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Economic Feasibility of Anaerobic Digesters

A viable anaerobic digestion system to process organic wastes can be costly, so producers who are considering adopting this type of technology need to examine all aspects of it. One key aspect to consider is the economic feasibility of anaerobic digesters.

This factsheet provides a fairly high level, theoretical approach to exploring the costs of the technology. Data is provided in the form of tables as well as through examples that are useful to determine the economic feasibility of adopting an anaerobic digester/biogas plant for agricultural operations. The numbers used in the tables are drawn from existing resources that are listed in the references section at the end of the factsheet.

Factsheet topics:

- background information
- manure/energy production
- co-digestion biogas energy potential
- examples: co-digestion of dairy manure and animal fat, estimation of capital cost and simple payback period

One key aspect to consider is the economic feasibility of anaerobic digesters

Background

Alberta has many agricultural operations that generate various types of organic wastes. These organic wastes require proper handling to reduce pollution and contamination.

Using anaerobic digesters to process these organic wastes appears to be an attractive option since the anaerobic digestion process can stabilize most agricultural, domestic and industrial organic wastes and produce biogas, a renewable energy. Biogas can be used as a fuel source to produce electricity and heat, just like natural gas.

The total capital costs of anaerobic digester plants are high and may range from a few hundred thousand to a few million dollars. However, most of the other waste processing technologies, which may also require a high capital investment, do not generate revenue like a biogas digester plant does.

Some of the feasibility studies in North America on anaerobic digesters concluded that the payback period ranges from 5 to 16 years when operated under optimum and worst conditions, respectively. Government financial incentives for producing green energy can potentially reduce the payback period significantly.

Manure/energy production

Table 1 contains data for daily manure and biogas production as well as the annual electricity and heat generation potential for the major livestock operations such as beef, dairy, swine and poultry. Table1 provides the data that will help agricultural producers estimate potential approximate annual revenue.

Table1. Manure/energy estimation				
Description	Manure quantity as excreted (kg/d)	Biogas production (m^3/d)	Electricity potential (kW)/year	Energy potential (GJ)/year
Beef	24.0	1.10	663	3.0
Dairy	62.0	2.01	1,227	5.5
Piglet*	3.5	0.16	98	0.4
Poultry (100 - layer)	8.8	0.85	516	2.3

* Multiply the values by 12 for every sow in a farrow-to-finish operation.

Example 1

Multiplying the amount of annual electricity and heat energy potentials in Table 1 by average electricity and heating costs provides the approximate annual energy revenue from anaerobic processing of manure as shown in Example 1.

Number of animals	=	100 dairy cows
Average cost of electricity	=	$0.06/ kWh
Average cost of heat	=	$5.5/GJ
Annual electricity potential	=	1,227 kWh (from Table1)
Annual heating potential	=	5.5 GJ (from Table 2)
Savings from electricity	=	100 x 0.06 x 1,227 = **$7,362**
Savings from gas	=	100 x 5.5 x 5.5 = **$3,025**
Total annual savings from energy	=	**$10,387**

Co-digestion biogas energy potential

Table 2 and Table 3 contain the ranges provided in the literature for total solids, volatile solids and biogas yield (m^3/tonne) and estimated total annual biomass production (tonnes) and energy potential (PJ) across the province. The purpose of these tables is to provide the total biogas energy potential in the province as well as to estimate the biogas energy potential for centralized digesters.

To assist in exploring the potential to locate centralized, manure-based biogas facilities, producers should check the following website for information on the relative amount of manure production in Alberta: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex10335

Table 2. Inventory of livestock and municipal feedstock materials and biogas energy potential in Alberta						
Feed material	Total solids %	Volatile solids % of total solids	Biogas yield m^3/tonne	Yearly biomass production in tonnes*	Yearly energy potential in PJ	Methane content %
Beef cattle manure	8-12	80 - 85	19 - 46	51,890,736	20.0 - 48.0	53
Hog manure-grower to finisher	9-11	80 - 85	28 - 46	2,452,800	1.4 - 2.3	58
Dairy manure	12	80 - 85	25 - 32	3,994,195	2.0 - 2.6	54
Poultry manure	25 - 27	70 - 80	69 - 96	1,728,987	2.4 - 3.3	60
Animal fat	89 - 90	90 - 93	801 - 837	87,000	1.4 - 1.5	N/A
Animal carcass (homogenized-bovine)	34 - 39	90 - 93	348 - 413	264,023	1.8 - 1.2	N/A
Municipal wastewater sludge	30-20	90	17 - 140	539,835	0.2 - 1.5	65
Household waste	N/A	N/A	143 - 214	N/A	N/A	N/A
Total manure (including municipal sludge)	–	–	–	60,606,553	25.7 - 57.4	50 - 70

Note: 1 PJ is 1,000,000 GJ. 1 GJ is 1000 MJ.

Table 3. Inventory of agricultural crops and biogas energy potential in Alberta						
Feed material	**Total solids %**	**Volatile solids % of total solids**	**Biogas yield m^3/tonne**	**Yearly biomass production in dry tonnes***	**Yearly energy potential in PJ**	**Methane content %**
Barley	36 - 86	90 - 95	169 - 291	1,404,671	4.75 - 8.18	60 - 70
Wheat	32 - 97	N/A	48 - 146	1,390,222	1.33 - 4.106	N/A
Oats	64	68	147 - 187	172,085	0.51 - 0.64	49 - 57
Rye	25 - 61	91 - 95	112 - 457	4,423	0.00 - 0.04	N/A
Triticale	27 - 66	93 - 97	150 - 554	9,526	0.03 - 0.11	60 - 70
Sugar beet leaves	N/A	N/A	40 - 50	197,887	0.16 - 0.20	49 - 57
Fodder corn	25 - 37	95	182 – 436	89,674	0.33 - 0.78	
Tame hay	N/A	N/A	80	699,344	1.1	
Leaves	80	90	72 - 216	N/A	N/A	N/A
Whey	1 - 5	80 - 95	6-45	N/A	N/A	
Grass silage	20 - 25	90	75 - 126	N/A	N/A	N/A
Distiller grain wastewater	N/A	N/A	58	N/A	N/A	57 - 60
Total straw and other roughages	70	90	105 - 158	3,901,007	8.19 - 12.33	60 - 70

* In this estimation, the requirement of cattle straw and soil conditioning was taken into consideration.

Example 2 – Co digestion of dairy manure and animal fat

Multiplying the corresponding biogas yield in Table 2 or 3 by the tonnes of available feed stock provides the total biogas potential in m3. One cubic meter of biogas is equivalent to 20 MJ of heat energy. When used as fuel for a co-generator, 1 m^3 of biogas can produce 1.7 kWh of electricity and 7.7 MJ of heat. Multiplying the total biogas potential in m^3 by 1.7 and 7.7 provides total electricity and heat energy potentials, respectively, as shown in Example 2.

Number of animals	= 100 dairy cows
Amount of animal fat available	= 250 tonnes/year
Biogas potential for animal fat	= 801 m^3/tonne (Table 2)
Biogas potential for 1,000 tonnes	= 250 x 801 = 200,250
Electricity produced from 1 m^3 of biogas in a co-generator	= 1.7 kWh
Excess heat available from 1 m^3 of biogas after producing electricity	= 7.7 MJ
Electricity produced from 200,250 m^3 of biogas	= 200,250 x 1.7 = 340,425 kWh
Heat available from 200,250 m^3 of biogas	= 200,250x 7.7= 1,541,925 MJ=1,541.9 GJ
Electricity production from 100 dairy cows	= 1,227 x 100= 122,700 kWh (Example 1)
Heat production from 100 dairy cows	= 5.5 x 100= 550 GJ (Example 1)
Total electricity production from dairy manure and animal fat	= 340,425 +122,700= 463,125 kWh
Total heat production from dairy manure and animal fat	= 1,541.9 + 550 =2,091.9 GJ
Average cost of electricity	= $0.06/ kWh
Average cost of heat	= $5.5/GJ
Savings from electricity	= 0.06 x 463,125 = **$27,787.50**
Savings from gas	= 5.5 x 2,091.9 = **$11,505.45**
Total annual savings from energy or the energy potential for exporting into the grid	= **$27,787.5 + $11,505.45 = $39,292.95**

Example 3 –
Approximate estimation of capital cost

Typically, the capital costs of a biogas electricity generating plant are $3,700 to $7,000/kWh. Example 3 illustrates how to estimate the approximate capital cost assuming a period of 30 days/year as a shutdown period for maintenance.

Even though it is possible to produce biogas energy continuously, as assumed in the examples, some experiences in North America show frequent interruption of operation due to unforeseen maintenance and process related issues. These types of interruptions may prolong the payback period. Unfortunately, in some worst case scenarios, there will not be any payback.

Total electricity production from dairy manure and animal fat from Example 2	= 340,425 + 122,700 = 463,125 kWh
Assuming 30 days/year for maintenance shut down, number of operating days/year	= 335
Assuming a 24h/d operation, the capacity of the electricity generator	= 463,125/335/24 = 57.6 kWh
Assuming capital cost of $ 7,000/kWh, total cost of the system	= 57.6 x 7,000 = $403,200

Example 4 –
Simple payback period

Typically, the running cost of a biogas electricity generating plant is $0.02/kWh. Example 4 illustrates how to estimate the approximate simple payback period.

Capital cost from Example 3	= $403,200
Operating cost assumed	= $0.02/kWh
Total electricity production from dairies and animal fat	= 463,125 kWh (Example 2)
Operating cost/year	= 0.02 x 463,125 = $9,262.50
Yearly energy revenue	= $39,292.95 (Example 2)
Subtracting operating cost from the yearly revenue	= $39,292.95 - $9,262.50 = $30,030.45
Government incentives for renewable energy production (2007-2012)	= $0.06/kWh
Total incentives	= 0.06 x 463,125 = 27,787.50
Total yearly revenue	= 30,030.45 + 27,787.5 = $57,817.95
The simple payback period	= 403,200/57,817.95 = 6.97 years

Note:

- Carbon credits and tipping fees may help to reduce the simple payback period. It is estimated that producing 1 MW of renewable energy is approximately equivalent to reducing 0.65 tonne of CO_2 emissions.
- The nutrient value in the digestate of the manure digester will be more or less the same as the undigested manure. Therefore, the land application cost of digestate is likely to be as same as the cost for land applying manure.
- Transportation costs for bringing in co-digestion substrate material may increase the simple payback period.
- However, the co-digestion process may result in increased nutrient value in the digestate. Therefore, approval from Alberta Environment and more testing during land application may be required.
- Some experiences in North America show that the digestion process is interrupted frequently due to unforeseen maintenance and process related issues which means the payback period will either be significantly increased or there will be no payback at all.
- Smaller digester facilities may significantly exceed the assumed capital cost per kWh, which also means the payback period will be significantly increased.
- Government incentives are assumed to be the same throughout the payback period in the above example, which may or may not be the case in the actual scenario.

Conclusion

The typical simple payback for a biogas plant may be about seven years as long as the existing government incentive program is available and biogas energy is produced continuously without interruption except for scheduled regular maintenance. Some experiences in North America show that biogas energy production is often interrupted due to unforeseen maintenance and process related issues.

Even though anaerobic digestion is a century-old process, the adaptation of this process successfully on the commercial scale for producing energy is still evolving. Frequent interruptions in the process show that the technology and process related knowledge still have room to improve. Despite these drawbacks, the potential for carbon trading and increased consumer awareness regarding practicing environmentally sound and sustainable agricultural production methods will certainly add to the benefits of continuing to work with this technology.

Links for case studies

1. MUS system, http://www.climatechangecentral.com/files/attachments/IMUS.pdf
2. Iron Creek biogem plant, http://www.climatechangecentral.com/files/attachments/BioGem.pdf
3. US case study, http://www.epa.gov/agstar/pdf/gordondale_report_final.pdf
4. European case study, http://www.epa.gov/agstar/pdf/gordondale_report_final.pdf

For additional information, check the following web pages:

Anaerobic Digesters, Agdex 768-1, http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex10945

Anaerobic Digesters: Frequently Asked Questions, Agdex 768-2, http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex11290

Biogas Energy Potential in Alberta, Agdex 768-3, http://www1.agric.gov.ab.ca/$Department/deptdocs.nsf/all/agdex11397

Integrating Biogas, Confined Feedlot Operations and Ethanol Production, Agdex768-4, http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex11839

Biogas Distribution– Rural Utilities Division of Alberta Agriculture and Rural Development, http://www1.agric.gov.ab.ca/general/progserv.nsf/all/pgmsrv13?opendocument

Incentives for biogas production– Alberta Bioenergy Producer, http://www.energy.gov.ab.ca/BioEnergy/bioenergy.asp

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