Waste-to-Energy Digesters

Summary:
This initiative encourages an expansion of regional digesters that can offer larger-scale and higher technology treatment for a mixture of feedstocks including: organic MSW, organic residual waste, manure, and biosolids.

Goals:
Install four ~~1megawatt (MW)~~ digesters, fitting the above description, by 2020.

Implementation Period:
2013 through 2020

Background Discussion on Anaerobic Digestion:
Thermophilic anaerobic digestion is the preferred strategy for future digestion facility planning, rather than the common mesophilic technologies that predominate on U.S. farms and wastewater treatment plants. Technologies common in Europe provide for mixed feedstocks, yield more gas, and are more efficient than manure-only digesters. The effluent (digestate) is closely monitored and can yield precision-agriculture soil amendment with a guaranteed nitrogen-phosphorus-potassium analysis for fertilizer application. Depending on the exact technology/vendor selected for these digesters, about 50 percent of the input is manure, and the remainder is some combination of food residues, crop residues, yard wastes, organic fraction of MSW, or sewage sludge. The European model for centralized digestion relies on processes that digest waste that has a moisture content of less than 25 percent. Utilizing drier feedstocks provides for a higher biogas yield and allows for a more stable digestion process that requires less mixing and disposal of wastewater.

Based on data provided by DEP on residual waste availability, it appears that York and Adams counties are potential locations for digestion facilities. These data, in addition to the availability of manure and organic MSW in PA, suggest that there would be ample feedstock to support four advanced, centralized, mixed-feedstock, anaerobic digesters, each requiring 25,000 tons of waste residuals per year. For a digester project to reach its full environmental and economic potential, a constant feedstock supply is required.

In the regional (centralized) model,

- New feedstocks for digesters include food waste and yard waste, as well as conventional manure and sludge.
- WTE digesters produce electrical power, along with high-grade solid and liquid end products.
- The business community can participate as both user and investor.
- Food companies would have an outlet for food waste.
- The concept expands upon local on-farm digesters that produce power for farm use and treated solid and liquid fertilizers.

Two known vendors of anaerobic digesters are Waste-to-Energy Solutions and BioFerm Energy Systems. Waste-to-Energy Solutions is a licensed vendor in PA and sells Niras[1] Danish digesters. BioFerm Energy Systems[2] is a German company that has recently expanded operations to North America.

Information received from a consultation with a representative of BioFerm Energy Systems was used to provide a reference case for the analysis of this work plan. The BioFerm system utilizes a dry fermentation technology, optimal for feedstocks with less than 25 percent moisture content. The minimum methane content of the resulting biogas is 55 percent, although higher levels have been realized. The elimination of most liquid from

[1] http://www.niras.com/Services/Energy.aspx
[2] http://www.bioferm-es.com/us/

the digester input eliminates the need for mixing of the input. Therefore, dry fermentation anaerobic digestion facilities use much less energy (5 percent of electricity and 3 percent of heat generated by the digestion process) than traditional digesters. BioFerm Energy Systems has completed construction on 27 digesters worldwide, with many more in development. A byproduct of all anaerobic digestion is a nutrient-rich digestate that, after processing, may be used as an organic soil amendment. If markets for electricity and direct heat are not available for a given anaerobic digestion facility, it is possible to process the biogas into a liquid vehicle fuel substitute for compressed natural gas. Further information on BioFerm's dry fermentation process is available on its Web site.[3]

Data sources/Assumptions/Methods for GHG:

The reference case digestion facility converts 25,000 tons per year in 8 fermentation chambers into 5.4 million kWh electricity and almost 22 MMBtu of direct heat through the dry fermentation anaerobic digestion process. In addition, 17,543 tons of marketable compost is produced as a result of the process. The methane displacement as a result of the combustion of the biogas is nearly 21 tCO_2e/yr.[4] The assumed GHG reduction from offset grid electricity is based on the assumption that this initiative would displace generation from an "average thermal" mix of fuel-based electricity sources of coal and gas. This mix is based on 50% natural gas and 50% coal from 2013 through 2020 and reflects the latest trend in Pennsylvania shifting towards a greater percentage of natural gas and less coal. The average thermal approach is preferred over alternatives because sources without significant fuel costs would not be displaced—e.g., hydro, nuclear, or renewable energy generation. Given the generation fleet's coal and gas combustion efficiencies, this equates to a CO_2 intensity of approximately 0.69 metric tons (t)/MWh. A natural gas emission factor of approximately 0.058 tCO_2e/MMBtu was used to estimate the GHG reduction from offset direct heat.

Data Sources/Assumptions/Methods for Costs:

The assumed capital cost for a reference case dry fermentation anaerobic digestion facility is $5.8 million. Approximate O&M costs include a front loader ($4,790 per year), compost processing ($16 per ton compost), maintenance ($4,200 per fermentation chamber per year), and facility operation (1 full-time-equivalent position per year: $52,600). Revenues received by the facility include the value of compost ($3~~0.00~~1.58/ton)[5], the wholesale value of electricity ($0.05/kWh) and thermal energy from the capture and use of excess heat ($~~4.38 to $4.91~~6.28 per MMBtu). The value of waste heat utilization reflects the 2011 average City Gate price for natural gas in Pennsylvania~~is based on projected costs of natural gas from 2013 through 2020, according to the U.S. Department of Energy, Energy Information Administration's Annual Energy Outlook 2012 report.~~ The analysis is somewhat conservative in that no other projections for increasing revenues from other commodities (electricity and compost) have been contemplated.

GHG Emissions Reduction Analysis:

The GHG reduction is estimated by computing the sum of the methane displacement, offset grid electricity, and avoided natural gas combustion for direct heat. The methane displacement is found by multiplying the number of digesters on line by the annual methane displacement value. The electricity generated per year in a single digester is multiplied by the projected grid-based, thermal mix, electricity emission factor, as referenced above, for each year and the number of digesters on line in each year to yield the GHG reduction from offset electricity generation. The GHG reduction from avoided natural gas combustion for direct heat is found by multiplying the direct heat produced per digester by the natural gas

[3] http://www.bioferm-es.com/us/wp-content/uploads/2009/03/bioferm-dry-fermentation.pdf

[4] Information regarding energy and compost outputs, as well as methane offset was provided by BioFerm Energy Systems. BioFerm asserts that these values are based on the average results of dry fermentation anaerobic digestion systems. Actual yields may differ depending on feedstock mix, facility location, and other factors.

[5] Based on discussion with BioFerm, but not a PA-specific value.

emission factor and the number of facilities on line in each year. The resulting cumulative GHG reduction for 2013–2020 is 0.33 $MMtCO_2e$ (see Table 1).

Table 1. Annual and Cumulative GHG Reductions

Year	Cumulative Number of Facilities	Methane Displacement ($MMtCO_2e$)	Offset Grid Electricity ($MMtCO_2e$)	Offset Heat Generation ($MMtCO_2e$)	Total ($MMtCO_2e$)
2013	0	-	-	-	-
2014	0	-	-	-	-
2015	1	0.02	0.004	0.001	0.03
2016	1	0.02	0.004	0.001	0.03
2017	2	0.04	0.008	0.003	0.05
2018	2	0.04	0.008	0.003	0.05
2019	3	0.06	0.011	0.004	0.08
2020	4	0.08	0.015	0.005	0.10
Total (2013-2020)		**0.27**	**0.05**	**0.02**	**0.33**

Additional GHG reduction potential includes reduced transport of solid waste to landfills and the downstream benefit of applying compost as a soil amendment. These benefits have not been included in this quantification. The transportation benefit would require additional assumptions regarding the relative distance between the waste source and the disposal facilities (digester versus landfill) and the efficiency of trucks used. The downstream soil amendment benefit would require additional research regarding the amount of fossil fuel-based fertilizer offset and the GHG emission profile of the production and use of the traditional fertilizer.

Cost-Effectiveness Analysis: The project costs include capital cost and O&M costs highlighted in the Data Sources for Costs section. The annualized capital cost is found by multiplying the assumed capital cost by the number of facilities on line and an annualization factor.[6] The O&M costs are found for each of the four O&M cost elements using the following calculations, with the sum of the products being the total annual O&M cost:

- Multiply the cost of the front loader by the number of facilities on line in each year.
- Multiply the compost processing cost by the per-facility quantity of compost produced and the number of facilities on line in each year.
- Multiply the maintenance cost per fermentation chamber by the number of fermentation chambers per facility (8) and the number of facilities on line in each year.
- Multiply the facility operation cost by the number of facilities on line in each year.

The revenues are calculated by taking the sum of the following products:

- Multiply the annual waste received (25,000 tons) by $10/ton
- Multiply the value of compost by the tons of compost produced and the number of facilities on line in each year
- Multiply the value of electricity by the amount of electricity generated per facility and the number of facilities on line in each year
- Multiply the value of direct heat by the amount of direct heat generated per facility and the number of facilities on line in each year and dividing by half (assumes only 50% utilization rate)

[6] The Capital Recovery Factor method of animalization is used, assuming a 5% interest rate and 15 year loan period.

The cost analysis produces an estimated cost of $0.26 million ($2010, NPV) for the project period 2013–2020. The cost-effectiveness over this time period is equal to $0.77 $/t$CO_2$e. The results of the cost-effectiveness analysis are presented in Table 2.

Table 2. Annual and Cumulative Costs and Cost-Effectiveness

Year	Cumulative Number of Facilities	Annualized Capital Cost ($MM)	Annual O&M Cost ($MM)	Annual Revenue ($MM)	Net Project Cost ($MM)	Discounted Project Cost ($MM)	Cost-Effectiveness $/tCO2e
2013	0	$0.00	$0.00	$0.00	$0.00	$0.00	
2014	0	$0.00	$0.00	$0.00	$0.00	$0.00	
2015	1	$0.56	$0.40	$~~0.93~~1.14	-$0.~~03~~19	-$0.~~03~~15	
2016	1	$0.56	$0.40	$~~0.93~~1.14	-$0.~~03~~19	-$0.~~03~~14	
2017	2	$1.12	$0.80	$~~1.85~~2.29	-$0.~~07~~37	-$0.~~05~~26	
2018	2	$1.12	$0.80	$~~1.86~~2.29	-$0.~~06~~37	-$0.~~04~~25	
2019	3	$1.67	$1.20	$~~2.80~~3.43	-$0.~~08~~56	-$0.~~05~~36	
2020	4	$2.23	$1.61	$~~3.73~~4.58	-$0.~~10~~74	-$0.~~06~~35	
Total (2013-2020)		**$7.25**	**$5.22**	**$~~12.09~~14.88**	**-$~~0.38~~2.41**	**-$~~0.26~~1.61**	**-$~~0.77~~4.82**

Implementation Steps:

Projects of this type are far more complex than typical renewable or alternative energy projects because of the need to involve multiple stakeholders to source the feedstock and host the facility. Educating multiple parties to the benefits of these projects and project facilitation are key elements to successful implementation.

Centralized mixed-feedstock anaerobic digestion projects are more viable if the following incentives are available:

- Allowance of renewable energy credits for carbon offset trading.
- Provision of renewable energy grants and loans from federal, state, and municipal funds.
- Purchasing agreements with utilities for electricity and direct heat provided by digestion facilities.

Potential Overlap:

No overlap is anticipated because despite utilizing manure for a portion of the feedstock energy resource for these projects it is envisioned that the manure-only digesters will be self-supporting, on-farm projects and not likely not participate or need to participate in the projects discussed in this initiative.

Subcommittee Comments: