AR No. #
Anaerobic Digester

Recommendation

We recommend installing an anaerobic digester to convert volatile manure into usable methane gas. Bio gas can be burned in a generator to provide an alternative source for 25.1% of your electricity while producing excess heat to reduce boiler natural gas use by 93.0%.

Assessment Recommendation Summary				
Energy (MMBtu)*	Energy (kWh)*	Cost Savings	Implementation Cost	Payback (Years)
11,441.3	628,552	$120,688	$540,150	4.5

* *MMBtu only represents natural gas and kWh only represents electricity.*
* *1 MMBtu = 1,000,000 Btu, 1 kWh = 3,413 Btu*

Background

Anaerobic digesters use bacteria and heat in an oxygen free environment to convert volatile manure into usable methane gas. The digestion of manure occurs in four basic stages; hydrolysis, acidogenesis, acetogenesis, and methanogenesis. It is the last stage in which volatile methane gas is produced; therefore, it is important for the digester to have an appropriate manure retention time to allow the manure to fully decompose. There are many different types of digester systems available. We recommend a plug flow digester designed to operate in the mesophilic range of 95^{o}F– 105^{o}F, but 95^{o}F-98^{o}F is ideal, with manure solid concentrations between 11 and 14 percent.

Biogas is piped off and burned in a generator to produce electricity. Waste heat from the generator is captured through a heat recovery system to provide heat for the digester core as well as the facility's heating needs. Excess methane that cannot be burned by the generator can be burned in a flare.

- **Odor Control** - The anaerobic microorganisms break down potential odor causing compounds. This offers a reduction in odors by up to 97% almost eliminating odors completely.

- **Clean Fertilizer -** Because the digestion process is anaerobic and operates in the mesophilic range, it kills almost all unwanted weeds and pathogens. The digestion process also reduces the volume of manure solids by up to 90% leaving a high quality concentrated fertilizer full of nitrogen, potassium, and phosphorous.

- **Environmental -** Most farms store manure in pits or lagoons where methane gas is generated and released to atmosphere. Methane gas is 21 times more potent than carbon dioxide in causing global warming. Capturing and burning the methane gas could help reduce the rate of global warming.

- **Reduce Water Contamination** - The improved manure handling system used by anaerobic digesters reduces potential surface ground water contamination.

Proposal

Install an anaerobic digester, refinery, and generator to convert volatile manure into usable methane gas. The generated bio gas can then be burned in a generator to produce electricity that can be sold back to the utility company. Excess heat from the generator can be recovered and used to offset heating costs.

As detailed on the following page, there is a 4.5 year payback with a $540,150 implementation cost and $120,688 annual savings.

Source: http://www.flickr.com/photos/kqedquest/769804439/

Note

Annual cost savings does not account for financial benefits resulting from the 595,678 pounds of high grade fertilizer produced annually as a byproduct of the digester process.

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Oregon State University OSU Energy Efficiency Center

Data Collected

Capacity Data

Number of Dairy Cows	(N_C)	1,500	cows

Energy Consumption Data

Annual Natural Gas Usage	(NG_U)	10,000.0	MMBtu/yr
Annual Electricity Usage	(E_U)	2,500,000	kWh/yr

Incremental Energy Data

Incremental Natural Gas Cost	(NG_C)	10.00	$/MMBtu
Incremental Electricity Cost	(E_C)	0.05000	$/kWh

Assumptions

Manure Production

Average Dairy Cow Weight	(W_C)	1,400	lbs	
Manure Production Rate	(P_R)	0.08	lb/lb-day	**(N. 1)**
Total Solids Percentage	(S_P)	12.5	%	**(Rf. 1)**
Volatile Manure Percentage	(M_P)	83	%	**(Rf. 1)**

Conversion Efficiencies

Solid to Gas Conversion Efficiency	(CE_1)	50	%	**(N. 2)**
Engine Efficiency	(E_E)	20	%	**(N. 3)**
Generator Efficiency	(E_G)	60	%	**(N. 4)**
Percent Energy Used by Digester	(DE_U)	35	%	**(Rf. 1)**

Conversion Factors

Day to Year Conversion Factor	(CF_1)	365	days/yr	
Methane Gas Conversion Factor	(CF_2)	5.62	ft^3/lb	**(Rf. 1)**
Methane Gas Conversion Factor	(CF_3)	1,000	Btu/ft^3	
Energy Conversion Factor	(CF_4)	1,000,000	Btu/MMBtu	
Energy Conversion Factor	(CF_5)	3,413	Btu/kWh	

Manure Breakdown

Total Manure Production	(MP)	61,320,000	lbs	**(Eq. 1)**
Manure Solids	(MS)	7,665,000	dry lbs	**(Eq. 2)**
Total Volatile Solids	(VS)	6,361,950	dry lbs	**(Eq. 3)**
Total Kjeldahl Nitrogen		344,925	lbs	**(N. 5)**
Total Phosphorus		53,655	lbs	**(N. 5)**
Total Potassium		197,098	lbs	**(N. 5)**

Equations

Eq. 1) Total Manure Production (MP)

$$N_C \times W_C \times P_R \times CF_1$$

Eq. 2) Total Manure Solids (MS)

$$MP \times S_P$$

Eq. 3) Total Volatile Solids (VS)

$$MS \times M_P$$

References

Rf. 1) Lusk, P. 1998. Methane Recovery From Animal Manures: A Current Opportunities Casebook, 3rd edition. NREL/SR-25145. Prepared by Resource Development Associates, Washington, DC, under contract to the National Renewable Energy Laboratory. Golden, CO.

Notes

N. 1) Units are in Pounds Manure per Pound Cow Weight per Day

N. 2) Solid to Gas Efficiency is based of a Plug Flow mesophilic digester system (Typical between 45 and 55 percent solid to gas conversion efficiency) **(Rf. 1)**

N. 3) Engine Efficiencies typically vary between 18 and 22 percent. We assume 20 percent for this analysis.

N. 4) Generator Efficiencies typically vary between 55 and 65 percent. We assume 60 percent for this analysis.

N. 5) These nutrients are not decomposed in the digester process and produce a high grade fertilizer for use on fields or for sale.

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Volatile Solids Breakdown

Total Volatile Solids	(VS)	6,361,950	dry lbs	**(Eq. 3)**
Ether Extract		198,334	dry lbs	**(Rf. 1)**
Cellulose		2,364,756	dry lbs	**(Rf. 1)**
Hemicellulose		915,389	dry lbs	**(Rf. 1)**
Lignin		930,645	dry lbs	**(Rf. 1)**
Starch		953,529	dry lbs	**(Rf. 1)**
Crude Protein		953,529	dry lbs	**(Rf. 1)**
Ammonia		38,140	dry lbs	**(Rf. 1)**
Acids		7,628	dry lbs	**(Rf. 1)**

Methane Gas Production

Gross Methane Gas Production	(GM_P)	17,877.1	MMBtu	**(Eq. 4)**

Energy Savings Summary

Electricity

Gross Electricity Production	(GE_P)	628,552	kWh	**(Eq. 5)**
Electricity Savings	(E_S)	$31,428	per yr	**(Eq. 6)**

Natural Gas

Gross Heat Production	(GH_P)	14,301.7	MMBtu	**(Eq. 7)**
Net Heat Production	(NH_P)	9,296.1	MMBtu	**(Eq. 8)**
Natural Gas Savings	(NG_S)	$92,961	per yr	**(Eq. 9)**

Implementation Costs Summary

Mix Tank/Manure Collection	(IC_1)	$35	/cow	**(N. 6)(R. 2)**
Digester	(IC_2)	$125	/cow	**(N. 7)(R. 2)**
Energy Conversion	(IC_3)	$160	/cow	**(N. 8)(R. 2)**
Miscellaneous	(IC_4)	$40	/cow	**(N. 9)(R. 2)**

Notes

N. 6) This cost includes excavation/grading, cement work, manure pump, piping, installation, etc.

N. 7) This cost includes excavation/grading, digester tank, heating, cover, start-up, installation, etc.

N. 8) This cost includes building, gas pump/meter, piping, engine-generator set, heat recovery system, installation, etc.

N. 9) This cost includes engineering, planning, permits etc.

N. 10) We assume that energy not converted into mechanical power in the engine will be converted into heat which will be recovered through a heat exchanger system.

Equations

Eq. 4) Gross Methane Production (GM_P)

$$\frac{VS \times CF_2 \times CE_1 \times CF_3}{CF_4}$$

Eq. 5) Gross Electricity Production (GE_P)

$$\frac{GM_P \times CF_4 \times E_E \times E_G}{CF_5}$$

Eq. 6) Electricity Savings (E_S)

$$GE_P \times E_C$$

Eq. 7) Gross Heat Production (GH_P) **(N. 10)**

$$GM_P \times (1 - E_E)$$

Eq. 8) Net Heat Production (NH_P)

$$GH_P \times (1 - DE_U)$$

Eq. 9) Natural Gas Savings (NG_S)

$$NH_P \times NG_C$$

References

Rf. 2) The Minnesota Project
http://www.mnproject.org/

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Maintenance Costs Summary

Annual Routine Maintenance Costs	(M_C)	$3,700	per yr	**(N. 11)**

Economic Results

Annual Cost Savings	(CS)	$120,688		**(Eq. 10)**
Implementation Costs	(IC)	$540,150		**(Eq. 11)**
Payback	(PB)	4.5	years	

Notes

N. 11) This includes maintenance measures such as monthly oil change, spark plug cleaning, valve adjustment, and periodic engine overhauls.

Equations

Eq. 10) Cost Savings (CS)

$$E_S + NG_S - M_C$$

Eq. 11) Implementation Costs (IC)

$$(IC_1 + IC_2 + IC_3 + IC_4) \times N_C$$