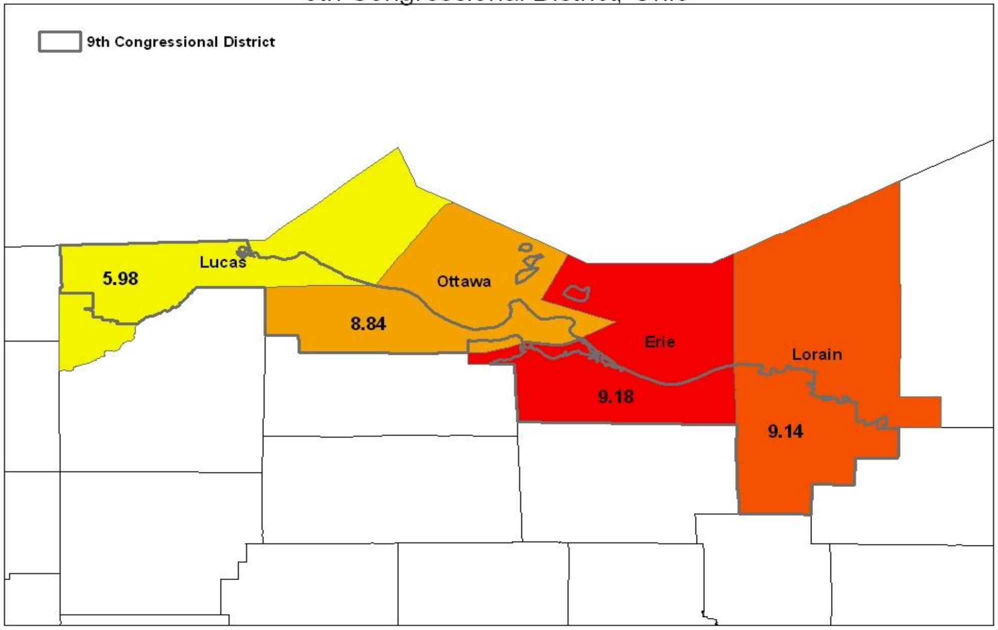
Corn Residue in Bone Dry Tonnes (BDT) by County
9th Congressional District, Ohio



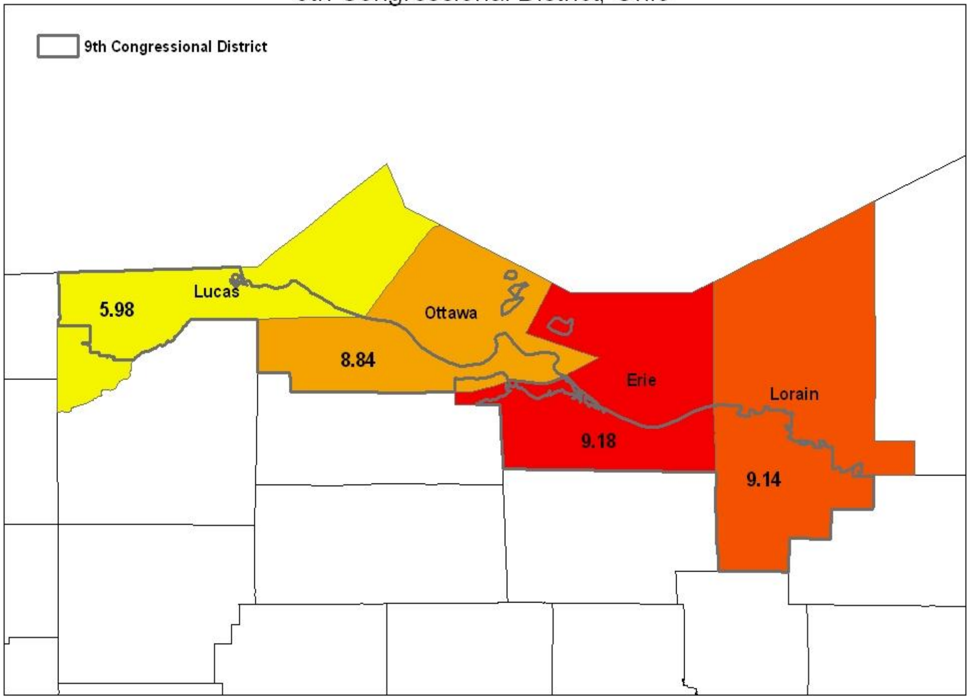
Wheat Residue in Bone Dry Tonnes (BDT) by County
9th Congressional District, Ohio



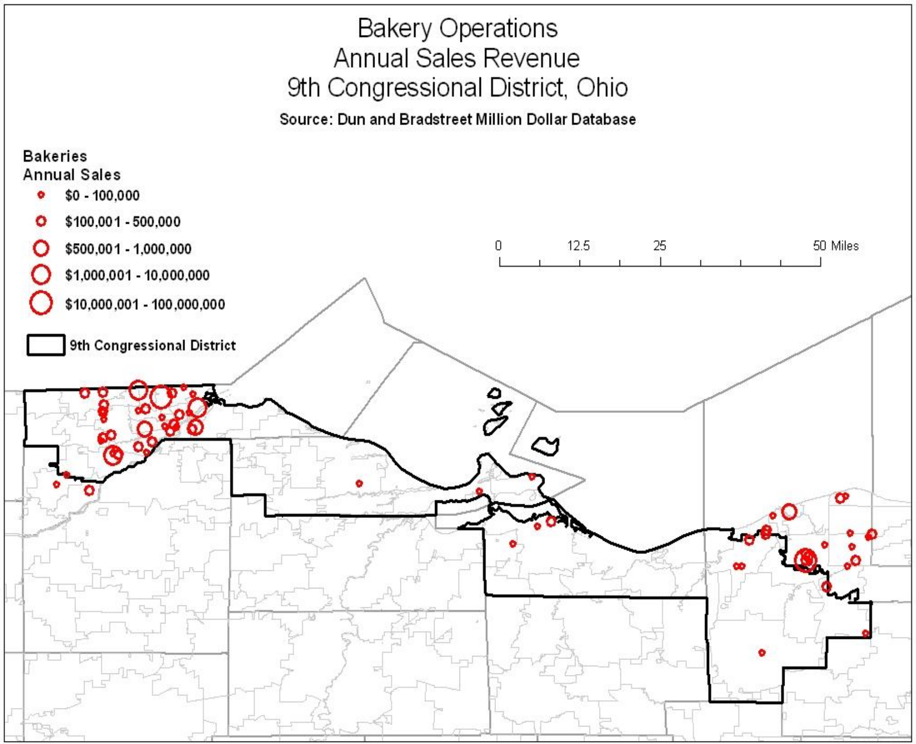
Methane From Corn Residue By County - Millions of Cubic Meters
9th Congressional District, Ohio



Methane From Corn Residue By County - Millions of Cubic Meters
9th Congressional District, Ohio



APPENDIX C: Food Processing Waste Data (Source: OARDC/OBIC , 2011)



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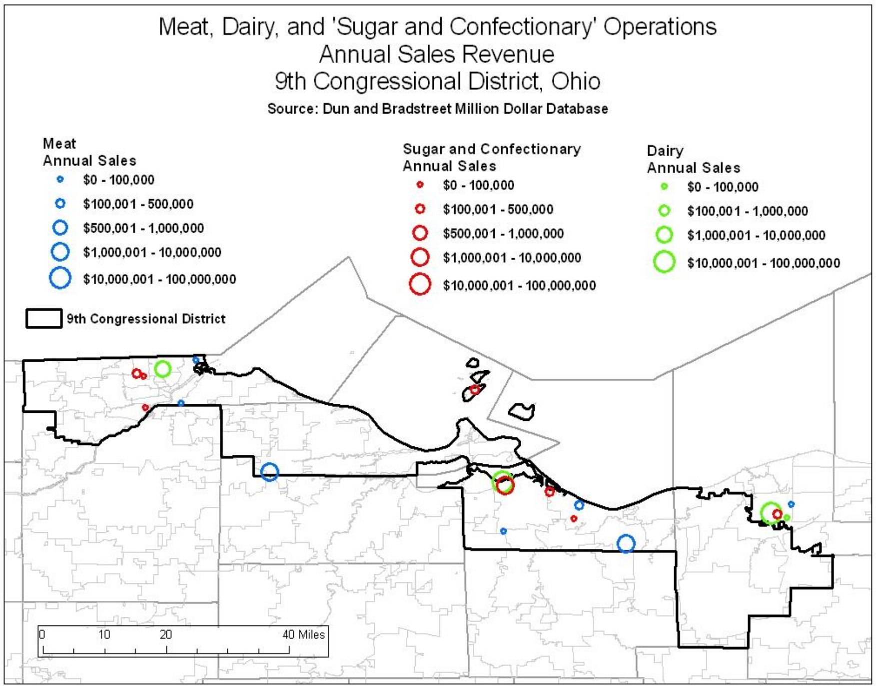

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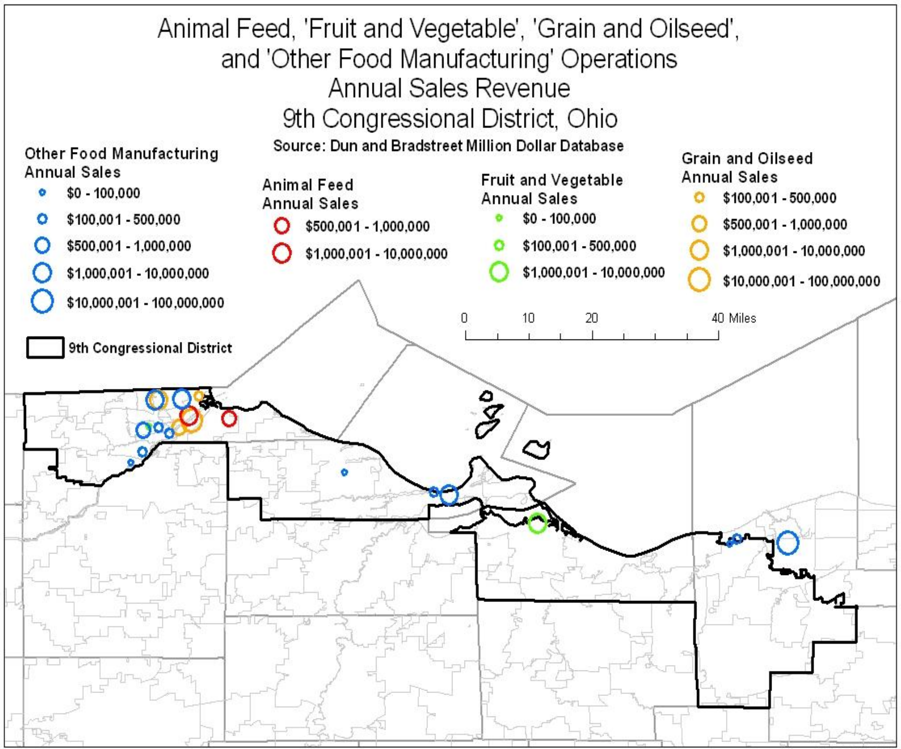

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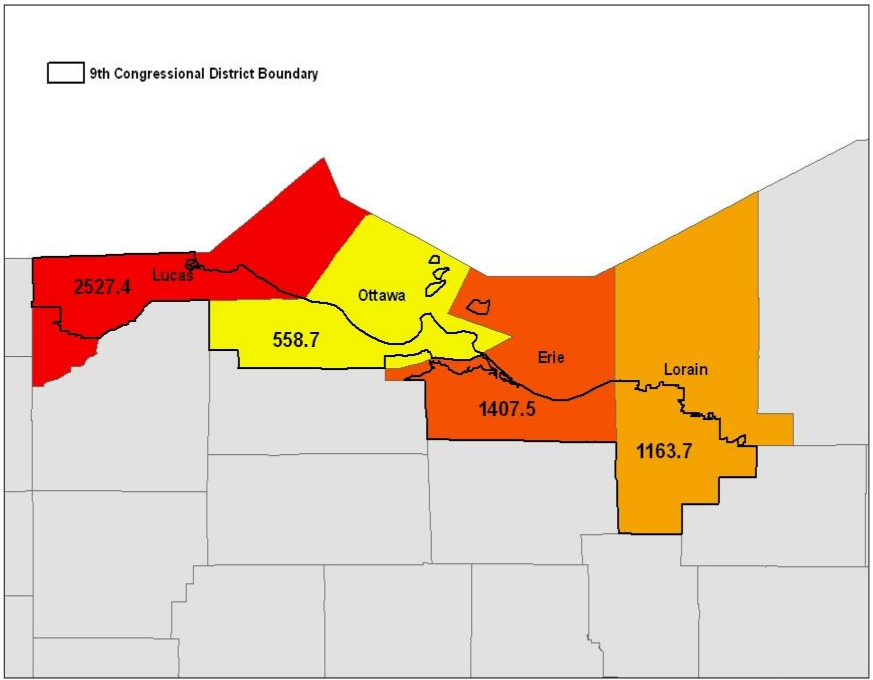
Estimated Annual Solid Industrial Food Processing Waste by County
(Tons Per Year)



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APPENDIX D:

Policy Brief on Anaerobic Digestion in Ohio

By Amanda Woodrum, Policy Matters Ohio

Background[21]

Livestock generate large amounts of manure that must be stored, spread on fields, or moved. When manure decomposes without oxygen in lagoons or pits, through "anaerobic digestion" it produces a biogas that is 60% methane.[22] Methane digester systems recover the methane in order to generate energy on site in the form of heat and/or electricity. Crop residues, food waste, wastewater treatment, fats and greases can also be diverted into digesters. In addition to capturing a valuable energy resource that is otherwise wasted, by trapping and burning methane, digesters can substantially reduce green house gas emissions. Emissions from the agricultural sector account for 6% greenhouse gas emissions nationally. A little over 1/10 of these emissions can be attributed to methane emissions from manure management. Methane is a potent greenhouse gas, one ton of methane having the equivalent effect as 24 tons of CO2.

Despite numerous economic benefits from methane recovery—including energy savings from self-generation, revenues to livestock producers from the sale of energy or renewable energy certificates, reduction of greenhouse gases and cleaner water, greater self reliance on homegrown renewable sources, reduced odors from the manure, and a byproduct that can be used as bedding or fill dirt—methane digesters have not seen widespread adoption. As of 2010, there were only 157 methane digesters nationally. The profitability of anaerobic digestion projects is determined largely by the cost of electricity, cost share and incentive policies, and the value of carbon offsets. Low electricity prices, combined with the undervaluing of the benefits to society from reduced emissions, often causes the costs to build and maintain a digester to exceed the monetary benefits to potential operators, impacting decisions whether to adopt the technology.[23]

There are policy reforms that can help reduce the costs and monetize the benefits of methane digester. Example of policy reform include requiring livestock producers or utility companies to reduce emissions by adopting certain technologies; providing grants, cost sharing programs, or incentive payments to support the development of methane digester projects; and taxing greenhouse gas emissions directly or indirectly and promoting robust carbon markets.[24]

Economics and Barriers

Research conducted by the United States Department of Agriculture suggests the decision to adopt a digester depends on several factors including the price of electricity, the farm's total current electricity expenditures, the start up and ongoing costs of the digester, the value placed on social benefits such as reduced pollution, the sale of solids separated from the methane, and the size of the operation.

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[21] The following report contributed significantly to the findings in this brief: Nigel Key & Stacy Sneeringer, United States Dept. of Agriculture, Economic Research Service, *Climate Change Policy and the Adoption of Methane Digesters on Livestock Operations* (Feb. 2011).

[22] U.S. Dept. of Agriculture, *Climate Change Policy and Methane Digesters* (Feb. 2011)(full cite supra).

[23] U.S. Dept. of Agriculture, *Climate Change Policy and Methane Digesters* (Feb. 2011)(full cite supra).

[24] Offsets are measured in tons of carbon dioxide equivalent emissions based on global warming potential.

3. **Electricity bills on farm (Price*Quantity)**. Higher electricity bills mean greater savings from self-generation for on-farm energy costs associated with heating, cooling, drying grain, pumping water, lighting, and operating machinery. However, Ohio electricity prices are artificially low, making the case for anaerobic digestion projects more difficult. There are several factors contributing to low electricity prices in Ohio:

Existing coal plants in Ohio are old, with their assets largely paid for (but very inefficient). Ohio's outdated electrical grid system hasn't been upgraded in decades. With roughly 30% efficiency rates, more energy is lost during generation and transmission than actually reaches the end user of electricity (for every three lumps of coal you put in you only get one out). Electric utilities have not entered the modern age of technology because they have not been required to meet efficiency standards, or upgrade the grid. And consumers haven't had to pay for the costs associated for doing so. These inefficiencies directly translate into the large levels of emissions produced in Ohio and cheap electricity. In Ohio, nearly half of all carbon emissions produced come from the electric power sector putting Ohio electric power industry 3rd in the nation behind Texas and Pennsylvania for the amount of carbon emissions it produces.

External costs of electricity not internalized by the utility.[25] Coal is a relatively cheap source of energy and approximately 87% of Ohio electricity is generated from coal. However, the price of coal-fired power doesn't reflect it's true cost to society. Electricity generation produces a significant amount of greenhouse gases, among other pollutants. The costs of these emissions—such as increased rates of asthma or climate weirdness—is born by the community generally. Because the costs from pollution are not born by the utility, they are in turn not reflected in the price charged to consumers, making the price of electricity artificially low.

Industrial rates for electricity are particularly low because they are cross-subsidized by residential and small commercial sectors. The industrial sector in Ohio, which includes agricultural users, pays 5.57 cents per kilowatt-hour. Compare that to the 10.4 cents paid by the commercial sector, and 11.3 cents for the residential sector (approximately double the industrial sector rate).[26] The higher prices in the residential and commercial sectors are made up in part by a subsidy to the industrial sector to reduce the cost of its electricity use. The national average rate for industrial sector electricity is 6.58 cents/kwh, and ranges from 4.6 cents/kwh in Idaho to 25.1 cents/kwh in Hawaii.

Policy Recommendations: Require electric utility companies to bear the full cost of generating electricity by increasing standards for efficiency, technology and emissions, and requiring them to upgrade to a 21st century electric grid.

4. **Price for selling surplus electricity**. If farms are able to sell excess electricity back to the grid, through a power purchase agreement, income from the sale provides additional incentive to adopt the technology. And a higher price at which a project can sell excess electricity increases project value.

Investor-owned utilities. Investor-owned utilities are reluctant to allow other producers of energy than themselves to sell power onto the grid and there are often significant barriers to doing so. When it does happen, rates paid are often low, based on the utility's avoided cost and without a

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[25] National Academy of Sciences, *Hidden Costs of Energy* at http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=12794

[26] http://www.eia.gov/state/state-energy-profiles-data.cfm?sid=OH#Prices

value placed on the social co-benefits. However, Ohio does have a renewable energy standard for its electric utility companies that has the potential of adding such a value to the equation (see the price of carbon section below).

Role for municipal power authorities and rural co-ops. Nationally, municipal utilities have been more open to securing renewable energy from local energy sources, but often do not have the internal expertise to do so (although there is now a federal program working to increase knowledge capacity at municipal utilities). In Ohio, most municipal utilities and rural co-ops simply purchase their electricity from AMP-Ohio rather than producing electricity themselves. However, of growing interest to publicly or community-owned utility companies across the country is the clean energy standard offer, or feed-in rate. A clean energy standard offer program allows utility companies to purchases clean energy from renewable project developers—at pre-established rates based on the average cost of projects plus a rate of return to the developers—via long-term contracts.

ROI based on avoided cost v. power purchase agreement v. clean energy standard offer. An Organ Dairy Digester study suggests that a price for selling power based on a utilities avoided cost was roughly 5.7 cents/kwh and would require a 20 year return on investment, negotiated power purchase agreement between a utility and livestock producer of 9 cents/kwh would take 15 years, while a clean energy standard offer program at 12 cents/kwh less than ten years and in some cases less than five.[27]

Combined Heat and Power Partnerships.[28] Another interesting potential is developing combined heat and power partnerships, where CHP units used directly by hospitals, institutions, public buildings, universities, and industrial firms could be powered by biogas. The public sector could support the formation of farm energy cooperatives and help develop these opportunities. There is also a growing coalition for combined heat and power developing a state policy platform to promote the CHP in Ohio.

Policy Recommendations: Federal, state, and local governments can support the development of municipal utility and business partnerships, with farming associations, to promote community digesters and biogas CHP projects, provide financial and technical assistance to increase the capacity of municipal utilities to take on these kinds of projects, create clean energy standard offer programs that include a feed-in rate for electricity from biogas CHP projects, and provide support for the coalition for combined heat and power effort through it's state policy platform to promote more efficient distributed generation among Ohio's investor-owned utilities. Also, municipalities, universities, schools, and hospitals should be encouraged to lead by example and adopt biogas CHP units.

5. **Price of carbon** – Higher carbon price makes selling carbon offsets more valuable. A farm's starting level of emissions determines quantity of emissions offsets that can be sold. Had it passed, federal climate change legislation would have created a robust national market for

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[27] Wisconsin Bioenergy Initiative, *The Biogas Opportunity in Wisconsin: 2011 Strategic Plan* (2007).
[28] Wisconsin Bioenergy Initiative, *The Biogas Opportunity in Wisconsin: 2011 Strategic Plan* (2007).

carbon offsets that would have significantly increased the demand for carbon offsets and their value, and increased the value of projects. Digester adoption spreads as carbon prices rise.[29]

Ohio's Renewable Energy Standard. Ohio passed legislation requiring 25% of electricity from Ohio's Investor-owned utilities come from advanced energy resources by 2025, half of which must come from renewable energy sources including biomass, and half of which must come from electricity generated within the state. This has created a market in Ohio for renewable energy credits (the sale of the environmental attributes of clean energy projects). The Public Utilities Commission of Ohio (PUCO) defined biomass to include energy derived from organic materials including food waste, animal wastes and byproducts, and biologically derived methane gas (landfill methane gas; or gas from the anaerobic digestion of organic materials, including animal waste, municipal wastewater, institutional and industrial organic waste, food waste, yard waste, and agricultural crops and residues).[30] The requirements start small and increase over time:

By end of year:	Renewable energy resources	Solar energy resources
2009	0.25%	0.004%
2010	0.50%	0.01%
2011	1.0%	0.03%
2012	1.5%	0.06%
2013	2.0%	0.09%
2014	2.5%	0.12%
2015	3.5%	0.15%
2016	4.5%	0.18%
2017	5.5%	0.22%
2018	6.5%	0.26%
2019	7.5%	0.30%
2020	8.5%	0.34%
2021	9.5%	0.38%
2022	10.5%	0.42%
2023	11.5%	0.46%
2024 and each year after	12.5%	0.50%

A disturbing trend in Ohio's renewable energy market is the large number of biomass co-firing projects proposed and their magnitude in size. These massive projects involve retrofitting inefficient coal plants to burn huge quantities of biomass, and pose a serious threat to the development of smaller more efficient biogas projects. Additionally, since the supply of renewable energy credits determines the value of the credits, the massive volume of these projects and the RECs may be putting downward pressure on the value of these credits in Ohio. Currently, Ohio's REC market is volatile, and the REC value relatively low.

Policy Recommendations: Require biomass projects meet certain levels of efficiency. This will discourage biomass co-firing while encouraging greater adoption of more efficient biogas technologies (like biogas CHP).

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[29] Nigel Key & Stacy Sneeringer, United States Dept. of Agriculture, Economic Research Service, *Climate Change Policy and the Adoption of Methane Digesters on Livestock Operations* (Feb. 2011).

[30] PUCO rule 4901:1-40-03 Requirements

6. **Cost share and incentive programs** defray the costs of building digesters.

Federal Programs

- *Federal Production Tax Credit (PTC) and Federal Investment Tax Credits (ITC)*. These tax credits have been used effectively by wind and solar developers. However, tax incentive driven policies typically don't typically work well for farmers unless they partner with investors who can use the credit.[31]
- *Rural Energy for America Program (REAP) Grant Program.* Federal grant program for renewable energy technologies including anaerobic digestion. Maximum incentive is 25% of project cost.
- *Rural Energy for America Program (REAP) Loan Guarantees.* Targeted to commercial and industrial sector, these loans guarantees can be up to $25 million.

Ohio Programs

Access to low-cost financing from state and local government, can reduce the long-term costs of the project.

- Ohio Air Quality Development Authority provides assistance, through tax credits and exemptions and low-cost financing of projects that improve Ohio's air quality. They received significant bonding authority for Qualified Energy Conservation bonds from the federal stimulus package in which they are using to target the development of municipal projects. As a result municipalities and municipal utilities make good joint partners for community digesters to take advantage of these funds. Legislation was passed in Ohio to allow Property Assessed Clean Energy (PACE), low-cost public financing for clean energy projects repaid via an assessment on the property.
- PACE programs in the Cleveland area and Toledo are getting underway, with plans to target commercial and industrial sector projects given issues with its application in the residential sector. Anaerobic digestion qualifies.

Ohio's Advanced Energy Fund. Ohio's Advanced Energy Fund has provided grants, low-interest loans, and incentive payments for clean energy projects. Unfortunately, the collection mechanism for the fund, a small surcharge on electric utility bills, was allowed to expire in January of 2011, putting the future of the state's incentive program in question. The program was small to begin with, but it should be extended and expanded.

Ohio Renewable Energy and Advanced Energy Project Property Tax Exemption.[32] Prior to SB232, a renewable energy facility that sold electricity to a 3rd party was considered a "public utility" for tax purposes. SB232 exempts qualified energy projects, including anaerobic digestion, from personal and real property taxes. Qualified projects that are 250kw or less, **for sale to 3rd parties**, are not subject to payments in lieu of property taxes. Qualified projects greater than 250kw, will be required to make payments in lieu of property taxes based on the size and type of facility, and the number of Ohio-based employees. They must also be placed in service by January of 2015 (unless it is a cogeneration facility then have until 2019), meet certain job-creation criteria, and offer to sell the RECs to Ohio's electric utilities. Projects larger than 5 MW require approval by county commissioners to receive the property tax exemption, must pay for road repairs necessary, and provide training. Projects greater than 2MW must establish partnerships with universities.

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[31] Wisconsin Bioenergy Initiative, *The Biogas Opportunity in Wisconsin: 2011 Strategic Plan* (2007).

[32] http://dsireusa.org/incentives/incentive.cfm?Incentive_Code=OH60F&re=1&ee=1

Ohio Energy Conversion Facilities Sales Tax Exemption. Ohio may provide 100% sales and use tax exemption for property used in energy conversion including solid waste conversion (project must be certified). Ohio may also provide an exemption from the state's corporate franchise tax where applicable. In addition, such property is not deemed an improvement to the property for real property taxation or as "used in business" for purposes of personal property taxation.

<u>There are numerous programs in other states that could serve as a model for Ohio</u>[33]

- *TVA Renewable Standard Offer Program* (Alabama).[34] A performance-based incentive program, paying as high as 16 cents per kw-h through long-term contracts up to 20 years in length. Anaerobic digestion qualifies for incentives under the program, among several other technologies.
- *Alabama Saves Revolving Loan Program.*[35] Biomass and CHP projects, among others, qualify for 2% interest loans over 10 years from the state to cover 100% of the project cost after grants, tax credits, and other incentives are deducted. ARRA dollars were used to capitalize the project.
- *Alaska Energy Authority Renewable Energy Grant program* ($50 million annual appropriations). Alaska provides grants to utilities, local governments, and independent power producers for **in-state** renewable energy projects including anaerobic digestion.
- *Arizona Public Service Utility Rebate Program*. Maximum incentive is 50% of projects costs up to $75,000.
- *Illinois Biogas and Biomass to Energy Grant Program.* This program specifically targets the development of in-state biogas and biomass demonstration projects, and provides grants up to 50% of the project costs, limited to $225,000 for biogas projects. Projects must be part of a CHP system.
- *Iowa state revolving loan program.* Provides 0% loans, with up to 20 year terms, for renewable energy projects including biomass, covers 50% of project costs up to $1,000,000.[36]
- *Kentucky office of Agricultural Policy—On-Farm energy efficiency and production grants.* Program specific to agricultural sector, and covers a host of measure that benefit farmers including efficiency audits and assessments. Covers 25% of project costs up to $10,000.
- *Maine Community-Based Energy Production Incentive.* This program is designed to encourage in-state, local owned renewable energy resources. The program provides up to 10 cents per kilowatt-hour, to be determined on a case by case basis, through long-term contracts for energy or renewable energy credits. Includes anaerobic digestion among many other technologies. The PUC may require investor-owned utilities to enter into long-term contracts for energy or RECS from community-based projects. Participation by cooperatives is voluntary.
- *Michigan Biomass Gasification and Methane Digester Property Tax Exemption.* 100% exemption from real and personal property taxes, but the equipment must be certified by the Michigan Department of Agriculture.
- *Minnesota Methane Digester Loan Program.* Minnesota Rural Finance Authority provides up to 45% loan principal, max $250,000, 10 year maximum loan term.
- *Minnesota Sustainable Agricultural Revolving Loan Program.* This farms only program provides $40,000 loans per family farm, or $160,000 for joint projects for on-farm energy production, at 3% interest for up to seven-year terms.
- *Minnesota Value-Added Stock Loan Participation Program.* Provides up to 45% of loan, up to $40,000 of loan principal, at 4%, for the purchase of stock in cooperatives, limited liability

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[33] Database of Incentives for Renewables and Efficiency at http://www.dsireusa.org/

[34] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=AL41F&re=1&ee=0

[35] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=AL44F&re=1&ee=0

[36] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=IA06F&re=1&ee=0

companies, or limited liability partnerships for a "value-added agricultural product" such as anaerobic digesters.

- *New Jersey Assessment of Farmland Hosting Renewable Energy Systems.* This is a property tax incentives, various technologies qualify including anaerobic digestion, up to 2MW for a maximum of 10 years. Farmland dedicated to agricultural purposes in New Jersey is assessed based on its productivity value, making a lower tax burden for farmers. Income generated from the sale of heat and power from renewable sources is not considered income for the purposes of assessment.
- *New Mexico Agricultural Biomass Income Tax Credit* (for wet manure turned into electricity). Annual limit of $5 million.
- *New York Anaerobic Digester Gas-to-Electricity Rebate and Performance Incentive.* Provides $1000 per kilowatt capacity AND 7 cents/kwh production payment, for a total incentive up to $1 million.
- *South Carolina Biomass Energy Production Incentive.* As a result of the Energy Freedom and Rural Development Act, South Carolina provides a one cent per kilowatt and 30 cents per therm, up to $100,000 per fiscal year per taxpayer, or $2.1 million per fiscal year for all taxpayers.
- *Vermont Standard Offer for Qualifying SPEED resources (including anaerobic digestion)*. Amount varies depending on the technology, long-term contracts for 15-20 years, with a maximum capacity of 2.2 MW. RECs are transferred to utilities except in the case of farm methane digesters who maintain RECs generated.

7. **Operation size.** Construction costs decline per animal head, producing higher profits for larger operations. Plus, higher profits for larger operations from carbon markets could cause greater concentration of market to promote economies of scale. To counter this, state and local governments can provide targeted support for smaller operations includes supplementing project with food waste products, sharing digesters with other smaller operation, and cost-share subsidies. There is a role for local governments in assisting in the development of this process. A centralized community digester, for instance, could serve multiple farms. State and local governments can also support the establishment of a biogas cooperative network.

8. **Farmers are not in the energy business**. They do not have experience with electricity or gas generation, and are concerned with management and maintenance required, a fear of failure and disruption and distraction from core business activities, and they do not have reliable data and information.[37] State and local governments and non-profits can provide engage in public education and outreach campaigns and support farmers and others by providing technical business assistance from a trusted source to help farmers address these issues and weigh their options.

Conclusion

This brief scratches the surface on the economics, barriers, and state policies to promote the adoption of methane digesters. Other states have pursued opportunities for methane recovery more aggressively, and programs in these states can serve as models to the development of a more robust program in Ohio. And there are good reasons to do so.

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[37] Floyd Schanbacher, The Ohio State University, OARDC, *Anaerobic Digestion, Overview and Opportunities.*

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