Manure Digesters

Initiative Summary:

Anaerobic digestion is a biological treatment process that reduces manure odor, produces biogas which can be converted to heat or electrical energy and improves the storage and handling characteristics of manure. This work plan recommendation or initiative analyzes the potential for increasing anaerobic digester deployment at medium to large-sized dairy and swine farms.

Currently, there are 26 manure digesters in Pennsylvania and at least 3 more under construction. At least 14 of these have been funded, in part, through DEP and other Commonwealth-supported financing programs. These digesters are converting the effluent from more than 14,000 dairy cows and 29,000 hogs into useable thermal energy and electricity.

Goals:

Install a total of 25anaerobic digesters on dairy farms of 500 or greater cows and 10 digesters at swine operations with 3,000 or more animals.

Implementation Period: 2013 through 2020. Implementation will increase steadily between 2013 and 2020.

Implementation Steps: Continuation of financial assistance through state, federal and private programs to help overcome the burden of up-front capital costs. Potential operators of anaerobic digesters could rely on several different funding programs/mechanisms, including grants, cash reimbursements, loan guarantees, industrial bonds, private funding, and other cost-sharing agreements. Many anaerobic digester operators apply for and receive a combination of funding mechanisms (e.g., loan guarantees and grants) to fund their projects. Some examples of programs where federal and state agencies provide grant funding for the construction and operation of anaerobic digesters include the Pennsylvania Department of Environmental Protection (PADEP), U.S. Department of Agriculture (USDA) and the Rural Energy for America Program (REAP) to mention a few. In addition there are accelerated outreach programs through state and federal institutions, such as the PSU Cooperative Extension Units, educating the agricultural community as to the multiple economic and environmental benefits associated with energy production and nutrient reduction strategies.

Data Sources/Assumptions/Methods for GHG:
Dairy Cow Anaerobic Digesters

This type of technology could be applied to beef cattle, although their methane emissions in Pennsylvania are far lower than emissions from dairy cattle. Swine manure emissions are considered later in this analysis.

Anaerobic digestion (AD) systems result in three areas of greenhouse gas emissions reductions. The first results from the collection and digestion of manure, which actually serves to increase methane emissions above business as usual without deployment of a digester. The difference in generated emissions beyond baseline levels is netted out. It is the destruction of the net balance of this methane that results in the first source of emissions reductions.

The second area of greenhouse gas reductions is obtained by offsetting fossil fuels used in the generation of electricity or for direct use as thermal energy. For the purposes of this analysis, it is assumed that the methane is used to create electricity, displacing fossil-based electricity generation, which is the norm.

Manure digesters operate most efficiently at about 120 to 130 degrees Fahrenheit, which is the approximate temperature at which most digesters are maintained. Since it never approaches this temperature in Pennsylvania, more methane will be created and captured in the digester than was previously released before digester installation. The increase in methane produced (and captured) was estimated by comparing the amount of methane captured in an AD, as found in the AA Dairy and Knoblehurst farms in New York, with the amount of methane created in a typical dairy farm (as found in the U.S. Environmental Protection Agency's [EPA's] State Greenhouse Gas Inventory Tool module). This module found that nearly four times as much methane was generated in ADs than would have been created under normal environmental conditions. This figure is applied to calculate the amount of methane captured and used to generate electricity in all ADs.

The policy objective begins in 2013 with 2 new digesters and ramps up linearly to a total of 25 new digesters in 2020. Table 1 shows the GHG reductions possible by installing this number of ADs at Pennsylvania dairy farms.

Table 1. GHG Reductions from Methane Utilization

Year	Cumulative Digester Total	Cumulative Dairy Herd Size Served	Baseline CH4 Capture (MtCO2e/Yr)	CO2 Offset from Electricity Generation (MtCO2e/yr.)	CO2 Reductions from Waste Heat Utilization (MtCO2)	Total CH4 Emission Reductions ($MMtCO_2e$)
2013	2	1,500	469	1.96	4	0.0005
2014	4	3,000	938	3.91	9	0.0010
2015	156	4,500	1,407	5.87	13	0.0014
2016	208	6,000	1,877	7.82	17	0.0019
2017	2511	8,250	2,581	10.75	24	0.0026
2018	3015	11,250	3,519	14.66	32	0.0036
2019	35520	15,000	4,692	19.55	43	0.0048
2020	4025	18,750	5,865	24.44	54	0.0059

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					Total	**0.0216**

Utilization Costs

The costs for dairy farm AD systems for farms with 500 or more cows is based on data and experiences from PA DEP, which has provided financing to several digesters in this size class, as well as those in NY state. Both states are leaders in the numbers of farm digesters installed. That data indicates that an average total cost for farms of this size is approximately $1,371 per head in $2010. Projected capital costs were made based on an assumed average 2.5% annual rate of inflation. Smaller-scale farm digesters, while feasible for those with centralized manure collection and handling systems, are generally less cost effective, hence the focus on larger farm installations. Table 2 provides perspective of Pennsylvania dairy farm size distribution and the projected trend toward larger farms due to improved economics.

Table 2. Estimated Breakdown of Dairy Farm Size (head)

Year	Percentage in Large Farms (>500)	Percentage in Medium Farms (100-500)	Percentage in Small Farms (<=100)
2013	6%	43%	52%
2014	6%	43%	51%
2015	6%	44%	50%
2016	6%	45%	49%
2017	6%	45%	48%
2018	7%	46%	47%
2019	7%	47%	46%
2020	7%	48%	45%

Annual O&M costs come from a USDA study comparing several types of digesters for both dairy and swine. This study reports O&M costs as a percentage of capital costs. Typical AD systems at Pennsylvania dairy farms are plug-flow digesters with reported annual O&M costs identified as 2.4% of capital costs. Electricity generated is calculated based on the average annual electricity generated/head on farms with ADs already installed. Data from DEP suggests that this value is approximately 1,887 kWh/head/year, which is then multiplied by the number of dairy cattle with a new AD system in place to determine total electricity generated. DEP estimates that on average about 35% of this electricity is used on the farm. Pennsylvania has among the best net metering laws in the country, and the revenue of this electricity generation is split between the value of what is used on site and that which is delivered into the electric grid. The value of electricity consumed on site was calculated based on actual statewide average rates and projected forward using projection estimates from the US Energy Information Agency. In this analysis, the rate class chosen was commercial and valued at a retail price of 10.56 cents per kWh in 2013, increasing to 12.47 cents in 2020. The rate at which electricity is sold back to the local electric distribution company is a wholesale rate and is determined by market forces but was estimated at 5 cents per kWh and does not change through 2020.

Utilization of waste heat from the engine jacket and generator from dairy digester systems represents a significant cost savings measure. Data from DEP suggests that an average system may yield 22.3 MMBtu (equivalent to about 170 gallons of heating oil) of recoverable heat that is typically used to offset heating oil needs. Carbon offsets associated with the displacement of fossil fuels (typically heating oil) used for heating and absorption chillers provides another source of revenue as does the revenue for carbon offsets associated with the capture and destruction of methane, as compared to baseline values if no digester were in installed.

The costs and revenues associated with the dairy digester aspect of this work plan recommendation are provided below in Table 3. All costs are reported in 2010 dollars and discounted using a 5% discount rate.

Table 3. Net Costs / Savings of Anaerobic Digesters for Dairy Cows

Year	Annualized Capital Cost (MM$)	Annual O&M Costs of Anaerobic Digesters (MM$)	Carbon Offset Revenue (MM$)	Value of kWh Used on Farm (MM$)	Revenue from Electricity Sales (MM$)	Value of Fossil Fuel Displaced by Waste Heat (MM$)	Net Annual Costs Savings (MM$)	Discounted Net Costs of Program (MM$)
2013	0.18	0.05	1,426	0.10	.09	0.001	0.03	0.03
2014	0.36	0.11	2,853	0.21	0.18	0.002	0.07	0.06
2015	0.56	017	4,279	0.33	0.28	7.60.003	0.11	0.09
2016	0.76	.23	5,705	0.45	0.37	10.30.004	0.17	0.12
2017	1.08	0.32	7,845	0.63	0.51	0.006	0.25	0. 18
2018	1.51	045	10,698	0.88	0.69	15.80.008	0.36	0.25
2019	2.06	0.62	14,264	1.21	0.92	0.011	0.52	0.34
2020	2.64	0.79	17,830	1.54	1.15	0.013	0.70	0.43
						Total	2.21	1.48

Cost-effectiveness is calculated by dividing total, discounted costs (over the entire period) by the cumulative GHG savings of the project to get a $/metric ton (t) figure. For example, in this analysis, the net cost is $2.21 million (found at the bottom of Table 3), and the GHG savings are 0.0216 MMt (located at the bottom of Table 1). This means that the cost-effectiveness of the implementation scenario is $93/ton.

Swine Anaerobic Digesters

Pennsylvania currently has anaerobic digesters operating at 7 swine operations. This work plan recommendation analyzes the potential of adding two additional ADs per year for a total of 16 through the end of year 2020. Among the benefits of farm-based digesters is their ability to control odors. Odor control has a very real value even if it cannot be effectively monetized. In fact, one of the longest running anaerobic digesters in Pennsylvania was installed at the Rocky Knoll Swine Farm in 1985 primarily for odor control.

The GHG reductions of this policy were estimated for Pennsylvania pig farms, which yield approximately 39% of total manure methane emissions. The emissions from pig farms were taken from the Pennsylvania greenhouse gas inventory. A manure management survey by the U.S. Department of Agriculture (USDA) found that 58% of large-scale (>1,000 head) pig farms used anaerobic lagoons. The availability of Pennsylvania-specific information on the breakdown of manure management technologies and farm size would improve this analysis.

CAFO farms are assumed to have more than 1,000 head of pigs. Most of these farms have anaerobic lagoons and those that don’t are believed to have anaerobic pits that can be replaced with ADs. Based on previous discussions with the Pennsylvania National Agricultural Statistics Service (NASS), it is assumed that swine population figures will remain constant between 2010 and 2020.[1] This analysis is based on swine farms with 3,000 pigs. Table 4 shows the implementation path used for this policy and the GHG reductions expected.

Table 4. GHG Emissions Reductions from Swine Farm Digesters

Year	Cumulative Digester Total	Cumulative Swine Herd Served	Baseline CH4 Digester (MtCO2e/Yr)	CO2 Offset from Electricity Generation (MtCO2e/yr.)	Total GHG Reductions (MMtCO2e)
2013	1	3,000	,802	0.08	0.0008
2014	2	6,000	1,604	0.17	0.0016
2015	3	9,000	2,406	0.25	0.0024
2016	4	12,000	3,208	0.34	0.0032
2017	5	15,000	4,010	0.42	0.0042
2018	6	18,000	4,812	0.51	0.0048
2019	8	24,000	6,415	0.68	0.0064

[1] Personal Communication with Mark Linstedt by Jackson Schreiber, PA Office of NASS. 5/21/09.

2020	10	30,000	8,019	0.85	0.0080
				Total	**0.0313**

BAU = business as usual; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Swine Manure Management Costs

The costs of this policy were estimated from data obtained from Moser, et.al.[2] a USDA Economic Research Service Report by Key and Sneeringer,[3] and data from PA DEP. The average capital costs for swine digesters was estimated at $42.49 per head ($2010) and projected forward at an assumed average annual rate of inflation of 2.5%. Operation and maintenance (O&M) costs were determined to be $0.02 per head. Table 5 presents more information on the costs/cost savings analyzed in this aspect of the work plan strategy.

Table 5. Net Costs / Savings of Anaerobic Digesters for Swine

Year	Annualized Capital Costs (MM$)	Annual O&M Costs (MM$)	Revenue from Carbon Credits (MM$)	Value of kWh Used on Farm (MM$)	Revenue from Electricity Sales ($MM)	Net Costs / Savings ($MM)	Discounted Net Costs / Savings ($MM)
2013	0.01	0.00	2,406	0.01	.0003	(0.001)	(0.001)
2014	0.02	0.01	4,812	0.02	.001	(0.001)	(0.001)
2015	0.03	0.01	7,218	0.04	.001	(0.001)	(0.000)
2016	0.05	0.01	9,624	0.05	.001	0.001	0.001
2017	0.06	0.02	12,030	0.06	.002	0.003	0.002
2018	0.07	0.02	14,436	0.07	.002	.006	0.004
2019	0.10	0.03	19,248	0.10	.002	0.011	0.007
2020	0.13	0.04	24,060	0.12	.3	.018	0.011
					Total	0.03	0.02

<u>Key Assumptions and Uncertainties:</u>The analysis for swine digesters is based on limited availability of data and specific for complete mix anaerobic digester technology. Costs would vary for other digester designs such as plug-flow systems. Also, if the amount of methane gas being generated pre and post anaerobic digester is significantly different it stands that the differences in the outcomes will be amplified. Different from dairy anaerobic digestion systems, swine operations in this analysis are assumed to use all of the waste heat captured to keep the

[2] Moser, Mark A., Mattocks, Richard P., Gettier, Stacy and Roos, Kurt "Benefits, Costs and Operating Experience at Seven New Agricultural Anaerobic Digesters" http://www.epa.gov/agstar/documents/lib-ben.pdf
[3] Nigel, Key and Sneeringer, Stacy. **"**Climate Change Policy and the Adoption of Methane Digesters on Livestock Operations" http://www.ers.usda.gov/media/131839/err111.pdf

digesters in homeostasis with no remaining waste heat being utilized on the farm. Carbon offsets or credits may be too few for a single or smaller project to pursue marketing. As such, it may be necessary for multiple owners of anaerobic digestion systems to pool their carbon credits to aggregate sufficiently large volumes for more efficient marketing.

Potential Overlap:

This work plan is recognized as potentially overlapping with the analysis of the Alternative Energy Portfolio Standard work plan. The degree of specificity and detail in this digester work plan is not used in the more macro-level analysis performed for the AEPS. The digester work plan necessarily requires a full accounting for implementation purposes and to remove costs and/or cost savings data related to electricity generation would prevent a transparent appreciation for the overall economics. Instead the assumption used here is that the farms would benefit only from the aspects of net metering and the sale of carbon offsets. The value of AEPS credits was appropriately not included in the digester work plan to avoid overlap. Analysis for the AEPS is based on operational costs and a mix of weighted average prices for the purchase of AEPS credits.

The potential for overlap between this work plan and the work plan for Waste-to-Energy Digesters was evaluated and determined that there is sufficient manure feedstock for both work plans so no overlap was calculated.

Grants and Cost-Sharing:

To help overcome the burden of up-front capital costs, operators of anaerobic digesters may rely on several different funding mechanisms, including grants, cash reimbursements, loan guarantees, industrial bonds, private funding, and other cost-sharing agreements. Many anaerobic digester operators apply for and receive a combination of funding mechanisms (e.g., loan guarantees and grants) to fund their projects.

Some examples of programs where federal and state agencies provide grant funding for the construction and operation of anaerobic digesters include the U.S. Department of Agriculture (USDA) Rural Energy for America Program (REAP), PA Department of Agriculture (PADA) and the PA Department of Environmental Protection (PADEP).

Other Cost-Sharing Agreements:

In other cost-sharing agreements, the farm operator and another entity (e.g., an electric utility, other company) share the capital and/or operating costs of the anaerobic digester. In exchange for providing funding, the entity receives a tangible return (e.g., owning the electricity generated) or receives environmental credits, such as the renewable energy credits/certificates (RECs) or the carbon offset credits.

Private Funding Sources :

Because grants and cost-sharing agreements may not cover the full costs, most farm operators interested in anaerobic digestion will have to provide at least some up-front capital to cover the capital cost of the digester. In these situations, farm operators will have to secure funds in a more traditional sense. Private funding or financing may come in the form of equity financing, debt financing, or some combination of both.

Loan Guarantees and Industrial Bonds:

A federal or state **loan guarantee** is a funding mechanism in which a federal agency guarantees the loan (i.e., full repayment of a loan). Loan guarantees typically lower the cost of financing an anaerobic digester by effectively reducing the interest rate required on a loan to purchase and install the digester. Loan guarantees also allow digester projects to attract a larger number of potential lenders than traditional loans. With the loan guarantee, potential lenders are guaranteed full repayment of the loan, even if the digester operator defaults on the loan.