Manure Digesters

Initiative Summary:
Anaerobic digestion is a biological treatment process that breaks down manure, thereby producing biogas which can be converted to heat or electrical energy, improving the storage and handling characteristics of manure, and possibly reducing manure odor. This work plan recommendation or initiative analyzes the potential for increasing anaerobic digester deployment at medium to large-sized dairy and swine farms. The produced biogas is typically 60% methane, 40% carbon dioxide and <1% trace gases, which yields a heat content of 600 BTU/scf, which classifies biogas as a medium-BTU fuel.

Currently, there are approximately 25 manure digesters in Pennsylvania, with the majority (19) being located at dairy farms, four at swine farms and two at farms with both swine and dairy herds. Based on the analysis conducted in this work plan, manure digesters using waste from large dairy operations are cost effective options for reducing greenhouse gases. The use of manure digesters using waste from swine operations can also reduce greenhouse gas emissions, but at a higher cost for a lower rate of reductions. Odor management and reduction of solids are co-benefits of this work plan.

Additionally, these digesters produce "biologically derived methane gas", which is defined as a Tier I resource under the Alternative Energy Portfolio Standards Act.

Implementation Period:
2015 through 2030

Data Sources/Assumptions/Methods for GHG:
Anaerobic Digester technology could be applied to beef cattle, poultry, and other animals, although their methane emissions in Pennsylvania are far lower than emissions from dairy cattle. Both dairy and swine manure emissions are considered in this analysis.

Anaerobic digestion (AD) systems can reduce greenhouse gas emissions in two different ways. Manure management practices on farms sometimes lead to the bulk storage of manure for extended periods of time. Under anaerobic conditions, found in manure management practices which involve creating a slurry or using long term bulk storage, methane gas can be generated as an end product in the breakdown of the solid organics in manure. An anaerobic digester allows for the capture and destruction of methane prior to being released to the atmosphere. Estimates of the amount of CO_2e captured are based on factors provided on the EPA State Inventory Tool.

The second area of greenhouse gas reductions is obtained by offsetting fossil fuels used in the generation of electricity and for direct use as thermal energy. For the purposes of this analysis, it is assumed that the methane is used in a combined heat and power source. Other co-benefits of using digesters for farm (and other animal manure) are improved odor control, improved quality of the resulting product for use as fertilizer as compared to manure, and the future potential for participation in nutrient management credit trading program relating to the Chesapeake Bay Watershed.

Dairy Cow Anaerobic Digesters
The calculations use two digesters per year and 800 dairy cows per farm to produce approximately 79,900 scf of biogas per day. A 200 kW generator at 34.5% efficiency requires 47.47 mmbtu/day, which is equivalent to 79,100 scf of biogas at an average heat content of 600 BTU/scf. The calculations below assume a 200kW generator will be run from the collected biogas and that the generator will run 24 hours a day year round. The dairy farm portion of this work plan assumes the addition of 30 anaerobic digesters

on dairy farms of 500 or greater cows The analysis assumes that 2 dairy digesters per year are brought on-line. Table 1 displays the projected GHG emission reductions for dairy farms.

Table 1.GHG Emissions Reductions from Dairy Farm Digesters

Year	Total # of digesters	Avg. KW rating of generator	Displaced CO2 emission for electricity (lb/MWh)	Displaced CO2 emission for Steam heat (lb/MWh)	Baseline CH4 Capture (MMtCO2e /Yr)	CO2 Offset from electricity Generation (MtCO2e/yr.)	CO2 Reductions from Waste Heat Utilization (MtCO2e)	Total CH4 emission Reducitons (MMtCO2e)
2015	2	200	1699	299.6	0.01378	2700	476	0.0170
2016	4	200	1699	299.6	0.02756	5400	952	0.0339
2017	6	200	1699	299.6	0.04134	8100	1428	0.0509
2018	8	200	1699	299.6	0.05512	10800	1904	0.0678
2019	10	200	1699	299.6	0.06890	13500	2380	0.0848
2020	12	200	1699	299.6	0.08268	16199	2857	0.1017
2021	14	200	1699	299.6	0.09646	18899	3333	0.1187
2022	16	200	1699	299.6	0.11024	21599	3809	0.1356
2023	18	200	1699	299.6	0.12402	24299	4285	0.1526
2024	20	200	1699	299.6	0.13780	26999	4761	0.1696
2025	22	200	1699	299.6	0.15158	29699	5237	0.1865
2026	24	200	1699	299.6	0.16536	32399	5713	0.2035
2027	26	200	1699	299.6	0.17914	35099	6189	0.2204
2028	28	200	1699	299.6	0.19292	37799	6665	0.2374
2029	30	200	1699	299.6	0.20670	40499	7141	0.2543
2030	30	200	1699	299.6	0.20670	40499	7141	0.2543
							Total	**2.0347**

Dairy Anaerobic Digester Costs

The costs for dairy farm AD systems for farms with 500 or more cows will differ based on the type of AD system installed. This work plan will assume a cost of $1,200,000 for a complete mix type of AD. Annual O&M costs are estimated to be approximately $25,000 a year based on DEP estimates. Electricity generated is estimated at $.09/kWh based on historical electricity prices.

Utilization of waste heat from the engine jacket and generator from dairy digester systems represents another cost savings measure. The annual savings from avoided fuel usage is estimated to be $25,000 based on PA DEP estimates. The end product can be used as bedding on the dairy farm, estimated to generate a savings of $50,000 based on PA DEP estimates.

The costs and revenues associated with the dairy digester aspect of this work plan recommendation are provided in Table 2.

Table 2. Net Costs / Savings of Anaerobic Digesters for Dairy Cows

Year	Capital Cost	Annual O & M Cost	Value of kWh	Revenue from fiber	Value of avoided fuel	Net Cost
2015	2,400,000	50,000	299,592	100,000	50,000	2,000,408
2016	2,400,000	100,000	599,184	200,000	100,000	1,600,816
2017	2,400,000	150,000	898,776	300,000	150,000	1,201,224
2018	2,400,000	200,000	1,198,368	400,000	200,000	801,632
2019	2,400,000	250,000	1,497,960	500,000	250,000	402,040
2020	2,400,000	300,000	1,797,552	600,000	300,000	2,448
2021	2,400,000	350,000	2,097,144	700,000	350,000	-397,144
2022	2,400,000	400,000	2,396,736	800,000	400,000	-796,736
2023	2,400,000	450,000	2,696,328	900,000	450,000	-1,196,328
2024	2,400,000	500,000	2,995,920	1,000,000	500,000	-1,595,920
2025	2,400,000	550,000	3,295,512	1,100,000	550,000	-1,995,512
2026	2,400,000	600,000	3,595,104	1,200,000	600,000	-2,395,104
2027	2,400,000	650,000	3,894,696	1,300,000	650,000	-2,794,696
2028	2,400,000	700,000	4,194,288	1,400,000	700,000	-3,194,288
2029	2,400,000	750,000	4,493,880	1,500,000	750,000	-3,593,880
2030	0	750,000	4,493,880	1,500,000	750,000	-5,993,880
Total	36,000,000	6,750,000	40,444,920	13,500,000	6,750,000	-17,944,920

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 (saving) is $ 17.945 million (found at the bottom of Table 2), and the GHG savings are 2.0347 MMtCO2e (located at the bottom of Table 1). This means that the cost-effectiveness of the implementation scenario is $ -8.819/ metric ton.

Swine Anaerobic Digesters

Pennsylvania currently has anaerobic digesters operating at four swine operations. This work plan recommendation analyzes the potential of adding ten additional AD at swine operations with 3,000 or more animals through the end of year 2030.Among the benefits of farm-based digesters is their ability to control odors. Odor control has a real practical value, particularly at swine farms, 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 using emission factors provided in the EPA State Inventory Tool. This analysis is based on swine farms with 3,000 pigs, with 2 new swine digesters brought on-line every three years.

The GHG emissions reductions from Swine farm digesters are provided in Table 3.

Table 3. GHG Emissions Reductions from Swine Farm Digesters

Year	Cummulative Digester Total	Avg. KW rating of generator	Displaced CO2 emission for electricity (lb/MWh)	Displaced CO2 emission for Steam heat (lb/MWh)	Baseline CH4 Capture (MMtCO2e/Yr)	CO2 Offset from electricity Generation (MtCO2e/yr.)	CO2 Reductions from Waste Heat Utilization (MtCO2e)	Total CH4 emission Reducitons (MMtCO2e)
2015	1	30	1699	299.6	0.00355	202	36	0.0038
2016	2	30	1699	299.6	0.00710	405	71	0.0076
2017	2	30	1699	299.6	0.00710	405	71	0.0076
2018	3	30	1699	299.6	0.01066	607	107	0.0114
2019	4	30	1699	299.6	0.01421	810	143	0.0152
2020	4	30	1699	299.6	0.01421	810	143	0.0152
2021	5	30	1699	299.6	0.01776	1012	179	0.0190
2022	6	30	1699	299.6	0.02131	1215	214	0.0227
2023	6	30	1699	299.6	0.02131	1215	214	0.0227
2024	7	30	1699	299.6	0.02487	1417	250	0.0265
2025	8	30	1699	299.6	0.02842	1620	286	0.0303
2026	8	30	1699	299.6	0.02842	1620	286	0.0303
2027	9	30	1699	299.6	0.03197	1822	321	0.0341
2028	10	30	1699	299.6	0.03552	2025	357	0.0379
2029	10	30	1699	299.6	0.03552	2025	357	0.0379
2030	10	30	1699	299.6	0.03552	2025	357	0.0379
							Total	**0.3146**

Swine Manure Management Costs:

The costs for swine farm AD systems for farms with 3,000 or more swine will differ based on the type of AD system installed. This work plan will assume a cost of $1,200,000 for a complete mix type of AD. Annual O&M costs are estimated to be approximately $25,000 a year based on EPA estimates. Electricity generated is estimated at $.09/kWh based on historical electricity prices.

Utilization of waste heat from the engine jacket and generator from dairy digester systems represents another cost savings measure. The annual savings from avoided fuel usage is estimated to be $5,000 based on PA DEP estimates.
The costs and revenues associated with the dairy digester aspect of this work plan recommendation are provided in Table 4.

Table 4. Net Costs / Savings of Anaerobic Digesters for Swine

Year	Capital Cost	Annual O&M Cost	Value of kWh	Value of avoided fuel	Net Cost	
2015	1,200,000	25,000	22,469	5,000	1,197,531	
2016	1,200,000	50,000	44,939	10,000	1,195,061	
2017	0	50,000	44,939	10,000	-4,939	
2018	1,200,000	75,000	67,408	15,000	1,192,592	
2019	1,200,000	100,000	89,878	20,000	1,190,122	
2020	0	100,000	89,878	20,000	-9,878	
2021	1,200,000	125,000	112,347	25,000	1,187,653	
2022	1,200,000	150,000	134,816	30,000	1,185,184	
2023	0	150,000	134,816	30,000	-14,816	
2024	1,200,000	175,000	157,286	35,000	1,182,714	
2025	1,200,000	200,000	179,755	40,000	1,180,245	
2026	0	200,000	179,755	40,000	-19,755	
2027	1,200,000	225,000	202,225	45,000	1,177,775	
2028	1,200,000	250,000	224,694	50,000	1,175,306	
2029	0	250,000	224,694	50,000	-24,694	
2030	0	250,000	224,694	50,000	-24,694	
Total	12,000,000	2,375,000	2,134,593	475,000	11,765,407	

Table 5. Annual and Cumulative (2013 – 2020) Cost-Effectiveness

	2030 Annual			2030 Cumulative		
	Reductions (MMtCO2e)	Cost ($MM)	Cost-Effectiveness ($/MtCO2e)	Reductions (MmtCO2e)	Total NPV (2014 $MM)	Cost-Effectiveness ($/MtCO2e)
Manure Digesters – Dairy	.2543	-5.994	-23.57	2.0347	.384	.19
Manure Digesters - Swine	.0379	-.025	-.651	.3146	8.363	26.58

Implementation Steps:

The following implementation steps help to address the financial aspects of digester development:

- Encourage PUC to withdraw proposed net metering regulations set forth as 52 Pa. Code §75.13(a)(3), which was published on July 5, 2014 in the Pa. Bulletin. This proposed regulation would limit the capacity of sources otherwise qualified to participate in net metering to 110% of the facility's historical electricity usage. In the alternative, encourage the PUC to exempt either all Tier I resources from the proposed net metering cap, or exempt electricity generated from biologically generated methane gas (as defined in the AEPS) from the proposed net metering cap. The proposed 110% size cap on net metering projects, if adopted by the PUC, will eliminate any reasonable possibility of future digester installation in Pennsylvania due to a 50% or more reduction in electricity savings. Development of these projects are already difficult given tight financial pro-formas and the difficulty in accessing capital for their development. Withdrawal of

the proposed regulation is supported by a broad coalition of farmers, renewable energy stakeholders, and environmental advocacy organizations and industry tradegroups, based on comments submitted to the PUC.

- Establish or expand State-funded programs that offer tax breaks to companies that install digesters.
- Encourage state funding through grants and loans for development of these projects through:
    - *Commonwealth Financing Authority's Alternative and Clean Energy Program (ACE).* ACE provides grants and loans that can be used for the development and construction of alternative and clean energy projects throughout Pennsylvania. For each job created, entities could receive $40,000 in grant funding for clean energy generation equipment.
    - *Pennsylvania Energy Development Authority (PEDA).* PEDA provides grants to Pennsylvania companies and organizations for clean, advanced energy projects. Manure digesters would likely qualify as "advanced energy" because it is biologically derived methane gas.
    - *Pollution Prevention Assistance Account (PPAA) Loan Program*. The PPAA provides low interest loans to small businesses undertaking projects that reduce waste, pollution, or energy use. The maximum loan amount is $100,000 for businesses with 100 or fewer full-time employees.
- Encourage use of food scraps in digesters. This would increase the amount of "fuel" that can be placed in the digester to produce biogas. Due to the tight economics of digesters, it is critical that they operate at or near 100% capacity. Modifying existing residual waste and/or municipal solid waste regulations to allow disposal of food scraps into farm-based digesters could increase the utilization rate of digesters and improve these projects economic viability.
- Encourage smaller farming operations to form local community authorities to apply for funding and centralize manure digesters for maximum benefits and reduced costs.
- Encourage private partnerships - large companies looking to locate certain operations in Pennsylvania could finance a portion of a manure digester in exchange for a power-purchase agreement.
- If denitrification of the manure occurs through the oxidization of ammonia (through aerobic *and* anerobic processes), nitrogen will be removed and the digester may be eligible to sell nutrient credits in the Potomac and Susquehanna River Basins.
- Manure digester operations should be encouraged to sell voluntary carbon emissions credits.

The following implementation steps do not relate to the financing of manure digesters:

- Outreach training – Educate designating for the support of building digesters with conservation districts, Penn State, and RCM digesters. Ensure that the outreach training includes an economic component that educates potential project developers regarding all possible financial benefits, including AEPS credits, net metering, State and federal grant and loan guarantee programs, etc.
- Encourage single farms and combination farms to build digesters through outreach training and removal of any existing barriers to joint projects and waste transportation between farmers.
- Creation of a General Plan Approval and General Operating Air Permit for biogas (as defined by the AEPS)-fired internal combustion engines.
- Modification of the General Plan Approval and General Operating Air Permit for Landfill gas-Fired Simple Cycle Turbines to include turbines fired on other biogases (as defined by the AEPS).