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

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

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. Table 1 provides the data that will help agricultural producers estimate potential approximate annual revenue.
**Table 1. Manure/energy estimation**

<table>
<thead>
<tr>
<th>Description</th>
<th>Manure quantity as excreted (kg/d)</th>
<th>Biogas production (m³/d)</th>
<th>Electricity potential (kW)/year</th>
<th>Energy potential (GJ)/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef</td>
<td>24.0</td>
<td>1.10</td>
<td>663</td>
<td>3.0</td>
</tr>
<tr>
<td>Dairy</td>
<td>62.0</td>
<td>2.01</td>
<td>1,227</td>
<td>5.5</td>
</tr>
<tr>
<td>Piglet*</td>
<td>3.5</td>
<td>0.16</td>
<td>98</td>
<td>0.4</td>
</tr>
<tr>
<td>Poultry (100 - layer)</td>
<td>8.8</td>
<td>0.85</td>
<td>516</td>
<td>2.3</td>
</tr>
</tbody>
</table>

* 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 (m³/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**

<table>
<thead>
<tr>
<th>Feed material</th>
<th>Total solids %</th>
<th>Volatile solids % of total solids</th>
<th>Biogas yield m³/tonne</th>
<th>Yearly biomass production in tonnes*</th>
<th>Yearly energy potential in PJ</th>
<th>Methane content %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef cattle manure</td>
<td>8-12</td>
<td>80 - 85</td>
<td>19 - 46</td>
<td>51,890,736</td>
<td>20.0 - 48.0</td>
<td>53</td>
</tr>
<tr>
<td>Hog manure-grower to finisher</td>
<td>9-11</td>
<td>80 - 85</td>
<td>28 - 46</td>
<td>2,452,800</td>
<td>1.4 - 2.3</td>
<td>58</td>
</tr>
<tr>
<td>Dairy manure</td>
<td>12</td>
<td>80 - 85</td>
<td>25 - 32</td>
<td>3,994,195</td>
<td>2.0 - 2.6</td>
<td>54</td>
</tr>
<tr>
<td>Poultry manure</td>
<td>25 - 27</td>
<td>70 - 80</td>
<td>69 - 96</td>
<td>1,728,987</td>
<td>2.4 - 3.3</td>
<td>60</td>
</tr>
<tr>
<td>Animal fat</td>
<td>89 - 90</td>
<td>90 - 93</td>
<td>801 - 837</td>
<td>87,000</td>
<td>1.4 - 1.5</td>
<td>N/A</td>
</tr>
<tr>
<td>Animal carcass (homogenized-bovine)</td>
<td>34 - 39</td>
<td>90 - 93</td>
<td>348 - 413</td>
<td>264,023</td>
<td>1.8 - 1.2</td>
<td>N/A</td>
</tr>
<tr>
<td>Municipal wastewater sludge</td>
<td>30-20</td>
<td>90</td>
<td>17 - 140</td>
<td>539,835</td>
<td>0.2 - 1.5</td>
<td>65</td>
</tr>
<tr>
<td>Household waste</td>
<td>N/A</td>
<td>N/A</td>
<td>143 - 214</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Total manure (including municipal sludge)</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>60,606,553</td>
<td>25.7 - 57.4</td>
<td>50 - 70</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Feed material</th>
<th>Total solids %</th>
<th>Volatile solids % of total solids</th>
<th>Biogas yield m³/tonne</th>
<th>Yearly biomass production in dry tonnes*</th>
<th>Yearly energy potential in PJ</th>
<th>Methane content %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>36 - 86</td>
<td>90 - 95</td>
<td>169 - 291</td>
<td>1,404,671</td>
<td>4.75 - 8.18</td>
<td>60 - 70</td>
</tr>
<tr>
<td>Wheat</td>
<td>32 - 97</td>
<td>N/A</td>
<td>48 - 146</td>
<td>1,390,222</td>
<td>1.33 - 4.106</td>
<td>N/A</td>
</tr>
<tr>
<td>Oats</td>
<td>64</td>
<td>68</td>
<td>147 - 187</td>
<td>172,085</td>
<td>0.51 - 0.64</td>
<td>49 - 57</td>
</tr>
<tr>
<td>Rye</td>
<td>25 - 61</td>
<td>91 - 95</td>
<td>112 - 457</td>
<td>4,423</td>
<td>0.00 - 0.04</td>
<td>N/A</td>
</tr>
<tr>
<td>Triticale</td>
<td>27 - 66</td>
<td>93 - 97</td>
<td>150 - 554</td>
<td>9,526</td>
<td>0.03 - 0.11</td>
<td>60 - 70</td>
</tr>
<tr>
<td>Sugar beet leaves</td>
<td>N/A</td>
<td>N/A</td>
<td>40 - 50</td>
<td>197,887</td>
<td>0.16 - 0.20</td>
<td>49 - 57</td>
</tr>
<tr>
<td>Fodder corn</td>
<td>25 - 37</td>
<td>95</td>
<td>182 – 436</td>
<td>89,674</td>
<td>0.33 - 0.78</td>
<td></td>
</tr>
<tr>
<td>Tame hay</td>
<td>N/A</td>
<td>N/A</td>
<td>80</td>
<td>699,344</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>Leaves</td>
<td>80</td>
<td>90</td>
<td>72 - 216</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Whey</td>
<td>1 - 5</td>
<td>80 - 95</td>
<td>6.45</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Grass silage</td>
<td>20 - 25</td>
<td>90</td>
<td>75 - 126</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Distiller grain wastewater</td>
<td>N/A</td>
<td>N/A</td>
<td>58</td>
<td>N/A</td>
<td>N/A</td>
<td>57 - 60</td>
</tr>
<tr>
<td>Total straw and other roughages</td>
<td>70</td>
<td>90</td>
<td>105 - 158</td>
<td>3,901,007</td>
<td>8.19 - 12.33</td>
<td>60 - 70</td>
</tr>
</tbody>
</table>

* 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 m³ of biogas can produce 1.7 kWh of electricity and 7.7 MJ of heat. Multiplying the total biogas potential in m³ 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 m³/tonne (Table 2)
Biogas potential for 1,000 tonnes = 250 x 801 = 200,250
Electricity produced from 1 m³ of biogas in a co-generator = 1.7 kWh
Excess heat available from 1 m³ of biogas after producing electricity = 7.7 MJ
Electricity produced from 200,250 m³ of biogas = 200,250 x 1.7 = 340,425 kWh
Heat available from 200,250 m³ of biogas = 200,250 x 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 = $27,787.50 + $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.

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/day 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 CO₂ 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.

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.
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://himarkbiogas.com/imus/

For additional information, check the following web pages:


References


David Spiess, 2006. Value-added opportunities for straw in Alberta. Alberta Agriculture and Rural Development


Lehtomaki, A., J. Rintala 2006. Biogas production from energy crops and crop residues. Department of biological and environmental sciences, University of Jyvaskyla, Finland.


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