

# Energy Opportunities Anaerobic Digestion: Methane Production for Alberta

Biogas technology has become an attractive treatment option for agricultural, food processing and municipal organic wastes for pollution control and energy recovery (Chen et al. 2008). The organic wastes are described as feedstocks for anaerobic digestion (AD). Almost all organic matter (OM) in the feedstocks can be converted to biogas through AD; however, some materials produce more biogas than others. The energy potential is influenced by the amount of biogas produced, the concentration of methane in the biogas and the amount of the feedstock available.

## Biogas

Biogas is a mixture of gas produced by AD. Primarily, biogas is methane (CH<sub>4</sub>), 55-75%, carbon dioxide (CO<sub>2</sub>), 44-24%, and trace amounts of water vapour and other gases (Alberta 2011). Methane is the prime component of natural gas so scrubbed biogas can be a valuable fuel source.

## Volatile Solids

The volatile solids (VS) analysis determines the amount of OM in the feedstock. Feedstocks containing more than 60 or 70% VS on a dry matter basis are good candidates for AD. The non-volatile solids, or ash content, of a feedstock takes up valuable digester volume and will not contribute to biogas production (Hamilton 2012).

OM with high energy contents produces more biogas than OM with lower energy contents.

## Methane Yield

Feedstock analysis can be performed to measure the biochemical methane potential, or methane yield. The biogas yield from a feedstock is not the same as the methane yield. Each feedstock or combination of feedstocks create different methane yields.

The methane yield is generally expressed as a function of the VS (normalized L/kg VS), and it can be calculated and expressed as a volume of gas per unit of feedstock (m<sup>3</sup>/1000 kg of feedstock), Example 1.

Generally speaking feedstocks rich with VS create higher volumes of methane than feedstocks with lower VS.

The energy, joules, created by the methane produced can be calculated using the lower heating value of methane (36 MJ/m<sup>3</sup>), and the methane yield (m<sup>3</sup>/1000 kg feedstock). The energy potentials of feedstocks in Alberta are shown in Table 1.

### Example 1. Methane yield converted to energy

Feedstock analysis provides the total solids, VS, as well as the methane yield expressed as a function of the VS of the raw feedstock. Using this information the potential energy can be calculated.

Methane yield: 312 N L/kg VS

VS of the sample: 95 kg/1000 kg feedstock

Methane yield as m<sup>3</sup> = VS \* CH<sub>4</sub> \* efficiency \* conversion  
= 95 \* 312 \* 0.9 \* 1/1000

Funded by


Agriculture and  
Agri-Food Canada

Agriculture et  
Agroalimentaire Canada

$$\begin{aligned}
 &= 27 \text{ m}^3/1000 \text{ kg of feedstock} \\
 \text{Energy from CH}_4 &= \text{CH}_4 * \text{lower heating value} \\
 &= 27 * 36 \\
 &= 966 \text{ MJ/1000 kg of feedstock}
 \end{aligned}$$

The energy calculated is not equivalent to the electricity that could be generated from the methane produced through AD.

## Co-digestion

Co-digestion for AD means more than one feedstock is used at a time to produce biogas. Co-digestion is used to increase the methane yield from low yielding feedstocks.

Care must be taken to select compatible feedstocks that enhance methane yields and avoid materials that may inhibit biogas and methane production. Agricultural feedstocks have successfully been co-digested with restaurant biowastes, food processing and crop residues (EPA 2012).

The quantity, availability, and cost of co-digestion feedstocks are important factors to consider. Other factors to consider include: regulations and permitting; digester capacity; mixing of the feedstocks; and nutrient balance.

## Feedstock Quantity

Valuable feedstocks for AD are dispersed throughout Alberta. Supermarket fresh fruit and vegetables and restaurant prep and plate wastes are available throughout Alberta, directly proportional to the population density. Manure is another potential feedstock that is available throughout the province yet highly variable due to animal density. In areas of Alberta, meat processing, as well as food, ethanol, oilseeds, and brewery processing produce potential feedstocks. The approximate distribution of the feedstocks is shown in Table 2.

Other feedstocks in Alberta have valuable OM however the quantities of the feedstocks are variable. For example, spoiled or excess straw and silage (greenfeed) may be available for AD in some years in various parts of the

province. Waxed cardboard is another valuable feedstock however the supply is ever changing due to packaging trends.

In some cases it may not be possible to collect and use all feedstocks, for example some manure is generated in pasture situations and is therefore not collected therefore it wouldn't be used to generate energy.

## Energy to Electricity

The power can be calculated using the feedstock quantity available and the energy created by the accumulated CH<sub>4</sub> (Vik 2003), Example 2.

### Example 2. Power potential

A watt (W) is the rate of energy conversion or transferred which is equivalent to a joule (J) per second. Knowing the amount of feedstock available for AD and the energy potential the energy as a W can be calculated.

$$\begin{aligned}
 \text{Energy from CH}_4 &= 966 \text{ MJ/1000 kg of feedstock} \\
 &\quad (\text{calculated in Example 1}) \\
 \text{Feedstock amount} &= 271000 \text{ kg/year} \\
 &= 0.0086 \text{ kg/second} \\
 \text{Energy} &= 966 * 0.0086 \\
 &= 8300 \text{ W}
 \end{aligned}$$

Alberta has 16 municipal districts or cities with the potential to create more than 50 MW of energy.

This energy potential does not take into account the efficiencies of a power generating unit. An example of a power generating unit is a combined heat and power unit which is a reciprocating gas engine that uses the gas, CH<sub>4</sub>, to drive a crank shaft. The crank shaft turns an alternator to produce electricity and heat is released during the gas combustion process. The heat can be recovered during cogeneration in order to maximize the energy conversion of the system. The electricity efficiency of a quality combined heat and power unit suitable for biogas is on average 40% with an additional 45% of the energy recoverable as thermal energy (Clarke Energy 2013). Approximately 15% of the input energy is typically lost.

## Feedstocks and Energy

The potential energy generated from the feedstocks can be seen in a series of maps produced by Alberta Agriculture and Rural Development. The energy is shown per municipal district or city. An additional factsheet for each map is also available describing the feedstock qualities as well as the methane potential.

Energy Opportunities  
Anaerobic Digestion: Manures

Energy Opportunities  
Anaerobic Digestion: Alberta Processing Co-Products  
(sugar beets, ethanol, potatoes, oilseeds and brewery)

Energy Opportunities  
Anaerobic Digestion: Meat Processing

Energy Opportunities  
Anaerobic Digestion: Restaurants

Energy Opportunities  
Anaerobic Digestion: Straw, Silage, Waxed Cardboard

Energy Opportunities  
Anaerobic Digestion: Supermarkets

## More Information

Increasing Anaerobic Digester Performance with Codigestion.

<http://www.epa.gov/agstar/documents/codigestion.pdf>

## References

- Alberta Agriculture and Rural Development. 2011. Biogas energy potential in Alberta. Agdex 768-3. Edmonton: Alberta, Alberta Agriculture and Rural Development.
- Chen, Y., J. Cheng, K. Creamer. 2008. Inhibition of anaerobic digestion process: A review. *Bioresource Technology* 99: 4044-4064.
- Clarke Energy. 2013. CHP efficiency for biogas. [www.clarke-energy.com/2013/chp-cogen-efficiency-biogas/](http://www.clarke-energy.com/2013/chp-cogen-efficiency-biogas/). (Accessed: 2013).
- EPA. 2012. Increasing anaerobic digester performance with codigestion. AgStar Report. United States Environmental Protection Agency.
- Hamilton, D.W. 2012. Anaerobic digestion of animal manures: methane production potential of waste materials. BAE-1762. Oklahoma: Oklahoma Cooperative Extension Service.
- Vik, T.E. 2003. Anaerobic digester methane to energy a statewide assessment. MCM. No. W0937-920459. Neenah, Wisconsin: McMahon Associates, Inc

Table 1. Energy potential from feedstocks in Alberta

<b>Feedstock</b>	<b>Methane Yield (m<sup>3</sup>/1000 kg of feedstock)</b>	<b>Energy Potential (MJ/1000 kg of feedstock)</b>	<b>Feedstock</b>	<b>Methane Yield (m<sup>3</sup>/1000 kg of feedstock)</b>	<b>Energy Potential (MJ/1000 kg of feedstock)</b>
Potato Chips	441	15865	Brewery spent grain	71	2567
Oilseed Meal	272	9780	Food Service Industry Average	70	2507
Sugar Beet Pulp	258	9300	Silage	70	2502
Cattle processing	248	8938	Feedlot Manure	61	2187
Sugar Beet Molasses	191	6886	Pressed Berries from Fruit Wine	39	1389
Straw – wheat and barley	168	6052	Potato Skins and Pulp	35	1254
Waxed Cardboard	153	5524	Supermarket Fresh Fruit and Vegetables	33	1173
Restaurant Plate Scraps	115	4128	Ethanol Whole Stillage	30	1095
Poultry processing	113	4071	Ethanol Thin Stillage	29	1036
Poultry Manure	91	3260	Restaurant Prep Waste	22	793
Ethanol Wet Cake	89	3191	Dairy Manure	15	546
Hog processing	82	2935	Hog Manure	4	156

Table 2. AD feedstock quantities in Alberta municipal districts and cities

<b>County / City Name</b>	<b>Manure (T/yr)</b>	<b>Supermarket (T/yr)</b>	<b>Restaurant (T/yr)</b>	<b>Processing (T/yr)</b>
M.D. of Acadia No. 34		11	7	
Athabasca County	400850	270	180	47
County of Barrhead No. 11	725350	231	154	181
Beaver County	441474	215	143	1866
M.D. of Big Lakes	125634	221	147	
M.D. of Bighorn No. 8	60670	32	21	
Birch Hills County	117878	35	23	237
M.D. of Bonnyville No. 87	505975	728	486	155
Brazeau County	245531	326	217	
Camrose County	544366	609	406	
Cardston County	810471	229	153	23
Clear Hills County	186201	70	47	
Clearwater County	674752	441	294	575
Cypress County	1179714	1624	1083	155
M.D. of Fairview No. 136	22015	106	71	

Flagstaff County	444999	181	121	263
M.D. of Foothills No. 31	1057291	1404	937	371722
County of Forty Mile No. 8	499009	129	86	
County of Grande Prairie No. 1	537699	1808	1206	631
M.D. of Greenview No. 16	35740	293	195	69
Kneehill County	738424	246	164	32228
Lac La Biche County	59692	184	123	
Lac Ste. Anne County	563749	330	220	56
Lacombe County	1091766	721	481	10004
Lamont County	298471	185	124	
Leduc County	574153	1393	929	50
M.D. of Lesser Slave River No. 124	34413	213	142	
County of Lethbridge	3792962	2455	1638	861584
Mackenzie County	6168	339	226	
County of Minburn No. 27	615413	223	149	177
Mountain View County	1012702	706	471	93
County of Newell	1196178	511	341	388333
County of Northern Lights	153749	123	82	
Northern Sunrise County	39657	69	46	
M.D. of Opportunity No. 17		67	45	
County of Paintearth No. 18	591041	88	59	37
Parkland County	392638	1608	1073	383
M.D. of Peace No. 135	33592	244	163	170
M.D. of Pincher Creek No. 9	874916	155	104	306
Ponoka County	1179401	398	265	2535
M.D. of Provost No. 52	732560	109	73	830
M.D. of Ranchland No. 66	115417	2	1	
Red Deer County	1298668	2980	1988	538665
Rocky View County	1074327	2632	1755	1277
Saddle Hills County	220935	50	33	
Smoky Lake County	142415	122	81	
M.D. of Smoky River No. 130	44731	101	67	
M.D. of Spirit River No. 133	14133	52	35	
County of St. Paul No. 19	676967	299	199	483
Starland County	339449	59	39	303
County of Stettler No. 6	978575	260	173	212
Sturgeon County	330065	790	527	20656
M.D. of Taber	2085046	374	250	85534
County of Thorhild No. 7	92598	75	50	

County of Two Hills No. 21	327050	115	77	41
County of Vermilion River	1144033	710	474	495288
Vulcan County	1803066	153	102	503
M.D. of Wainwright No. 61	612688	247	165	125
County of Warner No. 5	904824	226	151	51
Westlock County	652993	286	190	23
County of Wetaskiwin No. 10	652113	570	380	246
Wheatland County	1263137	472	315	1566
M.D. of Willow Creek No. 26	1481136	331	221	34246
Woodlands County	85423	305	204	
Yellowhead County	446563	631	421	
I.D. No. 24 Wood Buffalo		13	9	
Regional Municipality of Wood Buffalo		2555	1704	28
I.D. No. 25 Willmore Wilderness				
I.D. No. 12 Jasper		1		
I.D. No. 9 Banff		207	138	14
Kananaskis I.D.		276	184	
I.D. No. 13 Elk Island				
I.D. No. 4 Waterton		2	1	
I.D. No. 349				
Special Areas 3	245646	63	42	1454
Special Areas 4	317682	54	36	48
Special Areas 2	1132909	96	64	17
Municipality of Crowsnest Pass		122	81	
Strathcona County	142828	2030	1354	778
Municipality of Jasper		115	77	7
Edmonton	2265	17943	11968	947258
St. Albert		1349	900	
Calgary	7191	24588	16400	9294
Drumheller		176	118	
Fort Saskatchewan		449	300	410900

