Feasibility Study – Anaerobic Digester and Gas Processing Facility in the Fraser Valley, British Columbia

Prepared for:
BC BioProducts Association

BC BioProducts Association

Prepared by:
Electrigaz Technologies Inc

Electrigaz

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Abstract

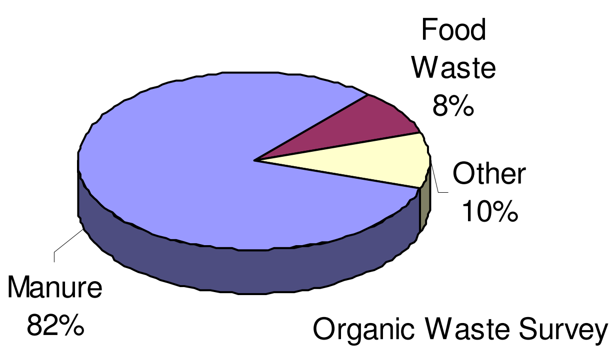
This study outlines the benefits and barriers to the implementation of anaerobic digestion in the Fraser Valley, British Columbia. A survey of organic material suitable for anaerobic digestion has been performed to evaluate the overall biogas energy potential. Applicable anaerobic digester technologies are presented and reviewed in light of economic viability. A regulatory scan was completed to assess policy barriers to the implementation of the technology. A case farm biogas project was studied to evaluate economic viability of anaerobic digestion under current British Columbia conditions. Finally a set of policy recommendations are put forward to address barriers to the development of biogas projects in the Fraser Valley.

Executive Summary

The BC Bioproducts Association in cooperation with the Ministry of Agriculture and Lands, Ministry of Energy, Mines and Petroleum Resources, Ministry of Environment, BC Greenhouse Grower's Association, BC Hydro, BC Milk Producers Association, National Challenges Systems Inc. and Great Pacific Bioproducts Ltd., requested a feasibility study to evaluate the potential to convert organic waste produced in the Fraser Valley into renewable energy.

Biogas plants are systems that use a bacteriological process called anaerobic digestion to convert organic waste into biogas. Biogas is a clean energy source that may be converted to electricity, heat or bio-fuel for automotive applications.

Activities in the BC Fraser Valley generate approximately 3.3 million tonnes per year of organic waste suitable for anaerobic digestion. The following chart shows that the vast majority of this waste comes from the agricultural sector.

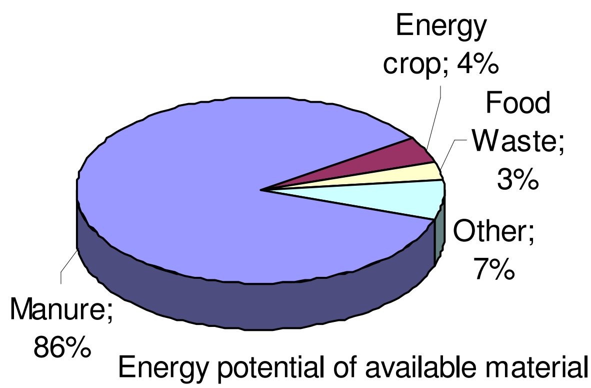


Today, a significant fraction of the non-agricultural organic waste produced in the Fraser Valley is land filled due to a lack of alternative disposal outlets. It was estimated that only 85% (2.8 M tonnes/year) of this organic waste would be readily available for anaerobic digestion.

Furthermore, biogas plants are capable of efficiently converting energy crops (corn silage) into biogas energy. For this study it was assumed that 1% of farm land would be converted to energy crops for bio-energy production.

The energy potential of readily available organic material in the Fraser Valley is estimated at 30 MW electric, equivalent to 400,000 barrels of oil per year, enough energy to power over 30,000 BC homes.

The following chart shows the energy contribution of each available organic waste stream.



Anaerobic digestion is a mature and proven technology that is providing solutions to energy supply and environmental concerns. Worldwide, Germany is the market leader with over 4,000 on-farm anaerobic digesters generating more than 1,200 MW of clean power.[1]

350 kW biogas plant, Germany

In BC, for geographical and feedstock availability reasons, the most sensible biogas system would be an on-farm anaerobic digester (photo) running on manure and accepting off-farm food waste as opposed to large centralized digesters found in Europe.

[1] German Biogas Association, www.biogas.org

Today, British Columbians enjoy one of the lowest electricity rates ($65/MWh) in North America [5]. The energy market in BC is dictated by clean and inexpensive hydro electricity. The *2007 BC Energy Plan: A Vision for Clean Energy Leadership* [15] instructed BC Hydro to develop a standing offer program to support the development of renewable energy production by offering to potential independent power producers a fixed-price with standard contract terms and conditions. The proposed fixed-price for the Fraser Valley is $81.05/MWh.

Small biogas plants (250 kWe) produce electricity at an average break even cost of $115/MWh. Under the current electricity market conditions anaerobic digestion power generation is not financially viable.

Biogas plants may choose to upgrade biogas to natural gas grade and sell energy via the gas distribution network. BC recently opened the gas market for direct marketing to end customers. Under these new rules, upgraded biogas estimated cost of $10/GJ, could be sold as green natural gas or "moothane" for $12/GJ to customers willing to pay more for environmentally friendly energy products which support local agricultural enterprises. Energy marketers are currently signing 5-year contracts with BC customers to supply "fossil-based" natural gas at $9/GJ.

By converting waste into energy, biogas plants reduce odours and pathogens, produce an enhanced fertilizer and reduce greenhouse gas emissions. Unlike "fossil-based" natural gas, biogas is a carbon neutral renewable energy source. Of all renewable energy sources (solar, wind, hydro) biogas is the most environmentally beneficial.

Metro Vancouver (GVRD) and the Fraser Valley Regional District have adopted an Air Quality Management Plan which seeks to reduce emissions in the region. The goals of the Air Quality Management plan fit very well with the benefits that can be achieved with the installation of biogas plants to treat animal manure and various organic residual materials. Given that anaerobic digestion treatment of manures significantly reduces GHG emissions, odours and potentially ammonia emissions, biogas installations could become part of a larger air quality enhancement plan for Metro Vancouver and FVRD. Moreover, local renewable energy production would result in fewer particulate and toxin emissions from fossil fuel based power generating stations.

Profitable on-farm anaerobic digestion combined with nutrient extraction technologies could offer practical and sustainable solutions to nutrient overloading and water quality issues. It should not be expected that anaerobic digestion alone would solve nutrient management problems in the Fraser Valley, but it would be an important first step to enable responsible manure management practices.

A regulatory scan revealed some legislative barriers to the development of biogas. It is believed that the following policy changes are required to enable a viable biogas industry in BC:

Establishment of clear rules and regulations for bringing off-farm waste onto farms for anaerobic digestion treatment.

Recognition of biogas energy production as a standard farm practice and modification of all applicable documents related to Agricultural Land Reserve Use to reflect this recognition.

Revision of BC Hydro's Standing Offer Program to determine an equitable feed-in tariff for each individual renewable energy sector. The current standing offer proposal appears to favour lower cost technologies such as run of the river hydro and wind power.

Anaerobic digestion feed-in tariff recommendations:

<250 kW	$150/MWh
250 kW–500 kW	$145/MWh
>500 kW	$130/MWh

Policies supporting anaerobic digestion would empower rural communities to develop a biogas industry that would create jobs, enhance agriculture's image as a responsible steward of natural resources, and generate significant rural economic returns. Assuming the establishment of favourable policies in BC like the ones adopted in Germany (see Appendix H) and based on the overall German experience, the table below presents potential economic forecasts for a biogas industry flourishing in the Fraser Valley:

	2015	2020	2030
Installed power (MW)	10	30	50
On-farm biogas systems (avg. 250 kWe)	40	120	200
Electricity generated (GWh/yr)	81	242	403
Total capital investments ($millions)	45	135	225
Contractors annual revenue ($millions)	10	30	50
Operators annual revenue ($millions)	11	34	56
Employment	123	369	615
CO_2 reduction (thousand tonnes)	62	185	308

In conclusion, under current environmental and energy policies, anaerobic digestion cannot develop to its full potential in BC. It is largely in the hands of BC policy makers to enable the development of an anaerobic digestion industry in BC by paving the way with innovative policies.

Acknowledgments

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Fraser Valley Anaerobic Digestion Feasibility Study Steering Committee:
BC BioProducts Association, BC Greenhouse Growers' Association, BC Hydro, BC Milk Producers Association, Organic Resource Management Inc., Great Pacific Bioproducts Ltd., Ministry of Agriculture and Lands, Ministry of Energy, Mines and Petroleum Resources, and Ministry of Environment.

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Glossary and Abbreviations

AD	Anaerobic digestion
ALCA	Agricultural Land Commission Act
ALR	Agricultural land reserve
BC	British Columbia
BCUC	BC Utilities Commission
Bio-methane	Biogas upgraded to natural gas quality
BSE	Bovine spongiform encephalopathy
CFIA	Canadian Food Inspection Agency
Cowpower	Electricity made from cow manure
DAF	Dissolved air flotation
DM	Dry matter content
Digestate	Anaerobically digested material
DW	Dry weight
EFP	Environmental farm plan
EPA	Electricity Purchase Agreement
FVRD	Fraser Valley Regional District
GHG	Greenhouse gases
GJ	Gigajoule, unit of energy
GVRD	Greater Vancouver Regional District (Metro Vancouver)
ICI	Institutional, Commercial and Industrial
IPPs	Independent power producers
kW	Kilowatt, unit of power
kWe	Kilowatt, unit of electrical power
kWh	Kilwatthour, unit of energy
kWhe	Kilwatthour, unit of electrical energy
LFV	Lower Fraser Valley
Moothane	Methane made from cow manure
MSW	Municipal solid waste
MWh	Megawatthour, unit of energy
MWhe	Megawatthour, unit of electrical energy
NGV	Natural gas vehicle
NRC	National Research Council
O&M	Operation and maintenance
Power Call	Open Bidding process through which BC Hydro acquires its power
SOP	BC Hydro Standing Offer Program
SRM	Specified risk material
Tonne	Metric ton
VFAs	Volatile fatty acids
VOC	Volatile organic compound
Wheeling	Moving electrical power over an electrical network
WWTP	Waste water treatment plant

Table of content

List of figures

List of tables

1. Introduction

The British Columbia Bioproducts Association spear headed an initiative with the Ministry of Agriculture and Lands, Ministry of Energy, Mines and Petroleum Resources, Ministry of Environment, BC Greenhouse Growers' Association, BC Hydro, BC Milk Producers Association, National Challenges Systems Inc. and Great Pacific Bioproducts Ltd. to commission a feasibility study to assess the biogas energy production potential of organic wastes produced in the Fraser Valley.

The Fraser Valley is a region of south western British Columbia surrounded by mountains to the North and East, the US border of Washington State to the south and the Straight of Georgia to the West. The Fraser Valley is divided in two regional districts: Metro Vancouver, urban region with a population of 2 116 965 and the Fraser Valley Regional District (FVRD), rural region with a population of 257 031.[2] The following figure presents a location map of the Fraser Valley

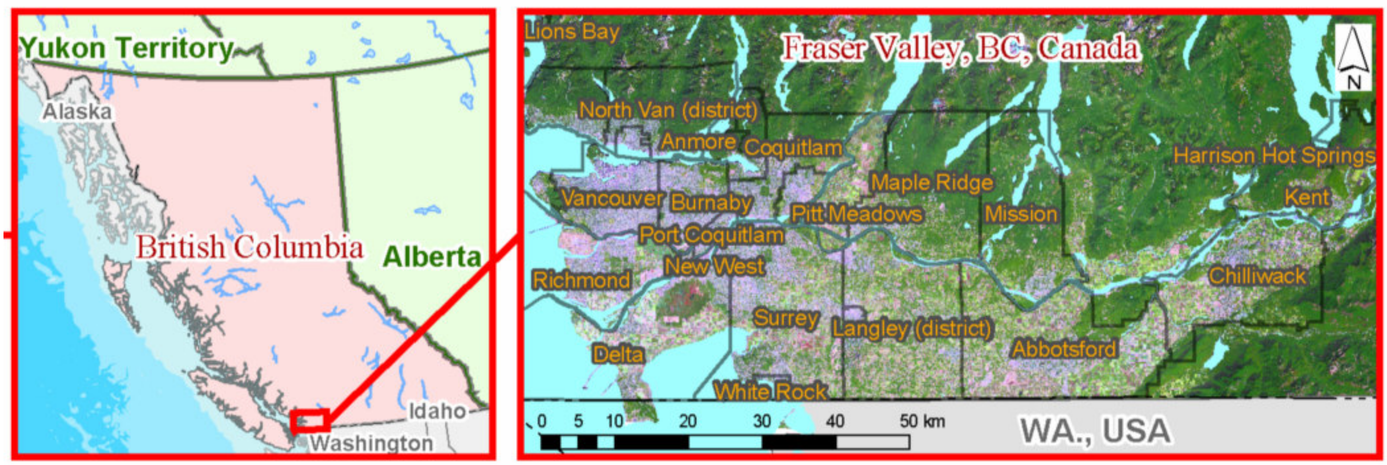

Figure 1-Location map of Fraser Valley

The Fraser Valley geographic configuration makes it prone to air quality concerns. Anaerobic Digestion has been identified as a potential solution that could offset this problem by reducing emissions from the agricultural sector and displacing the use of fossil-based energies in the region. Anaerobic digesters are systems that convert organic waste into biogas and quality fertilizer. Biogas is a clean energy source that may be converted to electricity, heat or biofuel for automotive applications.

Electrigaz general mandate was to evaluate the potential for biogas energy in the Fraser Valley, identify opportunities and barriers for the technology and make policy recommendations to facilitate the deployment of this renewable energy technology in BC.

[2] Population data from Statistic Canada, Census 2006

2. Fraser Valley Organic Waste Survey

For the purpose of this study, suitable agricultural and non-agricultural organic wastes (municipal/industrial) were considered for anaerobic digestion. Agricultural waste is regulated by Agricultural Waste Control Regulation and managed by farmers and private service providers. Municipal/industrial waste is regulated by BC Ministry of Environment through the Waste Discharge Regulation as well as municipal by-laws. Municipal waste is managed by Regional districts such as Metro Vancouver and FVRD through Solid and Liquid Waste Management Plans and facilities such as landfills, sewage treatment plants and waste incinerators. Industrial waste is largely managed by the industries themselves by purchasing capacity from Regional District operated waste treatment facilities or from private service providers.

In general, waste management is expressed in terms of production, collection and disposal of various waste streams.

Waste producers include farms, industries, institutions, stores, restaurants and citizens.

Waste collectors are private or public entities that gather various waste streams such as city garbage, commercial waste bins, food processor waste bins, grease traps, septage and sewerage to be transported to disposal sites.

Disposal sites take the form of wastewater treatment plants, landfills, composting sites, incinerators, farm land, silviculture and mining lands (outside Fraser Valley). Non-agricultural waste material is mainly disposed of at landfills.

With constant population growth in the Fraser Valley, Metro Vancouver and FVRD landfills are filling up rapidly. In 2005, the Vancouver landfill located in Delta had a 10% increase of municipal solid waste (MSW) disposed of at its site [26]. MSW is being transported longer distances for disposal, in Metro Vancouver, 33% of the MSW collected is sent 300 km from the city of Vancouver to the Cache Creek Landfill [50].

As indicated in the City of Vancouver report "The Next Steps in Waste Diversion" [27], cities are studying options to decrease the amount of MSW sent to landfill. Since recycling programs are well established in the Fraser Valley, research for alternative disposal sites for the organic fraction of MSW are being conducted [4, 27, 35, 36, and 37]. Diversion options being considered are backyard composting and centralized composting sites. Composting sites located in the Fraser Valley are mainly processing yard wastes [100]. In recent years, several sites composting food waste have been shut down due to offensive odor issues [80]. The Vancouver landfill will test a pilot food waste composting system at the end of year 2007[3].

[3] As indicated during a landfill visit by Nicole Steglich from the City of Vancouver Engineering Department

In this study organic waste is defined as organic material suitable for anaerobic digestion. This excludes wood products, cotton, leaves…

Evaluation of organic waste materials that is currently being land filled but could be diverted to AD treatment sites have been estimated using information provided by landfill waste material composition studies [23, 27, 45, 93] and MSW total fraction sent to landfill by interviewing all Fraser Valley landfill operators and consulting landfill annual reports [26, 50] and regional district web sites4.

Research was focused on organic waste streams suitable for anaerobic digestion. These originate from:

- Agriculture
  - Animal manure
  - Fruit, vegetable and pruning waste
  - Field crops waste
  - Energy crops
  - Dead stock

- Food processing industry
  - Dairies
  - Slaughterhouse & meat packing plants
  - Fish packing plants
  - Bakeries
  - Fruit & vegetable processing
  - Beverage industry

- Residential, Commercial and Institutional
  - Commercial food waste (groceries, restaurants)
  - Sewerage
  - Organic fraction of the residential garbage bag
  - Home composting material (fruit and vegetable)
  - Gardening waste (grass)
  - Sewerage sludge

[4] Metro Vancouver : www.gvrd.bc.ca and FVRD: www.fvrd.bc.ca

2.1. *Waste management practices*

In this section the survey methods used to derive the organic waste survey results are explained. A general explanation of current waste management practices is the region is also provided.

2.1.1. Agricultural waste

Survey methodology

For the agricultural sector, it was possible to evaluate waste production using readily available survey data and documented waste production coefficients. Organic waste produced by the agricultural sector has been evaluated using data from Statistics Canada - Census 2006. Using information on farm production, acreages cultivated and animal numbers, it was possible to estimate agricultural organic waste production.

Waste management practices

Manure produced on farm is generally used as a fertilizer on farm land. Most farmers value their manure and would not give it away. The exceptions are poultry farms and large hog operations that export their manure because they produce more manure nutrients than their landbase can handle sustainably. Surplus manure is exported to cash crop, berry and/or mushroom farms and composting sites. Some poultry producers practice on site composting to facilitate disposal of the material.

Greenhouses compost their cyclic crop waste on site or send wastes to landfill or composting sites for a fee.

Other farm wastes include dead stock and crop waste. Crop waste is normally tilled into the soil, composted or if possible fed to animals. Dead stock are composted on farm or picked up by a dead stock hauler or a rendering plant for a fee.

2.1.2. Food processing waste (Industrial waste)

Survey methodology

Metro Vancouver and FVRD house over 700 food processing industries of various sizes. It was impractical to survey all the food industries individually. However, food processors from each sector were contacted to establish typical waste management practices and disposal sites.

Food industry associations were also contacted but provided no specific information about their members' waste volumes. They were, however, able to provide useful information on management practices by activity sectors.

Surveying of waste collectors, to evaluate volumes of organic waste transported, proved unsuccessful. The waste industry cherishes its commercial privacy and did not share information that could be used in this study. Food processor waste volumes were therefore evaluated by researching disposal site information.

Waste management practices

Food processors produce wastewater that is often discharged into the sewerage system. Industries are equipped with grease traps to limit fat content ejected into the sewerage. Industries injecting heavily loaded wastewater pay a sewerage surcharge based on the organic load (kg BOD/day) and volume. Industries pay waste management companies to regularly service their grease traps. Large food processors may have their own wastewater treatment plant in which case they produce sludge and/or floatation fat (DAF).

All grease trap waste in the Fraser Valley is treated at the Iona wastewater treatment plant in Richmond at the cost of $68.91/m^3.[5]

Food processors can be divided into two major groups with fundamentally different waste management practices: fish & meat processors and meatless processors.

Meatless processors

Meatless waste can go to landfills, composting sites or be used as animal feed.
Land filling is the most expensive option at a cost of 65$/tonne[6], followed by composting sites. However, in the Fraser Valley composting of food waste is challenging and often results in severe odour and air quality issues that have forced a number of composting facilities to cease operations. Therefore, this disposal outlet tends to be unreliable.

Generally, meatless waste is used as animal feed (pet food, animal feed or directly to farms), free of charge to the receiver who assumes transportation cost. A few high quality waste streams are currently produced, such as brewer's grains, where receivers (cattle or dairy farmers) pay for the waste.

Fish & Meat processors

In the meat processing waste industry, the dynamic is different and constantly evolving. The bovine spongiform encephalopathy (BSE) crisis triggered dramatic changes in the animal by-product industry. Rendering plants used to purchase meat and fish waste, for a modest price.

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[5] Cost provided from Metro Vancouver Website, September 2007
[6] Cost provided from Metro Vancouver Website, September 2007

Currently, slaughterhouse, meat and fish packing waste are collected by the West Coast Reduction rendering plants for a fee ($0-$55/tonne).

Certain parts of the cow (specified risk materials or SRM) are considered potential health hazards and must be disposed of using strict procedures. Most of Fraser Valley slaughterhouses and meat packers are not setup for effective SRM separation. Often, all bovine and hog waste produced by the plants is considered SRM and is processed, for a significant fee, by the Calgary West Coast Reduction SRM approved rendering plant.

Disposal of SRM is regulated by the Canadian Food Inspection Agency and they do not approve disposal of SRM in anaerobic digesters.

Recently, the BC Ministry of Environment has allowed for land filling and incineration of slaughterhouse and poultry processing waste in a *Code of Practice for the Slaughter and Poultry Processing Industries* document (Appendix A). In recent years, several studies have been conducted in the Fraser Valley to evaluate the viability and environmental impact of sending slaughter and meat processing wastes to landfill with or without SRM [19, 34, and 87]. These studies show that with appropriate management practices, land filling of meat waste is possible.

Composting of meat and fish by-products is a waste outlet that is receiving increasing attention. The BSE crisis forced government agencies to study the risk of disposing of SRM. There are currently a number of meat waste treatment pilot projects but none are reliable disposal outlets at this time.

Because of SRM issues concerning cattle processing by-products and the current lack of separation capacity, it is primarily the fish and poultry processing wastes present in the Fraser Valley that are of interest for anaerobic digestion treatment.

2.1.3. Residential, Commercial and Institutional waste

Survey methods

For all other waste streams, the strategy was to gather information from disposal sites to generate quantity estimates. Landfills and sewerage treatment plants, which represent the majority of disposals sites, are managed or overseen by regional districts, FVRD or Metro Vancouver.

These agencies were cooperative and provided a lot of data and reports that helped evaluate overall organic waste streams at the following waste disposal sites:

- Landfills
- Composting sites
- Backyard composters
- Municipal sewerage plants

Waste management practices

Waste from residential, commercial and institutional sources come in solid or liquid form.

Liquid waste

Liquid waste is routed via the sewerage system to a wastewater treatment plant (WWTP). Similar to food processors, commercial and institutional organizations are equipped with grease traps that require frequent servicing.

The majority of sewerage plants in the Fraser Valley digest their sludge with anaerobic digesters, press it and send it to landfills, silvicultural land or mines.

Solid waste

Currently, most solid waste collected in the Fraser Valley is a mixture of organic and non-organic waste, all combined in one bin. These bins are common in the back of homes, schools, hospitals, restaurants, independent groceries, apartment buildings, etc., and their contents all end up in landfills.

Excluding large groceries, there is little to no infrastructure in place to accommodate source separation of organic wastes. This is understandable since currently the only outlet for the organic materials are composting sites that are constantly opening and closing. Today, even some source separated organics are landfilled for lack of organic waste outlets.

Most cities have yard trimmings collection programs to pick up leaves, branches and grass to be sent to composting sites. In Metro Vancouver, the Vancouver Landfill in Delta operates a yard trimming composting facility. In FVRD, several private composting facilities are in operation, that usually collect yard waste material only. Very few composting sites accept food waste.

Mission is the only municipality in the Fraser Valley that accepts food waste in their organic source separated brown bin program; however, it is not widely advertised since the receiving composting site does not want to process a high quantity of food waste in its facility.

Backyard composting is more and more popular, Metro Vancouver has distributed more that 100,000 backyard compost bins through its member municipalities since 1991 [27, 80]. These composters divert a significant quantity of household kitchen waste, grass and leaves from landfills.

2.2. *Organic waste survey results*

The BC Fraser Valley generates approximately 3.3 million tonnes per year of organic waste that is suitable for anaerobic digestion.

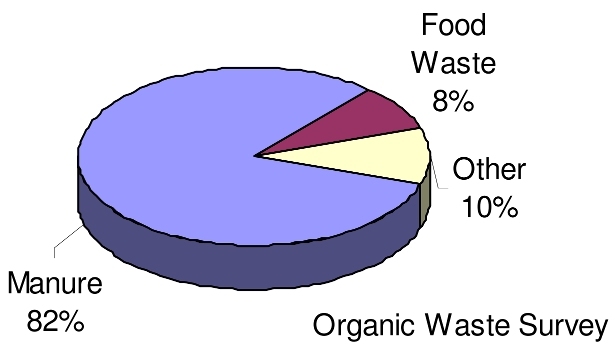

Figure 2 -Organic waste survey

The chart above illustrates that the vast majority of this waste comes from the agricultural sector, mostly from the dairy industry. Overall, the agricultural sector accounts for more than 80% of all organic waste produced in the Fraser Valley.

The chart below presents the manure breakdown by agricultural sectors.

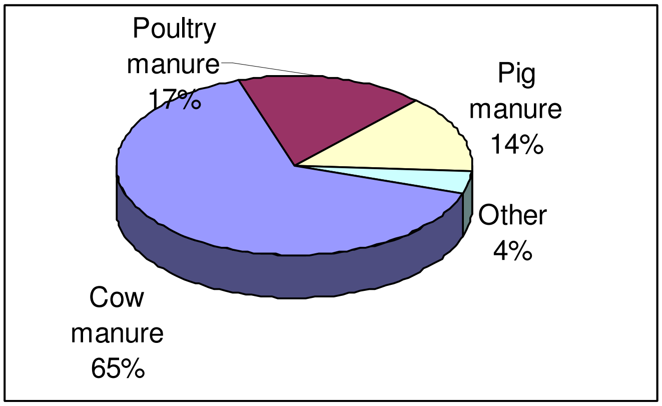

Figure 3 -Manure survey

Table 1 presents the organic waste survey result for the Fraser Valley. Details of the survey, data source and calculation method used are presented in Appendix B.

Table 1 - Organic waste survey results

Material Description	Quantity *tonnes/year*	Waste *%*	Origin	AD Potential
Manure				
Cow	1 750 008	52.5%	Farms	Excellent
Poultry	472 040	14.2%	Farms	Medium
Pig	388 718	11.7%	Farms	Good
Other	102 894	3.1%	Farms	Varies
Sub-total	*2 713 659*	81.5%		
Food Waste				
Landfill organics	216 000	6.5%	Residential and ICI*	Good
Composting facilities	25 000	0.7%	Residential and ICI	Excellent
Backyard composters	15 000	0.4%	Residential	Excellent
Fruit and Veg. Farms	23 600	0.7%	Farms	Good
Sub-total	*279 600*	8.3%		
Other				
Grass Clipping	25 000	0.7%	Residential and ICI	Good
Fat, Oil & Grease	10 300	0.3%	ICI	Excellent
Rendering Material	150 000	4.5%	ICI and Farms	Excellent
Septage	90 000	2.7%	Residential	Poor
WWTP Sludge	67 000	2.0%	Residential and ICI	None
Sub-total	342 300	10.2%		
Grand total	***3 335 559***	***100%***		

** ICI stands for industrial, commercial and institutional*

2.3. *Organic waste energy potential*

Energy potential was calculated based on tonnage results originating from the organic waste survey.

2.3.1. Total organic waste energy

The table below outlines the total biogas energy potential assuming that all organic waste produced in the Fraser Valley would be available for anaerobic digestion. An arbitrary 10% of crop land converted to energy crops (e.g. corn silage) was embedded in the calculations to demonstrate its potential.

Table 2 -Energy potential of all organic waste

Material Description	Quantity	Waste	Biogas	Energy	Energy
	tonnes/year	*%*	*m3/year*	*GJ/year*	*%*
Manure					
Cow	1,750,008	51.1%	39,200,171	846,656	21.0%
Poultry	472,040	13.8%	44,253,741	955,804	23.7%
Pig	388,718	11.3%	6,219,483	134,330	3.3%
Other	102,894	3.0%	7,717,066	166,675	4.1%
Sub-total	*2,713,659*	*79.2%*	*97,390,462*	*2,103,466*	*52.2%*
Energy Crop	247,500	7.2%	48,856,500	1,055,216	26.2%
Food Waste					
Landfill organics	216,000	6.3%	16,821,000	363,305	9.0%
Composting facilities	25,000	0.7%	1,946,875	42,049	1.1%
Backyard composters	15,000	0.4%	1,168,125	25,229	0.6%
Fruit and Veg. Farms	23,600	0.7%	1,837,850	39,694	1.0%
Sub-total	*279,600*	*8.2%*	*21,773,850*	*470,278*	*11.7%*
Other					
Grass Clipping	25,000	0.7%	2,273,963	49,114	1.2%
Fat, Oil & Grease	10,300	0.3%	5,969,880	128,939	3.2%
Rendering Material	150,000	4.4%	10,200,000	220,302	5.5%
Sub-total	*185,300*	*5.4%*	*18,443,843*	*398,355*	*9.9%*
Total	***3,426,059***	***100%***	***186,464,654***	***4,027,314***	***100%***
Sewage**			27,000,000	583,153	

Equivalent to:	122,742,176	m^3 of natural gas
	753,344	Barrels of crude oil
	58	MW electric
	53,276	BC Homes (electricity & heat)

** Assuming biogas of 60% methane and 40% conversion efficiency from methane to electricity*

*** Estimated and corrected (for fat,oil and grease diversion) biogas currently produced in Fraser Valley WWTP*

Note that almost 80% of the potential energy would come from the agricultural sector. Rendering material waste volume were estimated using slaughterhouses, meat packers and fish packing statistics as indicated in Appendix B.

2.3.2. Readily available organic waste energy

It is unlikely that current waste management practices and farm land cultivation practices would change overnight. Several assumptions were taken to derive the readily available organic waste material:

- Land dedicated to energy crop production was reduced from the arbitrary 10% to 1% to better reflect the reality of current farm practices.

- Access to non contaminated organics currently being land filled would require radical changes to the current municipal and private waste management practices. The diversion of organic waste from landfill is technically and politically difficult to implement. It is therefore not considered a readily available source of quality organic material for anaerobic digestion.

- Fish and meat processing waste are almost entirely handled by West Coast Reduction. They enjoy a monopoly over the rendering of fish and animal byproducts and they are charging processors a significant fee to pickup and use their waste. It is assumed that anaerobic digester operators could compete with West Coast Reduction to accept fish and poultry processors waste at a lower fee and capture about 15% of the current market.

- Accepting septage and wastewater treatment plant sludge at a biogas facility raises some concerns in dealing with contaminants such as heavy metal loading. It would not be recommended to accept these materials in agricultural digesters.

- Grass clippings and backyard composter materials would not be considered as readily available waste.

Based on these assumptions:

The energy potential of readily available organic material in the Fraser Valley is estimated at 30 MW electric, equivalent to 400,000 barrels of oil per year, enough energy to power over 30,000 BC homes.

The table below details the biogas energy potential of each readily available organic waste stream.

Table 3 -Energy potential of readily available organic waste

Material Description	Quantity	Waste	Biogas	Energy	Electricity*	Energy
	tonnes/year	*%*	*m3/year*	*GJ/year*	*kWh/year*	*%*
Manure						
Cow	1,750,008	62.0%	39,200,171	846,656	94,080,412	34.5%
Poultry	472,040	16.7%	44,253,741	955,804	106,208,979	38.9%
Pig	388,718	13.8%	6,219,483	134,330	14,926,760	5.5%
Other	102,894	3.6%	7,717,066	166,675	18,520,959	6.8%
Sub-total	*2,713,659*	*96.1%*	*97,390,462*	*2,103,466*	*233,737,109*	*85.7%*
Energy Crop	24,750	0.9%	4,885,650	105,522	11,725,560	4.3%
Food Waste						
Landfill organics	0	0.0%	0	0	0	0.0%
Composting facilities	25,000	0.9%	1,946,875	42,049	4,672,500	1.7%
Backyard composters	0	0.0%	0	0	0	0.0%
Fruit and Veg. Farms	23,600	0.8%	1,837,850	39,694	4,410,840	1.6%
Sub-total	*48,600*	*1.7%*	*3,784,725*	*81,744*	*9,083,340*	*3.3%*
Other						
Grass Clipping	0	0.0%	0	0	0	0.0%
Fat, Oil & Grease	10,300	0.4%	5,969,880	128,939	14,327,712	5.2%
Rendering Material	25,000	0.9%	1,700,000	36,717	4,080,000	1.5%
Sub-total	*35,300*	*1.3%*	*7,669,880*	*165,656*	*18,407,712*	*6.7%*
Grand total	***2,822,309***	***100%***	***113,730,717***	***2,456,387***	***272,953,721***	***100%***

Equivalent to:	65,395,162	m^3 of natural gas
	401,370	Barrels of crude oil
	31	MW electric
	32,494	BC Homes (electricity & heat)

** Assuming biogas with 60%methane and 40% conversion efficiency from methane to electricity*

Figure 4 shows the difference between total and readily available organic waste. Note that 100% of manure is available for anaerobic digestion because digestate can be substituted in applications that currently use raw manure.

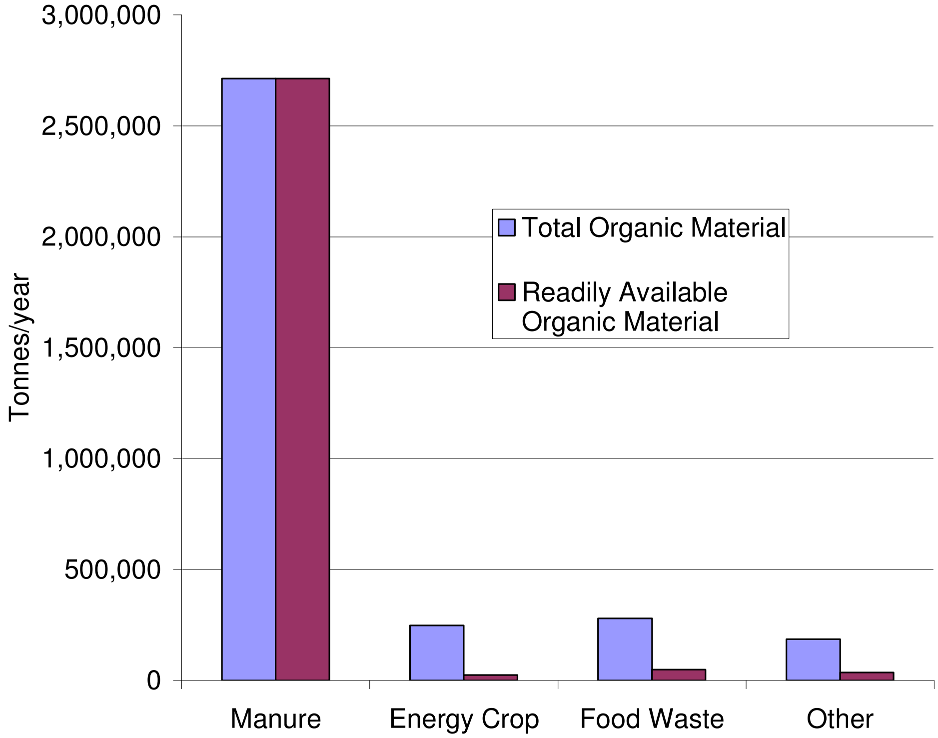

Figure 4 - Total and readily available organic material

Figure 5 presents the energy potential of total organic material compared to the available organic waste. Although the energy yield of manure is not high, it is the main source of energy since it is the most readily available substrate.

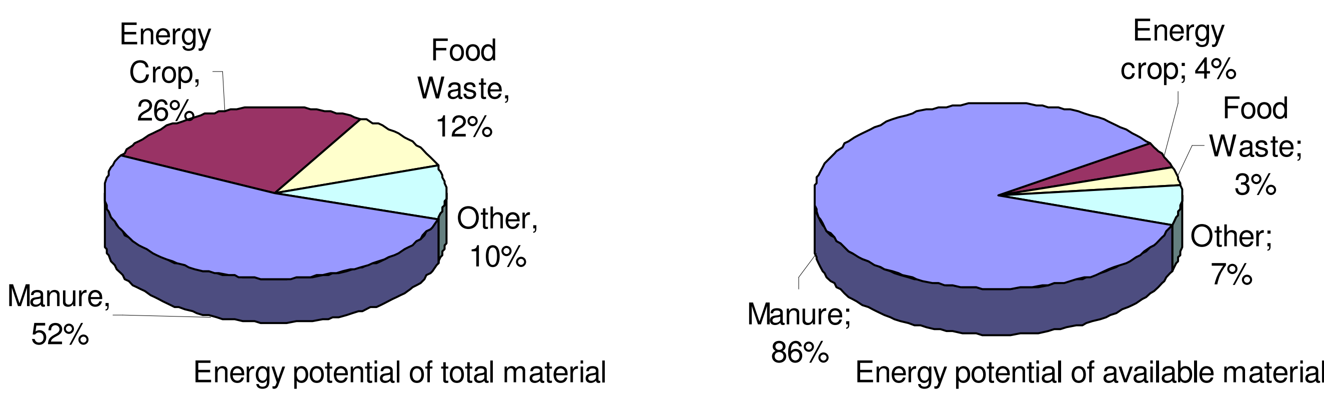

Figure 5 – Energy potential breakdown of total and readily available organic material

Figure 6 shows that waste such as food waste and energy crops, yield large quantities of biogas per tonne of material available. It also shows that manure contains less energy per volume than any other substrate.

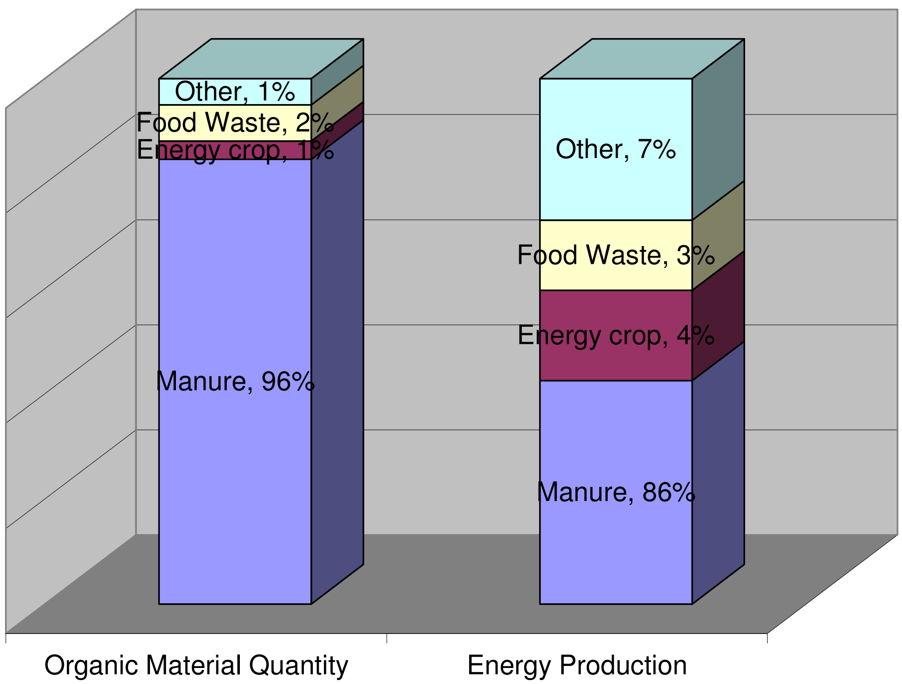

Figure 6 - Comparison of available organic material quantity and energy potential

3. Applicable Biogas Technologies

Biogas systems are composed of anaerobic digesters which convert waste into biogas and biogas conversion systems which convert biogas into useful energy forms.

The Fraser Valley waste survey demonstrated that the energy potential comes primarily from agriculture. Therefore, applicable anaerobic digesters are most likely be agricultural . The most probable scenario for the development of anaerobic digestion in BC is on-farm manure based systems accepting off-farm food processors waste, as opposed to large centralized industrial complexes.

3.1. Anaerobic digestion fundamentals

An anaerobic digester is a sealed vessel in which waste is fed, heated and mixed. In the absence of oxygen, anaerobic bacteria thrive by consuming the solid fraction of the waste and releasing methane and carbon dioxide (biogas).

Anaerobic digester efficiency is maintained by providing the right environment and right nutrients for bacterial population growth. Since bacteria cannot readily move, mixing is a very important component of digester design to ensure that bacteria get to the organic materials (feedstock). The quality and application rate of the feedstock are also very important. Figure 7 shows that different feedstocks provide different biogas yields.

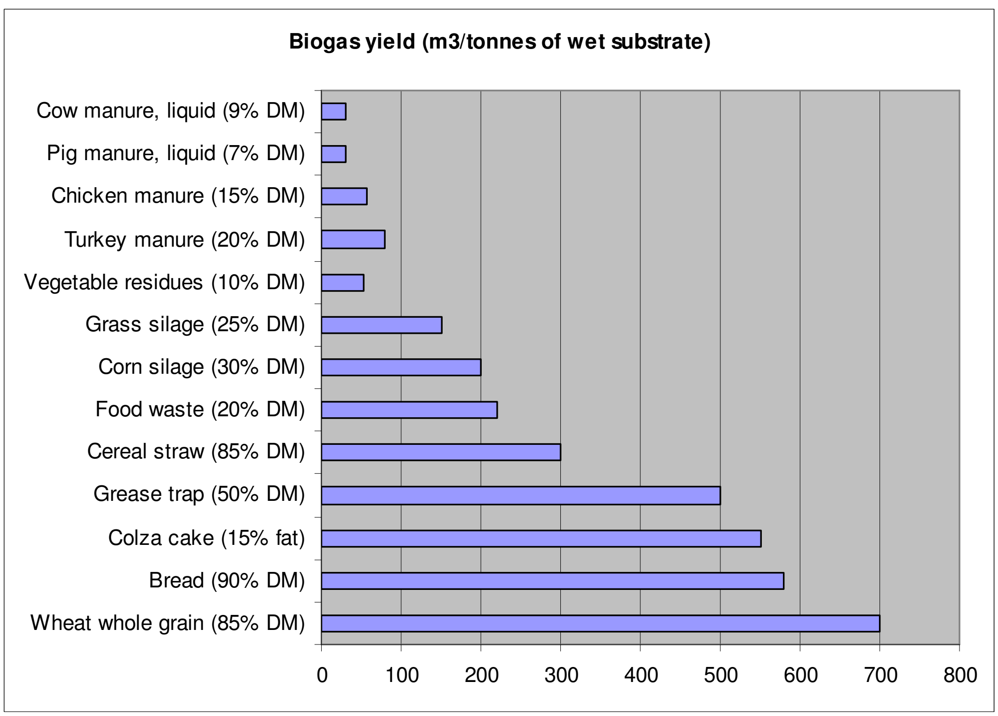

Figure 7 - Biogas yield per substrate [53]

The main challenge in digester design is bacteria washout. Better bacterial retention means smaller and faster systems with a better efficiency, because the bacteria population grows and the amount they can process in a given volume increases.

3.2. Centralized vs. Distributed biogas plants

The Fraser Valley waste survey demonstrated that the energy potential will come primarily from agriculture.

There is a potential for centralized biogas plants to be established in dense rural communities such as Chilliwack and Abbotsford.

However, trucking of manure and other substrates to and from centralized biogas plants may increase cost, social and environmental issues that would outweigh any economy of scale benefits. Manure pipelines are technical alternatives but may not be economically feasible for the distances involved[47].

Danish and German centralized biogas plants are often located near district heating plants (hot water) which can make use of the heat generated by the biogas engine throughout the year. In the Fraser Valley there are no such infrastructures. Greenhouses and other industrial processes could be considered for this application on a case by cases basis.

Since the overall potential for biogas in the Fraser Valley is relatively small (30MW) it is expected that applicable anaerobic digester technologies would likely be of agricultural type. The most probable scenario for the development of anaerobic digestion in BC would be on-farm manure-based systems accepting off-farm food processors waste as opposed to large centralized industrial complexes.

The adoption of policies promoting on-farm anaerobic digestion does not limit or hinder the development of centralized biogas plants.

3.3. Anaerobic digesters

Several anaerobic digester technologies exist. Each is designed to process specific waste streams. There are two main categories of anaerobic digesters: liquid digesters and solid digesters.

Table 4 - Anaerobic digester technologies comparison

Technology	Waste Type	Residence Time *(days)*	Energy Yield	Capital cost ($/kWe)	Operation Complexity
Liquid Digesters					
Plug flow	Thick manure	20-40	Poor	2,000-3,500	Low
Complete mix	Liquid & solid	20-80	Good	3,500-6,000	Medium
Fixed film	Liquid	1-20	Good	4,500-6,000	High
UASB	Liquid	0.5-2	Good	5,500-6,000	High
Covered Lagoon	Thin manure	20-200	Poor	2,000-3,500	Low
Solid Digesters					
Vertical	Food waste	20-40	Good	4,500-8,000	High
Horizontal	Food waste	20-40	Good	5,500-8,000	High

3.3.1. Liquid anaerobic digesters

Liquid systems are digesters in which the substrate inside the digester is adequately fluid to be pumped (less than 15% dry matter). These digesters can accept solid input, via a solid materials feeding device; bacterial breakdown of these solids ensures that the substrate inside the digester remains liquid.

Batch Systems

Liquid digesters may run in batches or continuously. Batch systems are digesters that are filled, mixed, left to digest, partially emptied and refilled. They are not emptied completely to ensure inoculation of fresh feedstock batches with bacteria from the previous batch. These systems exist, but they are not common. The Bio-Terre system in Quebec and Manitoba is an example.

Continuous Systems

Continuous systems are digesters that are fed daily and produce digested material output (digestate) on a daily basis. There are many types of continuous liquid digesters:

Plug flow

Typically horizontal, rectangular tanks that are half buried with a hard or flexible membrane cover installed to gather the biogas produced. The feedstock needs to be thick (8-12% DM) to ensure that feedstock movement maintains the plug flow effect. These digesters are generally not mechanically mixed. Feedstock enters at one end, pushing older substrate forward until it exits. Some systems will re-circulate substrate from the end of tank to inoculate the new material entering and speed up the degradation process. Substrate residence time: 20-40 days.

Complete mix

Typically vertical circular tanks with hard or flexible membrane cover that store biogas. Tanks can be designed in a vertical (top mounted mixer) or flat (side mixers) configuration. Complete mix digesters are always mechanically mixed. The fresh feedstock enters the tank and is immediately mixed with the existing, partially digested material. Substrate residence time: 20-80 days.

Fixed film

Any shape tank with bacterial support columns installed. Support columns are often lengths of plastic pipe attached to the roof of the digester. The fixed film digester is mixed by re-circulating the substrate over the bacterial supports. Bacteria fix themselves to the support and wait for the feedstock to flow by. The large mass of fixed bacteria provides a very efficient system. Substrate residence time: 1-20 days.

Upflow Anaerobic Sludge Blanket (UASB)

Typically circular tanks with hard tops but can be found as a rectangle tank. UASB are mixed by recirculation. They are not designed to accept high concentrations of suspended solids. UASB have been designed for agri-food waste water treatment. In a complete mix digester, there is no guarantee on solid residence time. In a UASB, a tri phase separator (gas, liquid, solid) ensures that solids spend a maximum amount of time in the reactor and minimizes bacteria washout. Influent is pushed through a thick sludge bed where bacteria rapidly degrade incoming solids and convert them to biogas. Substrate residence time: 0.5-2 days.

Covered lagoon

Typically a rectangular earthen lagoon covered with a flexible membrane to gather biogas. Feedstock needs to be thin (<3% DM). The covered lagoon digester may be mixed with recirculation but is generally not mechanically mixed. Feedstock enters at one end, pushing substrate out through an overflow pipe, maintaining a consistent liquid level. Substrate residence time: 20-200 days.

More details on each liquid digester configuration are presented in Appendix C.

3.3.2. Solid anaerobic digesters

Solid digesters are systems where the material inside the digester remains solid and is expelled in a solid form. Solid digesters may run in batches or continuously.

Batch Systems

Batch solid digesters function differently than liquid batch digesters. As bacteria break down the solids, the waste will produce leachate but not enough to turn the generally solid feedstock into liquid.

In a solid batch digester (garage style) material is piled into a sealed chamber, air is removed to let the solids digest anaerobically. Since the mixing of solids is difficult, leachate is collected via chamber drain and sprayed back on top of the pile to provide a "mixing" or inoculating effect. These systems are not common and will not be discussed further.

Continuous Systems

Continuous solid digesters come in two configurations:

Vertical solid digesters

A vertical cylindrical tank that is fed from the top with pre-chopped feedstock and where digested solids are removed from the bottom. Fresh feedstock material is processed into small pieces and mixed with digested material and fed to the digester using a screw system to ensure bacterial inoculation at the top of the digester. There is a vertical plug flow from the top to the bottom. A screw removes material from the bottom. Substrate residence time: 20-40 days.

Horizontal solid digesters

Horizontal tanks are fed at one end with chopped solids and digested solids are removed at the other end. This is a horizontal plug flow. The benefit of this system is that it is mechanically mixed using large paddles to ensure a good efficiency. Substrate residence time: 20-40 days.

More details on each solid digester configuration are presented in Appendix C.

3.4. *Biogas conversion technologies*

Table 5 - Applicable biogas conversion technologies

Technology	Cost	Efficiency	Complexity	Reliability
Simple combustion				
Burner	Low	High	Low	High
Boiler	Low	High	Low	High
Electrical Generator	High	Medium	Medium	High
Turbine	High	Medium	High	Medium
Fuel Cell	Very high	High	High	Low
Biogas Upgrading	Very high	High	High	Variable

3.4.1. Simple Combustion

Biogas can be burned using a modified natural gas burner to generate hot air for heating and drying applications.

Boilers are used to generate hot water or steam for industrial applications.

Any natural gas boiler or burner may be modified to burn biogas; however, the equipment must be made resistant to the sulphuric acid released by the combustion of biogas containing H_2S.

3.4.2. Electrical Generators

Internal combustion engines can be used to burn biogas and power an electrical alternator to generate electricity that can be sold on the power grid. Two types of biogas engines are available: diesel and gas. Gas engines are designed to burn a gaseous fuel instead of liquid. In a diesel biogas engine 5% of the produced energy will come from diesel oil which will be used as a pilot fuel to ignite biogas during combustion.

Biogas generators are relatively simple systems; however, efficiency of conversion from biogas energy to electrical energy is only 40% at best [39]. The rest of the biogas energy is converted to heat and noise. Heat from the exhaust and jacket can be recovered but needs to be used immediately or else it is lost to the atmosphere.

This is the most common and mature technology for the conversion of biogas. Equipment robustness and efficiency are constantly being improved.

3.4.3. Turbines

The turbine is a robust technology used for the conversion of natural gas into electricity; however, biogas, which has a lower BTU value than natural gas, is wet and corrosive and thus not an ideal fuel for the turbine.

To ensure reliable operation of biogas turbines, the gas requires considerable conditioning which is often not economically viable.

3.4.4. Fuel Cells

Molten-carbonate fuel cells (MCFCs) are high-temperature fuel cells that operate at temperatures of 600 º C and above. Molten carbonate fuel cells are not prone to carbon monoxide or carbon dioxide "poisoning", and they can use carbon oxides as a fuel, making them more attractive for fuelling with biogas.

This is still considered in the realm of research and development. Currently, fuel cells do not offer the reliability necessary to ensure economic viability of biogas projects. It will take many years before the fuel cell can surpass the internal combustion engine as a reliable biogas energy conversion technology.

3.4.5. Biogas upgrading

Biogas is typically composed of 60% methane and 40% CO_2. Natural gas as we know it is composed of 97% methane. Technologies such as pressure swing absorption and water scrubbing are used to remove CO_2 from the biogas stream, converting it to renewable natural gas (RNG). This gas can be injected into a natural gas pipeline for resale to residential and industrial consumers.

Biogas upgrading technology is becoming increasingly attractive as it does not have the heat lost and emission issues related to the internal combustion engine and electrical energy generation. Moreover, the final product is identical to natural gas and can be transported efficiently using the existing natural gas grid. Unlike natural gas, which contributes greenhouse gas emissions to the atmosphere, the combustion of upgraded biogas actually reduces greenhouse gas emissions to the atmosphere by displacing natural gas.

More details on these conversion technologies are presented in Appendix D

4. BC Energy Market

The electricity part of the energy market in BC is made up, to a large degree, by inexpensive and clean hydro electric power. BC Hydro imports in the order of 10% of its annual electricity needs from outside British Columbia, although plans are underway for BC Hydro to be electricity self-sufficient in the coming years.

The 2007 *BC Energy Plan: A Vision for Clean Energy Leadership* [15] calls for fundamental energy policy changes; however, as a policy document, it does not provide specific guidance to the implementation of these changes.

Only Quebec and Manitoba have electricity prices as low as BC's. The marginal price of electricity in North America is generally set by the cost of natural gas-fired, combined cycle generation.

In BC, there are three practical outlets for biogas developers to sell biogas energy:

- Electricity: BC Hydro electrical network
- Natural Gas: Terasen natural gas network
- Direct Biogas: Industries and Greenhouses

4.1. Electricity

Independent power producers (IPPs) can sell their power under:

- BC Hydro Net Metering Program
- BC Hydro Standing Offer Program
- BC Hydro Clean Power Call
- Direct power marketing

4.1.1. Net Metering Program

The net metering program allows BC Hydro residential and commercial customers (Appendix E) to resell electricity they generate at the same price that they are currently paying for power.

BC Hydro has established a simple process to make the interconnection of small generating units (with a capacity rating of 50 kilowatts or less) to BC Hydro's distribution system. If the amount of electricity supplied by BC Hydro is greater than the electricity generated by the customer; the customer will pay for the net electricity used at their usual rate. If the customer has generated more electricity than has been supplied by BC Hydro, their electricity charge on the bill will be zero. Any excess electricity will be carried over to the next billing period as a credit.

At the end of each year on the customer's anniversary date, BC Hydro will credit the customer for any remaining excess generation at the rate provided for in the Net Metering Rate Schedule of 5.4 cents per kilowatt-hour[7]. At BC Hydro's discretion, this credit will either be applied to the customer's future bills, or BC Hydro will make a one-time payout to the customer.

Since the program is limited to 50 kWe, it is not overly attractive to biogas projects as small projects are generally not economically viable. A 51 kW biogas generator installation would pay much more under the standing offer program.

4.1.2. Standing Offer Program

BC Hydro is in the process of developing the Standing Offer Program that would cover projects in the 50kW to 10MW size (the draft program rules are attached in Appendix F).

The program has goals to:

- Simplify the process, contract terms and conditions for small power projects in British Columbia;
- Offer competitive pricing for these projects relative to other supply sources; and
- Ensure cost-effectiveness, transparency, and fairness of the Program.

The major advantage of a SOP over a conventional call for power process is that prices are transparent and fixed. IPPs can develop their projects at any time without waiting for a call for power which tends to be a long and complex process that only large project developers can afford.

[7] Net Metering rates presented in BC Hydro website September 2007

Table 6 - Standing Offer Program Base Prices

Region of POI (point of delivery)	Base Price (2007$/MWh)	Environmental Attributes Price (if any) (2007$/MWh)	Total Price (2007$/MWh)
Vancouver Island	79.00	3.05	82.05
Lower Mainland	78.00	3.05	81.05
Kelly/Nicola	75.00	3.05	78.05
Central Interior	72.00	3.05	75.05
Peace Region	65.00	3.05	68.05
North Coast	66.00	3.05	69.05
South Interior	67.00	3.05	70.05
East Kootenay	71.00	3.05	74.05

The Standard Offer Program pricing has a base price for each region of the province to which is added an environmental attributes price, and with adjustments over time based on the consumer price index. The escalated base price is further adjusted based on the time of day (i.e. high load hours and low load hours) and month when the energy is delivered. Despite general interest, the draft program rules have been criticized for its low base prices and the fact that environmental attributes must be sold to BC Hydro at a fixed low price. SOP adjusted pricing was based on the average price paid for the 2006 call for power and is unlikely to reflect 2008 energy prices.

Moreover, the program pricing does not reflect the higher value of continuous power generation (hydro, biomass, biogas) compared to intermittent power sources (solar, wind).

For these reasons it is believed that if the program is ratified in its current form by the BC Utilities Commission (BCUC), it will generate limited interest from independent power producers (IPPs).

Several IPPs are convinced that they could capture a better price than what SOP is offering by bidding in the upcoming Clean Power Call.

Moreover, the Ontario Standard Offer Program offers $110/MWh and $145.2/MWh for peak hours. Even at this pricing level, the profitability of small biogas projects (250 kWe) is very limited since the break even cost is roughly $115/MWh. To reduce the producer's risk and ensure proper adoption of this technology, the Ontario Ministry of Agriculture instigated a subsidy program[8] that provides grants up to $400,000 for anaerobic digestion project development.

[8] www.ontario.ca/biogas

4.1.3. Clean Power Call

The 2007 Call for power was renamed the Clean Power Call.

BC Hydro is in the process of designing terms and processes for the Clean Power Call. Some of the proposed key aspects of the call are as follows:

- The call will be for "clean" energy as defined by the province in its forthcoming guidelines for clean and renewable resources, from projects using proven technologies.
- The acquisition target will be 5,000 GWh per year of firm energy through a competitive process.
- The call will accommodate larger projects with extended in-service dates.
- Draft term sheets will be issued in fall 2007 and stakeholder engagement sessions will begin shortly thereafter.
- BC Hydro plans to file an application for the call in late 2007 in support of a BCUC-sponsored negotiated settlement process (NSP).
- Issuance of the call is planned for spring 2008, subject to the regulatory review process.

In general, power calls are complex and time consuming bidding processes where IPPs compete against each other to sell power to BC Hydro.

It is unlikely that small, farm-based biogas systems (<1MW) would have the resources to under take such a process.

4.1.4. Direct power marketing

It is possible in BC for an IPPs to sell to BC transmission customers only, with stringent rules in place from the regulator regarding arbitrage etc. IPPs can sell directly to US customers, providing they arrange transmission/distribution access.

However, it is not simple to achieve, since it requires interconnection studies and agreements with BC Hydro Distribution, BC Transmission Corporation and final approval by the BC Utilities Commission. It is unlikely that small farm-based biogas systems (<1MW) would have the resources to undertake such costly process.

In practical terms it would require BC Hydro and BCUC to establish a “cowpower” tariff where customers would agree to purchase electricity at a premium price and for “cowpower” producers to be paid accordingly.

4.2. Natural Gas

The BC Utilities Commission has recently opened the gas market to allow gas companies (marketers) to market natural gas commodities directly to end customers using the Terasen gas distribution and billing system.

By upgrading biogas to natural gas grade, biogas producers have the option to sell their energy to:

- Terasen
- Energy marketers
- Direct to customers

4.2.1. Terasen

Terasen has expressed a tentative interest in acquiring upgraded biogas at a premium price under long term contracts (20 years). They are interested in acquiring and marketing renewable energy products for profit and for enhancement of their environmental image.

4.2.2. Energy Marketers

For reasons similar to Terasen, energy marketers are tentatively interested in marketing environmentally friendly products at a premium price to their end customers.

4.2.3. Direct to customers

Using the same mechanisms as energy marketers, a biogas producer could become a natural gas marketer and sell product directly to end customers.

Biogas producers could also avoid the Terasen network and sell upgraded biogas in compressed natural gas (CNG) form directly to natural gas vehicle (NGV) fleets or individual owners.

4.3. Direct Biogas

Natural gas and heating oil are used in greenhouses and industrial applications primarily to generate steam or hot water using boilers. It is also used in burners to generate hot air for heating and drying applications.

Biogas could be sold directly to greenhouses and industries looking for more economically stable and environmentally conscious energy sources. Biogas plants would, however, need to be located near its customers to avoid prohibitively expensive distribution costs (biogas pipeline).

5. Biogas Economics

It is difficult to perform economic projections on an industry such as biogas production, which is in its infancy in Canada. This section applies the best knowledge and information available from Canadian, US and European biogas industry experience to distil the essence of available biogas economics.

5.1. Capital Investment & Operational Cost

Anaerobic digesters are complex and finicky biological systems requiring careful planning and operation. Well-designed anaerobic digesters require considerable capital investment and operational costs.

5.1.1. Electricity generation

Power generation systems are the most common biogas conversion systems built around the world.

A capital cost rule of thumb of $5,000 per kWe installed was derived from real life economic analysis of over 120 biogas plants in Germany compiled by FAL [20, 21]. This capital cost assumption takes into consideration the current Canadian biogas market.

For example a 500-head milking operation importing 2,200 tonnes of glycerin (15% of manure volume) would generate approximately 4,000 MWh of electricity a year. A 500 kWe turnkey biogas plant would cost approximately $2.5 M CND to build in Canada.

Annual operation and maintenance (O&M) costs are also considerable. For a digester running on a free feedstock, the annual O&M cost would be about 15-20% of capital cost. This O&M cost includes labour, maintenance, equipment depreciation, insurance and financing cost.

Therefore, the electricity production cost (no profit) would be approximately $115 per MWhe.

Under the current standing offer program BC Hydro would pay $81.05 per MWhe, subject to adjustment as noted earlier.

5.1.2. Biogas upgrading

There exist very few examples of biogas upgrading facilities located on farms.

It is estimated that a 1,000-head dairy importing 5,000 tonnes of glycerin a year would generate about 500 m^3 biogas/hour. A biogas plant equipped with a biogas upgrading system would cost approximately $4.5 M CND and output about 2.5 million cubic meters or 95,000 GJ of natural gas per year.

Assuming that the digester is running on a free feedstock the annual O&M cost would be estimated at 20% of capital cost. This O&M cost includes labour, maintenance, equipment depreciation, insurance, gas scrubbing material and financing cost.

Therefore, the cost of each GJ produced (no profit) would be about $ 9.5 CND.

Currently in BC, natural gas energy marketers are signing customers for a 5 year contract at the rate of $9 per GJ for "fossil-based" natural gas.

5.1.3. Project depreciation and financing cost

Equipment depreciation and financing are important parameters of biogas economics.

- Civil equipment such as concrete work and tanks are depreciated on a 20-year schedule.

- General electrical and mechanical equipment such as motors, pumps and plumbing are depreciated on a 10-year schedule

- All biogas equipment such as generators, flow meters, mixers are depreciated on a 5-year schedule [20,21].

Therefore, calculations take into consideration that the equipment is constantly refinanced and that the cost for the service of the debt is more or less fixed. It could be argued that some of the initial expenses, such as engineering, will not require re-financing and that the debt service cost should go down over time. However, anaerobic digestion often relies on external feedstock (off farm waste, energy crops) and various other processes which may introduce significant fluctuation in the performance of the economic model. It is therefore wise to build into the model some contingency margins to generate a more conservative scenario.

5.2. Revenue streams

Biogas plants can generate revenue from sources other than energy sales; however, a 20-year energy contract with an energy utility is the best guarantee to secure project funding. The following is a list of potential revenue streams generated by a biogas plant.

5.2.1. Electricity

Power sales under the current BC Hydro Standing Offer Program will pay $78 per MWhe; this price does not include the value of environmental attributes.

5.2.2. Heat

Heat may be used to offset building heating costs or sold to greenhouse or industrial complexes to displace natural gas, currently selling at a retail price of roughly $9 per GJ. A potential thermal energy customer must be located close to the biogas plant as heat transportation is difficult.

Heat loads are often fluctuating daily and seasonally. Heat revenue security is often difficult to achieve.

5.2.3. Reduced manure spreading cost

The use of a covered manure storage to recover biogas will increase biogas recovery by up to 15% [63] and decrease rain water load in the manure pit, thus reducing hauling and spreading costs. Winter precipitation in the Fraser Valley can reach 1 m, thus covering manure storage could therefore result in a reduction of manure spreading costs of up to 30%.

5.2.4. Reduced fertilizer cost

The mineralization of nitrogen in the biogas plant increases the crop nutrient value of the manure, thereby reducing the need for synthetic fertilizers. There are no solid studies that prove this, but a generally accepted rule of thumb used in the European biogas industry calculates an avoided fertilizer cost of 10€ per animal unit per year.

5.2.5. Environmental attributes

Environmental attributes are essentially carbon credits which trade on various regulated and voluntary markets. Today, a tonne of carbon emissions trades for $1.90 on the voluntary

Chicago Climate Exchange, whereas the regulated Alberta carbon market has set a price of $15 per tonne.[9]

Under the BC Hydro Standing Offer Program, IPPs must sell their environmental attributes at the price of $3.05 per MWhe. Although speculative, it could be argued that these environmental attributes could have a much higher value in the future.

5.2.6. Reduced bedding cost

The solid fiber in the digestate may be extracted using a liquid/solid separator to make bedding for use on the farm. This is applicable primarily to the cattle and dairy industries. A 200-head dairy may have annual bedding costs of $30,000 of more that could be completely offset with the use of separated digestate organic material.

5.2.7. Off-farm waste gate fees

Industrial food waste may be accepted to be processed in the anaerobic digester to increase energy output and generate gate fee revenue.

This may generate considerable revenue since current disposal fees are $65/tonne at the landfill and up to $55/tonne at the rendering plant. Securing a long term contract with a waste hauling company is, however, difficult and the supply of waste must be constant and consistent throughout the year, which poses additional challenges.

Great care must be taken in contracts so that waste haulers guarantee the quality of the waste they bring on farm to avoid digester contamination.

5.3. Project Financing

Because current BC energy market conditions are unfavourable and there are perceived risks, the financing of biogas projects at reasonable rates is difficult. To finance biogas projects, long term (20 yrs) energy contracts and demonstration of feedstock security is mandatory.

5.3.1. Institutional bank funding

These projects can be debt financed but will require significant equity (cash down) or backup by securities. Farm Credit Canada has funded the development of an anaerobic digester for BayView Flowers in St-Catharines, Ontario. Terms of this transaction are confidential.

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[9] http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/cl11618

5.3.2. Government programs

Provincial

There is currently no program in BC that would provide direct support to finance the acquisition of anaerobic digestion equipment. However, the BC Energy Plan established a $25 million Innovative Clean Energy (ICE) fund aimed to support the development of clean energy technologies such as anaerobic digestion. ICE fund program criteria are currently under development.

Federal

The eco-Energy for Renewable Power program will pay an incentive of $10 per MWhe produced but is only available to projects of 1 MWe or larger. Moreover, the eco-Energy Technology Initiative will fund research, development and demonstration to support the development of the next-generation clean-energy technologies such as anaerobic digestion.

The capital cost allowance system allows for the accelerated tax depreciation of eligible capital cost for equipment that producing renewable energy from waste. Such equipment is generally eligible for Class 43.1, which provides for an accelerated deduction of 30%. However, for high-efficiency cogeneration systems the rate is 50% per year after the first year (Class 43.2, Income Tax Regulations). This results in the ability to significantly reduce cash taxes in the early years of a project [88].

Where the majority of the tangible property acquired for use in a project is included in either Class 43.1 or Class 43.2, certain start-up expenses for the project may be eligible for treatment as Canadian Renewable and Conservation Expenses (CRCE). These expenses may be deducted in the year incurred, carried forward indefinitely for use in future years, or transferred to investors under qualifying flow-through share agreements.[10]

5.3.3. Private funding

Venture capital and private equity firms are looking for return on investments of around 30%. Under current conditions, on farm anaerobic digestion is unlikely to provide this level of return. However, anaerobic digestion project with strong technical and commercial fundamentals should attract private participation in a structure where financial risk and inputs are shared with the public sector.

[10] Vol. 140, No. 23 — June 10, 2006. Regulations Amending the Income Tax Regulations (Capital Cost Allowance)

5.4. *Economic viability*

Despite its potential, it is unlikely that current BC policies and market conditions could support the development of a thriving biogas industry.

Without gate fee revenue from off-farm waste, most biogas plants will generate negative cash flow. As explained earlier, significant challenges exist currently in securing fixed price, long term waste-processing contracts.

Furthermore, without government policies or incentives establishing a resell price for electricity at $145/MWh and/or bio-methane at $12/GJ, the development of an anaerobic digestion industry in the Fraser Valley could be painstakingly slow.

5.5. *Rural Economic Development*

With the right market conditions, a farm based anaerobic digestion industry becomes a powerful rural economic development engine. The German experience demonstrates that anaerobic digestion can have a significant positive economic impact on rural communities.

Table 7 - German biogas economic figures[11]

	2005	2020
Installed power	650 MW	10 000 MW
Electricity from biogas	2.8 TWh/a	76 TWh/a
Share of total electricity production	0.8%	17%
Annual Turnover for Constructors	650 Million EUR	7 600 Million EUR
Annual Turnover for Operators	> 360 Million EUR	11 100 Million EUR
Effect on Employment	8 000	85 000
CO_2 Emission Reduction	4 Million t/a	103 Million t/a

[11] Data provided by the German Biogas Association www.biogas.org

The establishment of a successful biogas industry could enable the adoption of policies forcing diversion of organic waste from landfills which would increase the readily available material and overall biogas energy potential. Based on the German experience, it could be forecasted that the Fraser Valley rural communities would benefit from the following economic returns:

Table 8 - Fraser valley biogas economic forecast

	2015	2020	2030
Installed power (MW)	10	30	50
On-farm systems (avg. 250 kWe)	40	120	200
Electricity Generated (GWh/yr)	81	242	403
Total capital Investments ($millions)	45	135	225
Constructors annual revenue ($millions)	10	30	50
Operators annual revenue ($millions)	11	34	56
Employment	123	369	615
CO2 equivalent reduction (thousand tonnes)	62	185	308

6. Environmental Impact

Anaerobic digesters are biochemical systems that convert various waste streams into biogas and digested material (digestate).

The environmental impacts of on-farm anaerobic digestion depend on the manure management system that the digester amends or replaces, as well as the actual use of the biogas produced. Biogas conversion by flaring, combustion for electricity and/or steam production, or upgrading to bio-methane fuel can provide a number of direct environmental benefits. These include:

- Odour control
- Pathogen reduction
- Improved water quality
- Reduced GHG emissions

Potentially negative environmental impacts of anaerobic digesters that combust biogas include the generation of nitrogen oxides (NO_x) and potentially increased ammonia emissions during manure spreading.

Similarly to raw manure, disposal of digestate via land application, irrigation, composting or treatment may raise farm nutrient management and water quality concerns.

Since the bulk of readily available organic waste is of agricultural source, the study focuses on the impact of anaerobic digestion on air and water quality compared to normal agricultural activities.

This chapter does not attempt to perform quantitative environmental impact comparisons between anaerobic digester-equipped farms with current farm practices, because there are great variations in emissions from current farm practices across different farm sectors and different management practices.

6.1. *Air Quality*

Agriculture can contribute to local air quality degradation and greenhouse gases emissions by generating significant amount of odours, ammonia, nitrous oxide, methane, hydrogen sulphide and particulate matter emissions.

Properly designed anaerobic digesters should not generate significant emissions since the production of biogas is performed in sealed, gas-tight vessels. It is unlikely that biogas would escape directly to the atmosphere. This could occur only in the event of technical problems. Contingency plan equipment such as a flare would mitigate this unlikely scenario.

Typical anaerobic digestion produced raw biogas composition is:

CH_4	~60%
CO_2	~40%
NH_3	0-300 PPM
H_2S	50-5000 PPM
N_2*	1-4%
O_2*	< 1%
H_2O	Saturated 2-5% (mass)

*Only present if air is injected into the digester for H_2S reduction

The components raising air quality concerns are:

Ammonia (NH_3)

A high level of ammonia (>100 PPM) in the biogas stream indicates an unstable digestion process which is self limiting and unlikely to be an emission concern. Proper clean combustion of ammonia yields nitrogen (N_2) and water vapour.

As the ammonia concentration in biogas is low [67], there is virtually no literature assessing ammonia emissions for the incomplete combustion of biogas.

With a biogas density of 1.21 kg/m^3 and an ammonia concentration of 100 ppm, we calculate a maximum ammonia emission factor of approximately 5.3 g/GJ for biogas escaping directly into the atmosphere.

Hydrogen Sulphide (H_2S)

Controlled combustion of biogas containing hydrogen sulphide (H_2S) will result in emissions of sulphur dioxide (SO_2). Hydrogen sulphide levels vary with substrates being digested. The H_2S level in biogas may be reduced significantly by injecting air (to 5% of biogas volume) into the gas storage portion of the digester to catalyze a biochemical reduction of H_2S into elementary sulphur. A typical level of H_2S acceptable for biogas combustion equipment is approximately 200 PPM.

The anaerobic digestion process in itself should not be considered as a direct air pollutant emitter; however, the utilization of its by-products (biogas and digestate) could raise air quality concerns such as:

- Odours
- Biogas combustion emissions
- Biogas upgrading emissions
- Digestate management emissions

6.1.1. Odours

Anaerobic digestion provides cost effective odour reduction. Natural fermentation of manure results in production of ammonia, hydrogen sulphide and volatile fatty acids (VFAs) which are responsible for most of odour issues [29]. In a sealed and properly functioning anaerobic digester, VFAs are metabolized by anaerobic bacteria reducing the overall odour emission from the manure. Anaerobic digestion results in significantly lower odour emissions compared to baseline manure management practices.

According to anecdotal reports [57], many of the anaerobic digesters processing animal manure in the USA were built specifically to address odor complaints from neighbors. Although difficult to objectively measure, these odors are perceived as a serious environmental problem by residents in close proximity to farms. Fortunately, anaerobic digestion is a good method for controlling these odors, particularly if used in conjunction with a system to scrub the H_2S out of the biogas stream.

An extensive study conducted by the Danish Department of Energy (1995) [40] concluded that the digested slurry is not odour free, but odour is significantly reduced and the smell is less offensive. The decrease in odour emissions during land application, compared to raw manure, has been one of the main drivers for expansion of the Danish AD sector. The study, which compiles 10-years of experience from 13-centralized Danish AD plants, also notes that there may be an increase in odour close to the digester due to the concentration of odorous feedstock delivered to and/or stored at the central digester site.

Off-farm material may generate odour if not stored properly prior to use in the anaerobic digester. Off-farm material does not present added odour concerns if the feedstock is properly stored, and digested, and the digestate properly stored and land applied.

6.1.2. Biogas Combustion Emissions

There are three types of commonly used biogas combustion equipment:

- Flares
- Reciprocating internal combustion engines
- Boilers

Emission factors are expressed in g or mg per GigaJoule (GJ) of biogas converted. A GigaJoule (GJ) of biogas is equivalent to 44 m^3 of biogas at 60% CH_4 which is a typical yield from the digestion of 1.5 tonnes of dairy manure. Emission factors may vary greatly between biogas equipment available on the market. The numbers in this chapter are provided as general information and guideline for regulating agencies.

Flares

Assuming biogas with a negligible levels of ammonia and an H_2S level of approximately 200 PPM, proper flaring of this biogas would result in the following emission factors:

Table 9 - Emission Factors for biogas flaring

Substance	Emission Factors [12]	Units
Carbon Monoxide (CO)	2.4	g/GJ
Sulphur Dioxide (SO2)	23.3	g/GJ
Oxides of Nitrogen, expressed as NO_2 (NOx)	19.7	g/GJ
Total Particulate Matter (TPM)***	36.9	g/GJ
Particulate Matter less than or equal to 10 microns (PM10)	36.9	g/GJ
Particulate Matter less than or equal to 2.5 microns (PM2.5)	36.9	g/GJ

*** With gas-fired combustion sources most of the particulate matter is less than 2.5 microns in diameter, therefore this emission factor can be used to provide the estimates of PM10 and PM2.5 emissions.

Biogas Engines

Again assuming a biogas stream with negligible levels of ammonia and H_2S levels of approximately 200 PPM, results from years of measurements in the Danish biogas market has established average emissions from stationary biogas engines to be as follows:

[12] Biogas Flare and Sour Gas calculator, NPRI Toolbox, Env. Canada based on AP-42 US EPA Clean Air Criteria emission factors are from the US EPA's WebFIRE (version December 2005) database. http://www.ec.gc.ca/pdb/npri/documents/2004ToolBox/toolBox_e.cfm

Table 10 - Emission factors for biogas engine combustion [74]

Emission	Units	Emission Factors	Min.	Max
NO_x	g/GJ	540	119	1856
CH_4	g/GJ	323	166	770
NMVOC	g/GJ	14	7	34
CO	g/GJ	>273	109	>743.4
N_2O	g/GJ	0.5	-	-
TSP	g/GJ	2.63	-	-
PM10	mg/GJ	451	-	-
PM2,5	mg/GJ	206	-	-
SO_2	g/GJ	19	0	25

Note that all biogas engines are not created equal. Some manufacturers make great efforts to develop lean burn biogas engines to limit their emissions.

Table 11- Emission factor for various biogas engines [74]

Engine Types	Ulstein Bergen	Caterpillar	Jenbacher	MWM	MAN	Fiat Totem
Efficiency (%)	39.1	35.3	35.9	36.7	-	23.5
NO_x (g/GJ)	168	880	268	796	119	840
CO (g/GJ)	606	184	248	128	300	520

Each biogas engine manufacturer will have their own emissions factors available for their specific equipment.

The table below shows emission factors [72] of average biogas engines vis-à-vis other combustion technologies.

Table 12 - Emission factors comparison [72]

Emission	Units	Natural gas engines	Biogas engines	Gas turbines	Municipal waste incineration plants	CHP combusting straw	CHP combusting wood
NO_x	g/GJ	168	540	124	124	131	69
CH_4	g/GJ	520	323	1.5	<0.6	<0.5	<2.1
NMVOC	g/GJ	117	14	1.4	<1	<0.8	<3.4
CO	g/GJ	175	>273	6	<8	63	79
N_2O	g/GJ	1.3	0.5	2.2	<1.3	1.4	<0.8
TSP	g/GJ	0.76	2.63	0.1	<2.02	3.97	7.94
PM10	mg/GJ	189	451	61	1126	133	1944
PM2,5	mg/GJ	161	206	51	1084	102	1226
SO_2	g/GJ	x	19	x	<24	47	<1.8

Biogas Boilers

Proper combustion of sour biogas (200 PPM of H_2S) in boilers would result in the following emission factors:

Table 13 - Boiler emission factors

Substance	Emission Factors [13]	Units
Ammonia	2.2	g/GJ
CO	58.6	g/GJ
NOx	69.8	g/GJ
PM primary	5.3	g/GJ
PM10 primary	5.3	g/GJ
PM2.5 primary	5.3	g/GJ
SOx	19.2	g/GJ
TOC	7.7	g/GJ
VOC	3.8	g/GJ

[13] Natural gas combustion calculator, NPRI Toolbox, Env. Canada based on AP-42 US EPA Clean Air Criteria emission factors are from the US EPA's WebFIRE (version December 2005) database. http://www.ec.gc.ca/pdb/npri/documents/2004ToolBox/toolBox_e.cfm

6.1.3. Biogas Upgrading Emissions

There are four basic techniques for biogas upgrading (chemical scrubbing) [30] and all have very different emissions and effluents. Since a biogas upgrading facility does not actually combust any gases, it is unlikely to release any of the criteria air pollutants; however, depending on the type of biogas upgrading technologies used, the upgrading facility may release air toxins.

Table 14 - Biogas upgrading techniques [30]

Techniques for upgrading biogas	Suitable for a capacity (Nm3/h) of <500	500 - 2000	>2000	Pre/post Treatment	Methane loss	Other Comments
Gas washing Liquid absorbs CO_2	Yes	Yes	Yes	High	Low	When washing with chemical liquid
Membrane filtration Separating CO_2 using membranes	Yes	Yes	No	Medium	High	Easy to apply, quality decreases over time
PSA (Pressure swing adsorption) Active carbon adsorbs CO_2	Yes from 200 m^3	Yes	Yes	Low	Medium	Also removes some of any N_2 and O_2 that may be present
Cryogenic technique Separation of liquid CO_2	Yes	Yes	Yes	Low	Low	Liquid CO_2 suitable for recycling

This table lists techniques for CO_2 removal. Several solutions are offered for further treatment.
Suitability is based on investment and operational costs compared to profits with current technology.
Price indication: an upgrading installation for more than 200 Nm^3 of biogas per hour costs over 1 million euros.

There are virtually no readily available emission data for biogas upgrading at this time. Ammonia and H_2S have to be scrubbed prior to biogas upgrading and are most likely to end up in solution in a liquid or solid effluent. They should not present significant emission issues.

The onus will be on the technology manufacturers to demonstrate to permitting authorities the emission levels of their equipment.

6.1.4. Digestate Management Emissions

It is important to note that up to 15% [62] of biogas may be produced in the digestate storage. It is paramount that digestate storage be covered to limit direct emission to the atmosphere.

As a result of a higher pH and increased ammonium concentrations, ammonia emissions from storage and digestate spreading potentially increases compared to emissions from raw manure application. Ammonia emissions from storage of raw manure were measured at 8 % of total nitrogen content whereas gaseous ammonia losses from digested manure were measured at 21 % in the same study [71]. When the storage for the digested manure was covered by straw or a floating tarp, however, the ammonia emissions were reduced to less than 1 % of the total nitrogen content.

Ammonia emissions may be reduced considerably by covering the digestate storage and applying digested manure with proper equipment in good meteorological conditions. The emissions may be also reduced significantly if the manure is applied directly to the soil with injection equipment or similar low pressure devices [52] to avoid ammonia volatilization.

6.2. Water Quality

Authorities concerned with water quality will look at the impact that anaerobic digestion has on the following environmental parameters:

- Biological Oxygen Demand (BOD)
- Pathogens
- Nutrient leaching

As in the management of untreated manure, care must be taken to minimize the risk of contaminating surface and/or groundwater. Digested manure must be applied in a manner that will minimize the risks of nitrate leaching to groundwater and surface runoff.

6.2.1. Biological Oxygen Demand reduction

Biological oxygen demand (BOD) is a measure of the amount of oxygen used by microorganisms in the biochemical oxidation of organic matter; BOD concentrations in dairy wastewater are often 25 to 40 times greater than those in domestic wastewater.

The anaerobic digestion process is an effective way to reduce high BOD in the effluent. Anaerobic processes can remove 70% to 90% of the BOD in high-strength wastewater at a lower cost than aerated systems can, in terms of both land and energy inputs, [57, 67].

Anaerobic digesters produce biogas by degrading volatile solids available in the feedstock, therefore reducing the overall BOD of the digestate and, therefore, the potential for water quality degradation.

An Environmental Protection Agency (EPA) study of a plug flow digester in Wisconsin determined the reduction in BOD of digested slurry compared with raw dairy manure. This [67] showed a reduction of 40 % in volatile solids and 39% in BOD.

6.2.2. Pathogens reduction

Anaerobic digestion is considered an efficient process to reduce pathogens.

In an EPA evaluation of a plug flow digester in Wisconsin [67], a reduction in fecal coliform concentration of more then 99 % was determined. The same report claims a 90 % reduction in fecal streptococci concentration. Both types of bacteria were analyzed as colony-forming units (CFU) per 100 ml of manure.

A study to evaluate the required retention times for sanitation according to European Union regulations [65] concluded that the required 4 log10 reduction of fecal enterococci was achieved after 300 h at 35 ºC (mesophilic) and 1-2 h at 55 ºC (thermophilic) anaerobic digestion. Since retention time in an on-farm anaerobic digester is typically around 20 days, i.e. 480 h, it is suggested that the mesophilic process may be adequate for pathogen reduction. However, the study author cautions that fecal enterococci may not be an appropriate indicator organism at 35 ºC, given that porcine parvovirus readily survives at the 35 ºC temperature. At the higher temperature (55 ºC), however, the porcine parvovirus will only survive for 11-12 h.

6.2.3. Nutrient management

The Fraser Valley produces a large amount of high value agricultural products requiring intensive land management. Large quantities of nutrients are applied to the land, especially those associated with animal production, to the point where there are excess nutrients present relative to crop requirements [56]. The accumulation of crop nutrients may result in environmental problems such as the pollution of both surface and groundwater resources.

An anaerobic digester will have minimal effect on the total nutrient content of the digested manure; however, the chemical form of some of the nutrients will be changed. A digester decomposes organic materials, converting approximately half or more of the organic nitrogen (org-N) into ammonium nitrogen (NH_4^+-N). Some phosphorus (P) and potassium (K) are also released into solution as organic material is mineralized. A minimal amount of the P and K will settle out as sludge in during anaerobic digestion treatment.

Anaerobic digestion systems cannot solve the nutrient excess issues. Only proper nutrient management planning can limit the effect of nutrient overloading in an agricultural region.

Anaerobic digestion does not provide an end solution to the nutrient problems but enables responsible manure management practices that combined with nutrient extraction technologies could offer practical and sustainable solutions. Supporting the development of anaerobic digestion in the Fraser Valley would be a concrete first step in addressing nutrient management overloading issues and protecting water quality.

Off-farm waste

One of the concerns regarding the import of off-farm wastes is that it increases the load of nutrients on a given unit of farmland. Nitrate leaching and/or phosphorus over loading can be caused by inappropriate handling, storage and application of digestate as fertilizer and this is exacerbated if the nutrient content of the digestate has been augmented by nutrients from off-farm waste. Farmland nutrient loading is regulated in various ways across Canada to avoid water pollution intensive agricultural production.

It is important to note that off-farm waste may represent a small volumetric fraction of waste handled by the anaerobic digester but may increase a farms nutrient load significantly. The acceptance of off-farm waste material should be possible only under the scope of a comprehensive nutrient management plan supervised by an agronomist.

Land application

Currently, the most cost effective way to make use of the digestate is as an organic fertilizer. Proper application equipment, i.e. injection or low-pressure drop nozzles, should be used to minimize volatilization losses of ammonia during application.

The application of digestate should be conducted according to a nutrient management plan. The fertilizer plan must be detailed enough to recommend specific nutrient application rates for each agricultural field, based on the type of crop, normal yield levels, the anticipated percentage of nutrients in digestate, the availability of nutrients in the digestate, the type of soil (texture, structure, quality, pH), the existing reserves of macro and micro nutrients in the soil, the irrigation conditions and climatic, as well as geographic conditions. Experience in Denmark has shown that from both an environmental and an economic point of view, an optimum application of digestate as fertilizer should seek to fulfill the phosphorus requirements of the crop and to supplement with mineral fertilizer to meet nitrogen requirements, if necessary.

Liquid/Solid Separation

Using a screw-press separator, digestate may be separated into its liquid fertilizer and solid fibre components. The solid portion will typically contain 20% to 40% of the phosphorous and the liquid fraction will contain most of the nitrogen [67]. It has been demonstrated in Quebec [94], that natural settling of solids in digested pork manure will result in a 50% concentration of phosphorous in the sludge found at the bottom of static manure storage.

Employing advanced manure management technology such as separation systems provide additional tools for effective nutrient management.

Unlike raw manure, digested solids will compost easily without any major odour issues and may be used as bedding on the farm or sold as composted material for horticultural applications.

Nutrient extraction

Additional advanced technologies are available for nutrient extraction that would produce an organic nitrogen concentrate, an additional liquid stream containing the majority of mineralized phosphorus and potassium, and a relatively clean water stream. Currently, these processes are in relatively early stages of development and remain expensive alternatives to direct land application of raw digestate.

Centralized biogas plants may provide a concrete solution to nutrient overloading issues. The concentration of large volumes of waste and manure into one facility for energy extraction could provide an opportunity to perform nutrient extraction and alleviate some of the Fraser Valley nutrient overload problem.

The UBC Dairy centre, in partnership with Ostara Nutrient Recovery Technologies Inc.[14] and Envirotech International, are launching a research program at their Agassiz facility. This facility is designed to develop new technologies for on farm nutrient extraction and energy recovery from dairy and cattle manure.

6.3. Greenhouse Gas Emissions

The use of anaerobic digestion to create biogas from manure can reduce greenhouse gas (GHG) emissions in two distinct ways. First, when used in combination with a manure management system that stores manure under anaerobic conditions, it can prevent the release of methane, a potent greenhouse gas, into the atmosphere. Second, the biogas or bio-methane generated by the anaerobic digestion process can displace the use of fossil fuels that generate GHGs.

Multiple methods have been developed by IPCC [54] and the Canadian Government to measure GHG emission reductions resulting from the implementation of anaerobic digestion on farms. Animal production facilities can adopt any of a number of biogas combustion techniques, resulting in numerous GHG emission reduction scenarios. A detailed comparison between baseline and AD process effects on GHG reduction would be required for each scenario. These analyses are complex and beyond the scope of this study.

Tools do currently exist, however, that can provide general guidelines for measurement of GHG emissions and/or reductions resulting from anaerobic digestion activities. According to IEA Bioenergy, use of anaerobic digestion in livestock waste management reduces the livestock waste global warming potential by 79 %.[95]

In absence of clear policies and regulations from the Canadian federal government, values of carbon credits associated with greenhouse gas emission reductions and offsets in the Canadian market are highly speculative and difficult to forecast. Only Alberta has a regulated carbon credit market that sets a cap value of $15 per tonne of CO_2. There are also voluntary

[14] http://www.journalofcommerce.com/article/id24265

markets such as the Chicago Climate Exchange where tonnes of CO_2 currently trade at approximately $1.90 USD.

6.3.1. Carbon Dioxide (CO_2)

The Danish Gas Technology Centre [73] has stated that typical manure-based biogas system using stationary combustion technology has an emission factor of 83.6 kg/GJ based on a biogas composition of 65% (vol.) CH_4 and 35% (vol.) CO_2.

6.3.2. Methane (CH_4)

Agricultural methane is not a local air quality degradation agent but a large contributor to global greenhouse gas effects. By recovering methane and subjecting it to combustion processes, overall greenhouse gas emissions from stored organic waste can be reduced by approximately 90% [95]. Potential displacement of fossil fuels would result in additional greenhouse gas reductions as well as complimentary local air quality improvements.

In general, biogas generated from anaerobic digestion contains about 60% CH_4. It is this component, methane (which is also the main component of natural gas), that can produce energy. In addition to being an energy resource, CH_4 is also a GHG with 21 times the global warming potential, by weight, of CO_2. Globally, CH_4 constitutes 22% of anthropogenic GHG emissions in terms of carbon equivalents [58].

A Danish study [59] derived a methane emission factor for biogas engines estimated at 323 g/GJ. The emission factor for biogas engines was based on 18 emission measurements made at 13-different plants. The emission factor is lower than the factor for natural gas, mainly because most engines are lean-burn open-chamber engines, not pre-chamber engines.

6.3.3. Nitrous Oxide (N_2O)

Nitrous oxide originates from manure storage, manure spreading and synthetic fertilizer spreading. Most studies [95] on the subject conclude that anaerobic digestion does not reduce overall nitrous oxide emissions significantly.

7. Rules and Regulations

This section is designed to provide insight into the pertinent federal, provincial and municipal rules and regulations that will be of interest to any individual or organization seeking to establish a biogas generating plant in British Columbia.

It should be used as a guide to assist project developers in identifying pertinent regulations that may guide the biogas installation planning process. The document, however, should not be considered as all encompassing. Project proponents will need to conduct their own due diligence in identifying additional regulatory requirements, especially related to local municipal bylaws that may apply to biogas installations.

7.1. Federal Rules and Regulations

Building codes, based on National Building Codes, covered by the National Research Council of Canada

Building codes provide standard requirements for all buildings constructed. It is the responsibility of the biogas plant developer to ensure that all plans and construction procedures are approved and sealed by a professional engineer.

Fire codes, based on the National Building Codes, covered by the National Research Council of Canada

Fire codes will provide standard requirements for all buildings constructed. It is the responsibility of the biogas plant developer to ensure that all the proper engineering stamps are assigned to installation blueprints and where necessary, that local governance bodies (Fire Marshall's office) have completed all the lawful scans and inspections necessary.

Plumbing Codes, covered by the National Research Council of Canada

Plumbing codes will provide standard requirements for all buildings constructed. It is the responsibility of the biogas plant developer to ensure that all the proper engineering stamps are assigned to installation blueprints and the appropriate scans and inspections are completed.

Note: High pressure steam power generation may require adherence to regulations for plumbing and/or high pressure welding. Biogas plant proponents are encouraged to discuss any high pressure steam installation planning with appropriate installers and consult the NRC Building, Fire and Plumbing codes for specific details. On-farm generators will likely not use high pressure steam, however, larger industrial installations may make use of steam electricity generation technology or direct fired biogas to produce thermal energy.

> Note: National construction codes (building, fire, plumbing) can be accessed at: http://www.nationalcodes.ca/ncd_home_e.shtml

Canadian Food Inspection Agency Enhanced Feed Ban

In response to the discovery of bovine spongiform encephalopathy (BSE) infected cattle in the Canadian herd, the Canadian Food Inspection Agency has developed an enhanced feed ban to ensure that ruminant Specified Risk Materials (SRM) do not enter any part of the food, feed or fertilizer chain. Anaerobic digestion is not a CFIA approved disposal method for SRM. Detailed information on the enhanced feed ban can be accessed at the following web address.
http://www.inspection.gc.ca/english/anima/heasan/disemala/bseesb/enhren/enhrene.shtml

Government of Canada, Health of Animals Act, 1990, c.21

The federal Health of Animals act provides guidance on how to dispose of disease infected animals to ensure that they do not infect other animals or enter the human or pet food chains. The act does not specify disposal methods, but rather suggests that in the event that an animal has to be disposed of, the applicable federal Minister will dictate the proper disposal methods.

For both the CFIA Enhanced Feed Ban and the Health of Animals Act described above, the federal government provides guidance on how to treat infected animal materials. If a biogas plant were designed and built to accept infected or non-infected animal materials for treatment, the onus would fall on the project proponent to prove that any pre-treatment or that the main treatment of the animal materials would be sufficient to render the output products from the plant completely inert and free of communicable diseases.
http://laws.justice.gc.ca/en/ShowFullDoc/cs/H-3.3///en

Canadian National Energy Board

The national energy board has regulatory jurisdiction over energies that cross provincial boundary lines. If electrical energy or biogas in a natural gas pipeline network were to be exported from British Columbia, all appropriate NEB regulations would apply. The National Energy Board has jurisdiction or influence over the following acts: *National Energy Board Act*, *Canada Oil and Gas Operations Act*, *Canadian Environmental Assessment Act*, *Northern Pipeline Act*, and certain Provisions of the *Canada Petroleum Resources Act*, as a result of the *Canada Transportation Act.*

The NEB oversees the following areas of oil and gas exploration and exploitation:

- The construction and operation of interprovincial and international pipelines;

- Pipeline traffic, tolls and tariffs;
- The construction and operation of international and designated interprovincial power lines;
- The export and import of natural gas;
- The export of oil and electricity; and
- Frontier oil and gas activities.

Government of Canada, Department of Fisheries and Oceans, Fisheries Act, R.S., c. F-14,s.1.

The fisheries act prohibits the direct or indirect discharge of deleterious substances into water frequented by fish. Environment Canada maintains responsibility for enforcing subsection 36(3) of the Fisheries Act. This regulation could be of importance if biogas project proponents were to propose to treat digestate to discharge quality for discharge into local water resources, or if a digestate spill occurred at the site and entered surface water fish habitat.
http://laws.justice.gc.ca/en/F-14/index.html

Government of Canada, Agriculture and Agri-Food Canada, Fertilizers Act, R.S., 1985, c. F-10

The fertilizers act specifies the labelling and quality control standards for the production and sale of fertilizers, organic and chemical, in Canada. Biogas plants designed to accept and treat animal slaughter wastes and produce liquid or solid fertilizers for sale, will need to meet the requirements of the Fertilizers Act, specifically the handing and treatment of Specified Risk Materials (SRM).
http://laws.justice.gc.ca/en/F-10/index.html

Government of Canada, Environment Canada, Canadian Environmental Protection Act, 1999, c. 33, C-15.31

The Canadian Environmental Protection Act (CEPA) is an overarching regulation designed to protect and maintain the health of the Canadian environment as a whole. Projects who receive federal incentive funding may be required to complete a CEPA review. Biogas plant proponents are strongly encouraged to consult with a CEPA agent during the project planning phases to ensure compliance with all applicable CEPA regulations.

The National Pollutant Release Inventory (NPRI) is a component of CEPA which may be pertinent to a biogas plant depending on the size of the installation. The NPRI component of CEPA stipulates that, above a specified threshold level, emissions of a defined list of pollutants into the Canadian environment must be reported on an annual basis. These data are accessible to the Canadian public. Appendix G contains the threshold values above which an individual or company is required to report emissions to Environment Canada. It is unlikely that a biogas plant will be required to report to the NPRI; however, biogas plant operators are encouraged to maintain current knowledge of reportable substances and report emissions wherever necessary.
http://www.ec.gc.ca/CEPARegistry/the_act/

Government of Canada, Canadian Environmental Assessment Act, 1992, c. 37, C-15.2

The Canadian Environmental Assessment Act is a federal statute that requires federal departments to conduct environmental assessments for prescribed projects and activities before providing federal approval or financial support. According to the Act, an environmental assessment (EA) must be conducted "before irrevocable decisions are made". For most projects, this means the EA must be completed and a decision rendered before construction has commenced, and preferably before any construction tenders or contracts are let. Proceeding with construction of a biogas plant before an EA is completed will jeopardize federal support, if federal funding has been secured.
http://laws.justice.gc.ca/en/C-15.2/29299.html

Canadian Standards Association, Standard for Biogas Generation

A CSA Standard for Landfill Gas and Municipal Sewerage Treatment Plants has been developed and approved and a CSA Standard for Agricultural Biogas projects is currently in the very early stages of development. Biogas project proponents are encouraged to contact the Canadian Standards Association for a copy of this standard.
http://standardsactivities.csa.ca/StandardsActivities/underdevelopment.asp

7.2. *Provincial Rules and Regulations*

Environmental Management Act, B.C. Reg. 330/81 Environmental Impact Assessment Regulation

The guidance for developing an Environmental Impact Assessment for any development project in British Columbia suggests that the proponent must present, in writing, an assessment of how the project would positively or negatively affect the natural environment. The regulation offers six key areas of interest that must be included in the assessment: (a) water quality, (b) air quality, (c) land use, (d) water use, (e) aquatic ecology, and (f) terrestrial ecology. Any other potential effects of the project on the natural environment not covered by the above six areas must also be disclosed, and it is the responsibility of the project proponent to identify these potential impact areas.
http://www.qp.gov.bc.ca/statreg/stat/E/03053_03.htm

Environmental Assessment Act, [SBC 2002] Chapter 43

The Environmental Assessment Act gives power to the Environmental Assessment Office or the Lieutenant Governor in Council to request an environmental assessment (EA) of a development project, if deemed necessary. In the case of a biogas development project, the executive director of the EA office may deem it necessary to complete a full EA for the project, given the technology has not gained a significantly foothold in British Columbia to date. Beyond a special decision by the EA office, a biogas project being considered in BC would definitely require a provincial environmental impact assessment if the proposed plant is over 50MW in size.
http://www.qp.gov.bc.ca/statreg/stat/E/02043_01.htm#section8

Environmental Management Act, Health, B.C. Reg. 131/92 Agriculture Waste Control Regulation

The requirements under this legislation are summarized in the following statement taken directly from *Part 10 — Use and Storage of Agricultural Products* of the regulation, 'Agricultural products such as livestock, poultry, farmed game, fur bearing animals, animal and poultry feeds, forage silage, forage crops, vegetables and chemical fertilizers must be managed, used and stored in a manner that prevents the escape of agricultural waste that causes pollution'. This regulation will apply to biogas plant installations and any digestate produced through AD treatment will be required to be properly stored as outlined in the regulation.

The following language extracted from the regulation, concerning on-farm composting, would likely be applied to a biogas plant site as it is currently applied to composting sites:

> Agricultural waste may be composted on a farm if
>
> > (a) the agricultural waste being composted consists only of agricultural waste

(i) produced on that farm, or

(ii) produced elsewhere but being composted for use on that farm only,

The precedence for importing off-farm organic materials for on-farm processing has been set through the *Agricultural Land Reserve Use, Subdivision and Procedure Regulation* and suggests that "Class A compost can be produced on the farm, using imported materials, as long as 50% of the nutrient product produced is used on-farm." This rule is what is currently being used to refine points (i) and (ii) above.

Specific requirements that restrict or otherwise dictate manure application rates state that manure shall not be applied at rates that exceed the amount required for crop growth. It is also stated that agricultural wastes simply must not be produced, stored or used as nutrient sources in such a way as to cause pollution. The regulations also specifically state that no agricultural wastes can be directly discharged to watercourses or groundwater resources.

The *Agriculture Waste Control Regulation* will not prove to be a significant obstacle to the construction of a biogas plant as long as the farm importing organic materials is capable of handling the imported nutrient load using environmentally sustainable agronomic principles, ie. nutrients are not applied at levels that exceed crop removal. With careful planning it may be possible to construct a regional nutrient management plan that would cover a number of farms if a centralized biogas plant was being considered, that would be acceptable to pertinent regulatory bodies.
http://www.qp.gov.bc.ca/statreg/reg/E/EnvMgmt/131_92.htm

Environmental Management Act and Health Act, B.C. Reg. 18/2002 Organic Matter Recycling Regulation

This regulation does not apply to agricultural waste composting facilities which are regulated under *Agricultural Waste Control Regulation, B.C. Reg. 131/92*. The majority of biogas installations will produce a liquid fertilizer nutrient by-product for use on site and may choose to install liquid solid separation equipment to produce a compost bedding material. This act will not apply under these conditions if the compost material originated on-farm. If a commercial biogas plant were to produce a solid waste stream that would require composting, however, this act states that all food wastes, food processing wastes, manures and animal bedding can be composted into Class A Biosolids, which can be readily used as a soil amendment, so it does not appear that there are any components of this regulation that will pose specific challenges for biogas plant installations, hoping to compost rejected solids from the system. The composted material must be applied to croplands according to the rules stipulated in the schedules that accompany the regulation.

This regulation specifically states that anaerobic treatment of organic materials is acceptable for treating organic materials prior to land application.

This regulation is currently under review, and the final regulatory guidance document should be revisited as part of the biogas plant design and development process before proceeding with any project. Additional information regarding the review can be found at: http://www.env.gov.bc.ca/epdiv/ema_codes_of_practice/omrr/omrr_intentions.pdf

Environmental Management Act, B.C. Reg. 320/2004 -Waste Discharge Regulation

This act is only applicable when a discharge of materials is made to the environment. Biogas installations in BC will likely be closed-nutrient loop units which will not consider direct discharge of treated effluent a viable business proposition. This act may apply to industrial installations where conventional sewage treatment technology is used to purify the digestate liquid, for example, and will apply to any installation that is required to make a direct discharge of contaminated effluent to a BC waterway.
http://www.qp.gov.bc.ca/statreg/reg/E/EnvMgmt/320_2004.htm

Agricultural Land Commission Act, [S.B.C. 2002] Chapter 36

A precedent has been set in Delta that renewable energy generation on BC farms is not considered an agricultural activity under the *Agricultural Land Commission Act*. Given the current movement to fully engage the sector in the growing bio-economy, including renewable energy generation, it is advisable that the act be modified to include energy production as a recognized farm practice. This strategy will eliminate any potential negative taxation or permitting issues that might arise, and possibly reduce the administrative workload that a producer will have to bear to have land reclassified as non-agricultural, simply to construct a biogas plant.
http://www.alc.gov.bc.ca/legislation/Act/alca.htm#section20-3

Recommendation: Change ALCA to include bio-energy and anaerobic digestate generation on the list of normal farm practices

Agricultural Land Reserve Use, Subdivision and Procedure Regulation, B.C. Reg. 171/2002

This regulation outlines what is considered a normal farm practice in the province of British Columbia. The regulation specifically states that Class A compost can be produced on the farm, using imported materials, as long as 50% of the nutrient product produced is used on-farm.

The construction of a centralized biogas plant where more than 50% of the product being treated will need to be exported off-site, will likely be zoned as an industrial site and will be required to obtain all the necessary permits prior to construction.
http://www.qp.gov.bc.ca/statreg/reg/A/171_2002.htm

Recommendation: Change Agricultural Land Reserve Use, Subdivision and Procedure Regulation to include bio-energy and anaerobic digestate generation on the list of normal farm practices

Food Safety Act, B.C. Reg. 349/2004 - Meat Inspection Regulation

There does not appear to be any part of this regulation that will have bearing on the planning or operation of a biogas installation. The only component of this regulation that may apply states in Part 3 9, 1(f) that the operator 'ensures that the slaughter establishment or meat processing establishment is connected at all times to a waste disposal system that is constructed and operates in compliance with all enactments', the waste management facility could technically be composed partly or in whole of a biogas plant.

Safety Standards Act, B.C. Reg. 103/2004 - Gas Safety Regulation

The regulation specifically states that landfill gas operators and digester gas producing installations at municipal sewerage treatment plants are governed by this regulation. This regulation is therefore a key consideration for potential biogas plant installers and operators. All safety, inspection, record keeping and Standard Operating Procedures outlined in this regulation should be considered by biogas plant personnel and plant developers. The requirement to comply with the regulation is not likely to impose any significant obstacles to the construction and operation of a biogas plant in BC. The regulation is design to ensure safety for plant workers and surrounding residents.
http://www.qp.gov.bc.ca/statreg/reg/S/103_2004.htm

Safety Standards Act, B.C. Reg. 104/2004 - Power Engineers, Boiler, Pressure Vessel and Refrigeration Safety Regulation

This regulation outlines the level of training and certificates required for an individual to oversee the operation of a boiler system in British Columbia. This act will be of specific interest to biogas installations where thermal energy is being produced in large quantities using high pressure steam. However, the act does also encompass the production of thermal energy for greenhouse applications. In all cases where a biogas plant is being considered for construction, the act should be consulted to ascertain the level of expertise that will be required to be maintained on staff to oversee the operation of thermal energy generations equipment.
http://www.qp.gov.bc.ca/statreg/reg/S/104_2004.htm

Grid Interconnection Regulatory Requirements

BC Hydro outlines all the rules and requirements for an independent power producer to gain access to the BC power grid. These resources can be accessed at:
http://www.bchydro.com/info/ipp/ipp992.html

Specific to regulatory requirements, the above website offers guidance regarding applicable grid-interconnection regulations; however, if the generator is to generate power at less than 60kV, no specific regulations currently exist that would affect the installation of a biogas energy generator. Any pertinent regulations that do exist will be identified during a 'Interconnection Design/Impact & Facilities Study' required to be completed by any party wishing to connect to the BC Hydro Distribution System. Power generators producing power at greater than 60kV are governed by the BC Transmission Corporation. It is unlikely that a biogas plant will choose to place power on the grid at greater than 60kV.

National Gas Pipeline Interconnection Regulatory Requirements

Similar to power grid interconnection, there are no specific regulations governing connection to the natural gas (NG) distribution system. The NG distribution system is a network of small pipelines that deliver gas to end-use customers, whereas the transportation system is a much more extensive system operating at much higher pressures and moves gas from upgrading stations to substations where the flow is divided among numerous distribution lines to deliver gas to end users. If a centralized biogas plant were to generate quantities of biogas sufficient to connect to the transmission system, the project proponent would be required to comply with a much more detailed regulatory regime, including numerous National Energy Board regulations that govern the transmission of NG across provincial boundaries. Additional regulatory requirements governing the safety of NG transmissions system connections will be important considerations as the transmission system operates at 19-28 kPa (400-600 PSI) of pressure, compared to the distribution system which operates at ~3 kPa (60PSI) pressure.

The British Columbia Utilities Commission has jurisdiction over the NG pipeline system, operating under the Utilities Commission Act, and is a key source of information and assistance in establishing interconnection to the NG distribution network.

Pipeline Act, B.C. Reg. 360/98 - Pipeline Regulation

Any facility proposing to build a NG pipeline will be required to conform to the application and construction requirements outlined in the Pipeline Regulation http://www.qp.gov.bc.ca/statreg/reg/P/Pipeline/360_98.htm

Permitting Guidelines for Importation of Non-agricultural Waste to On-farm Waste to Energy Systems

There are no regulations that currently exist, describing requirements for the collection, handling and treatment of non-agricultural wastes in an on-farm biogas plant. Importation of off-farm waste likely requires amendments to regional Solid and Liquid Waste Management Plans which are under the jurisdiction of Regional Districts, in this case Metro Vancouver and FVRD.

Developing clear guidelines directing the importation of off-farm sourced materials to a biogas plant site for anaerobic processing should be considered a significant priority if a successful biogas industry is to be created in British Columbia.

Recommendation: Develop clear guidelines to allow for the importation of off-farm sources of organic materials to be treated using anaerobic digestion technology

7.3. Local Bylaws Rules and Regulations

If biogas plant installations were included on the list of normal farm practices, the Agricultural Land Commission Act would not allow local bylaws to restrict access to biogas technology. However, if the status quo is maintained and a producer would have to rezone the property on which a biogas plant was to be constructed, a series of public consultations will have to be held according to the rules set out in the *Agricultural Land Commission Act.* This administrative burden may deter some potential biogas producers from making a significant effort towards installing the technology. Outside of this overarching set of regulations, local bylaws governing odour, noise, dust, etc., will need to be fully explored by the project proponent in conjunction with the local government body responsible for bylaw accountability and enforcement.

Metro Vancouver and Fraser Valley Regional District Air Quality Regulations

The Metro Vancouver/FVRD Air Quality Management Plans are similar and specifically suggest the following actions for the agriculture sector:

The management of manure on farms can release ammonia, which may cause odours and contribute to the formation of fine particulate matter. Metro Vancouver will work with the appropriate policy-makers to identify and implement effective and harmonized strategies that will reduce ammonia and particulate matter emissions, reduce odour complaints, and improve visibility.

According to the Air Quality Management Plan, on-farm stationary combustion source emissions are regulated under a *Metro Vancouver Air Quality Bylaw*. A legal dispute is currently underway; however, regarding Metro Vancouver's right to regulate on-farm stationary combustion source emissions under its own Air Quality Bylaw. Potential biogas plant installations in the Metro Vancouver area should ensure that the results of this legal dispute are known and pollution control systems are designed accordingly.

The goals of the Air Quality Management plan fit very well with the benefits that can be achieved with the installation of a biogas plant to treat animal manure and various organic residual materials. Given that anaerobic digestion treatment of manures significantly reduces GHG emissions, odours and, depending on the plant design, ammonia emissions as well, biogas installations could become part of a larger air quality enhancement plan for Metro Vancouver and FVRD.

Biogas plant proponents should, however, be encouraged to adopt plant designs that are capable of storing digestate in a fully sealed structure to minimize post-digestion ammonia emissions. Furthermore, in the majority of cases it is likely that digestate will be used as an inert crop nutrient product. The end users of this product should also be encouraged to use currently available manure injection technology to apply the digestate to further minimize the loss of ammonia nitrogen from the digestate product.

Metro Vancouver, Air Quality Management Bylaw No. 937, 1999

This bylaw regulates air pollutants from industrial, commercial or institutional sources and encompasses the agricultural sector. Any air pollutant discharged must be exempted by permit through this bylaw, which is designed to augment and not supersede any of the provincial waste management regulations discussed previously. This bylaw will be applicable to any stationary engine or boiler installation located at a biogas plant facility. To minimize the efforts that must be expended to comply with this bylaw, any potential biogas project proponent should install the most efficient, low-emissions co-gen or boiler system possible to minimize penalties imposed by this bylaw.

FVRD, Air Quality Management Plan

The Fraser Valley Regional District has adopted an Air Quality Management Plan which seeks to form partnerships with local businesses, First Nations, and public representatives to effectively reduce emissions in the region. Anaerobic digestion should find favour in the FVRD air quality plan given that organic waste treatment and renewable energy generation will reduce the incidence of methane, nitrous oxide, and ammonia emissions from manure storages, landfills and other organic residuals treatment centers. Renewable energy production will also result in fewer particulate and toxin emissions from hydrocarbon fuel based power generating stations.

7.4. *Additional Information*

BC Environmental Farm Plan & Canada-British Columbia Environmental Farm Plan Program.

The BC Environmental Farm Plan (EFP) process, as is the case in all Canadian provinces, is designed to achieve the following:

- Encourage farmers and ranchers to be better stewards of the land;
- Ensure the future of the BC agricultural industry through the further implementation of Beneficial Management Practices;
- Foster partnerships with agencies;
- Be a proactive process to help farmers and ranchers identify environmental opportunities and risks on their own land;
- Be confidential and voluntary;
- Raise awareness of progress being made on the land;
- Improve farm profitability;
- Improve the public perception of agriculture;
- Reduce conflicts between agriculture and environmental interests; and
- Reduce wildlife impacts to agricultural lands.

The process is voluntary and non-regulatory, however the funding opportunities attached to the EFP process may prove beneficial to individuals interested in building biogas plants if used to partially or wholly pay for engineering or feasibility costs, flexible covers for biogas reactors, etc. The funding limit for each individual farmer is capped at $50,000 and is available only after an EFP has been completed and deemed acceptable by the appropriate EFP review body.

8. Case farm study

To better illustrate the reality of developing a farm-based biogas project in the BC Fraser Valley, an operational farm was selected and technical and economic feasibility analyses were performed to assess project viability.

The majority of organic waste produced in the Fraser Valley is cow manure. Fresh cow manure is considered an ideal feedstock for anaerobic digestion since it has a balanced carbon to nitrogen ratio, a good buffering capacity and is rich in anaerobic bacteria. Cow manure is also the most forgiving feedstock for anaerobic digestion.

Poultry manure is the second largest source of organic waste in the Valley but presents difficulties for anaerobic digestion. Grit settling and a high nitrogen content pose another level of complexity for stable anaerobic digestion of this feedstock.

For these reasons it was decided that the most simple, stable, reliable and representative biogas system would be a dairy farm anaerobic digester accepting off-farm waste.

8.1. Case farm selection procedures

On July 25th, 2007 a biogas workshop took place in Abbotsford and producers were requested to come forward if they were interested in participating in the case farm study. The BC Milk Producers Association also circulated a letter to its members to request expression of interest from producers that could meet minimum requirements such as farm size, three phase power, gas connection, available land, etc. A total of seven (7) dairy producers expressed interest in participating in the study.

The following selection criteria were instrumental in selecting a final case study farm:

- 200+ milking cows (average of letter of interest received)
- A commercial farm (not academic), to reflect production realities
- Proximity to an intermediate pressure gas pipeline
- Proximity to a residential area to demonstrate AD social benefits: odour reduction, heat use in public buildings
- Proximity of additional manure resources

8.2. Case farm description

The selected case farm is a dairy farm milking 250-cows, located in the municipality of Chilliwack.

Figure 8 -Case farm satellite view

The case farm includes 300-acres of grass land and is composed of two farm sites located 250-meters away from each other.

8.2.1. Eastern farm site

The eastern farm is vacant and is not being used except for the storage of manure in its rectangular concrete pit and silage in its bunkers. There are 2-houses on the eastern farm site.

Figure 9 -Case farm eastern site

The site has access to three phase power and natural gas. The site is also close to the Rosedale elementary school which is scheduled for refurbishment in the near future. The site is located near a Terasen pipeline tap station that is an interconnection between the pipeline (high pressure) and the distribution network (low pressure).

8.2.2. Western farm site

The western farm site is where all the manure resources are produced. The site is equipped with a large free stall barn, a smaller conventional barn, a 28-stall milking parlour, silage bunker storage and an earthen manure storage facility.

This site does not have access to three phase power.

Stalls in the free stall barn are bedded with sawdust. Dry cows and replacement heifers are bedded on a sawdust pack in the conventional barn.

The free stall barn is cleaned with scrapers which deposit manure into a concrete pit. When the pit is full, liquid manure is pumped to the exterior manure storage.

Figure 10 -Case farm western site

The solid pack manure is cleaned with a tractor. It represents approximately 3% of the total manure produced. Excess manure is pumped and stored in the eastern farm manure pit.

Manure is applied to cropland with a drag line injection system where manure is pumped from the manure pit directly to the tractor via a flexible rubber hose. The system has the advantage of reduced land compaction (no heavy tanker traffic), ammonia volatilization and odour emissions as manure is directly injected into cropland soils at a low pressure.

A manure pipeline is also installed to deliver manure from a neighbouring farm to the case farm fields. The drag line system is attached to this pipeline allowing for efficient application of the neighbouring farms manure resources.

Manure application is completed according to a nutrient management plan produced by an agronomist.

8.3. Feedstock & biogas energy potential

8.3.1. On-farm feedstock

According to the farm owner, the farm generates and aggregates from the neighbouring farm, approximately 18,000-tonnes of cow slurry and 330-tonnes of cow manure annually.

8.3.2. Off-farm feedstock

It is assumed that 2300-tonnes per year of high energy off-farm waste could be accepted, for a $25/tonne gate fee. This off-farm waste would represent 17% of total waste handled on the farm.

In Ontario, for example, the Ministry of Environment has limited the amount of off-farm material to 25% of the waste mass produce on farm (Appendix I)

8.3.3. Biogas Energy Potential

Table 15 - Case farm study energy potential

Feedstock description	Annual quantity	Dry matter	Biogas produced	Energy	Electricity*
	(tonnes/year)	*(%)*	*(m³/year)*	*(GJ/year)*	*(kWh/year)*
Cow slurry	11 000	7	172 480	3 415	379 456
Cow manure (w/bedding)	330	15	17 820	353	39 204
Fat, oil and grease	2 300	36	799 848	19 003	2 111 599
	13 630		990 148	22 771	2 530 259

* Assuming a 40% electrical conversion for 60% CH_4 biogas

8.4. Site Schematic and process flow chart

Figures 11 and 12 represent the process flow chart and biogas equipment layout schematic, respectively.

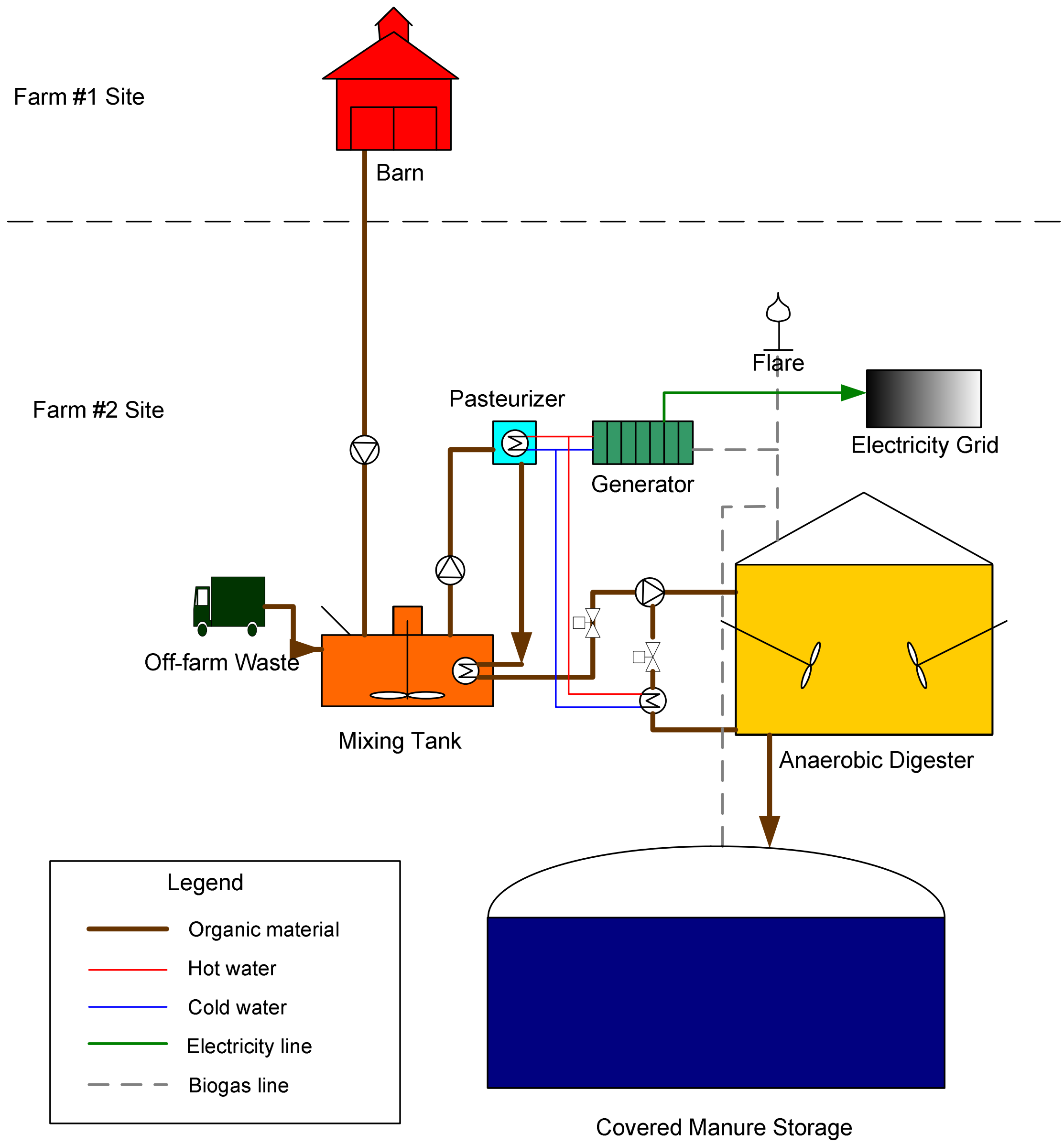

Figure 11 –Case farm process flowchart

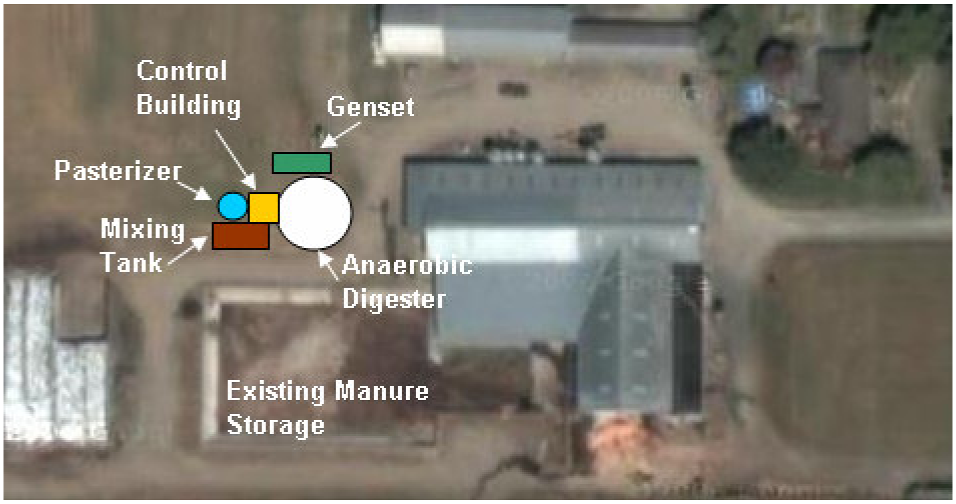

Figure 12 - Farm with scaled anaerobic digester plant

8.5. Recommended biogas plant specifications

As the biogas plant would be located on the eastern site, manure will have to be delivered to the plant by pumping regularly from the barn scraper pit into the biogas mixing pit via a pipeline or hose.

The recommended biogas system would be a single mesophilic tank (35° C) side mixed digester. A single digester coupled with covered storage would ensure simplicity and cost effectiveness of the system.

8.5.1. Mixing pit

The mixing pit would be an insulated underground roofed concrete tank with a capacity of 400 m^3 equipped with 2-top mounted mixers. The mixing pit would also be equipped with a large trap door that could be opened for accepting solid or liquid off-farm waste , but would remain closed otherwise to reduce odour emissions.

Depending on the off-farm waste being delivered, the tank may require the installation of a bio-filter to further reduce odour issues and a cutting pump to ensure substrate homogenization.

8.5.2. Anaerobic Digester

The digester would consist of a half buried 1200 m^3 concrete tank with a diameter of 16-meters and a depth of 6-meters. The tank is equipped with a central concrete pillar upon which a wooden sub-floor would rest to form the roof structure. Gapped wooden boards complete the construction of the structural roof.

A double membrane cover system would be attached to the rim of the concrete tank using a tube and groove system. The top membrane is kept inflated with a small blower. This system prevents precipitation accumulation on the digester roof. The inner membrane inflates and deflates depending on biogas production.

The tank foundation and walls would be insulated with foam boards and cladding is attached to the walls with steel brackets.

The top 1-m of the inside wall will be covered with concrete corrosion protection membrane that will be placed on the forms prior to placing concrete. Membrane anchors are installed in the concrete to keep the membrane in place once the concrete forms are removed.

The digester would be equipped with 3-side mounted mixers.

Digester heating would be performed by re-circulating manure through a tube-in-shell heat exchanger.

The digester would be equipped with negative and positive pressure safety release valves.

8.5.3. Pasteurization unit

Off-farm rules and regulations may require pasteurization of all off-farm waste [101]. Pasteurization is defined by raising the waste material temperature to 70^{o} C for one hour.

In this scenario, material would be pumped from the mixing pit into a 50-m^3 pasteurizer. After pasteurization the material would pass through a heat exchanger in the mixing pit before being fed into the digester. This would reduce the temperature of the feedstock material to avoid thermal shocking and increase temperature in the mixing pit, thus reducing the pasteurizing system heat load.

Pasteurization units increase biogas plant complexity and cost.

8.5.4. Biogas treatment

Because the base substrate is cow manure we do not expect a very high level of sulphur in the biogas produced.

H_2S removal would be performed by continuously injecting ambient air, equivalent to 5% of biogas volume produced, into the digester. Depending on off-farm feedstock included in the feedstock recipe, this should result in H_2S levels acceptable to the biogas engine operation specifications.

Water vapour in the biogas is reduced by piping the biogas line underground to provide cooling and water vapour condensation.

8.5.5. Biogas utilization equipment

This biogas plant yield is too small (100 m^3/hour) to justify a biogas upgrading unit, not to mention the administrative effort it would require selling this small amount of energy to Terasen, energy marketers or end customers.

For this reason it is recommended to focus on power production and securing gate fees for accepting off-farm waste materials.

The plant would use a 12-m containerized 250 kWe diesel generator system complete with negative and positive pressure release valves.

8.5.6. Contingency plan

The biogas plant should be equipped with a flare (150 m^3/hour) to avoid unnecessary emissions during servicing of the engine.

Since the generator is a diesel engine, there is no need for a backup boiler. The generator may be run on diesel to provide necessary heat to re-start the digester in case of a digester die out.

8.5.7. Electrical equipment

The electrical generating equipment will require being equipped with a three phase transfer trip and a step up transformer for connecting to the electrical grid.

The transfer trip will ensure that the electricity generation equipment is disconnected in the event of a power failure. This is to protect the electrical line workers.

8.5.8. Manure separator

Manure separation would be recommended and the fibre component used as bedding for the cows. This would reduce bedding and manure spreading costs and would eliminate sawdust in the manure stream, as it is a non-desirable substrate for anaerobic digestion.

8.5.9. Manure storage cover

It would be recommended to cover the manure pit with a floating cover to maximize biogas recovery and minimize ammonia emissions, odours and rainwater dilution.

8.5.10. Mechanical and control building

This building is necessary to house pumps, heat exchangers, control systems, office, etc.

8.6. Economic analysis of the project

It is very difficult to perform an accurate economic analysis for a virtually non-existent industry. Since there are no general contractors experienced in biogas plant construction in BC, the proposed project would involve a number of inexperienced contractors, augmenting the risk of running over budget. The assumptions used in this analysis take this fact into consideration and are using the best knowledge available from other projects built in Canada, US and Europe.

Table 16, 17 and 18 present only a snapshot of the operator's annual cash flow for the first 5 years of the project. See Appendix J for more details on pro-forma economic calculations and assumptions to complete the economic analysis.

8.6.1. Capital investment

Based on a rule of thumb of $5,000 per installed kWe, it is estimated that the digester system alone would cost around $1.25 million. This does not include the cost of the pasteurization unit, separation unit and manure storage cover.

It is therefore estimated that this 250 kWe biogas plant would cost approximately $1.5 million CND. Appendix K provides an equipment list and cost breakdown to corroborate this cost estimate.

8.6.2. Cashflow analysis –current energy market

Even considering significant gate fee revenues for off-farm wastes, the current price of electricity does not support the development of anaerobic digestion projects in the Fraser Valley. Note that the federal EcoEnergy incentive is available to 1MWe or greater projects.

Table 16 - Economic analysis for current energy market

	Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*
Revenue/Savings					
Electricity*	$158,911	$160,500	$162,105	$163,726	$165,363
Heat Savings	$4,000	$4,120	$4,244	$4,371	$4,502
GHG Carbon Credits	$0	$0	$0	$0	$0
EcoEnergy Incentive	$0	$0	$0	$0	$0
Manure spreading	$5,000	$5,150	$5,305	$5,464	$5,628
Bedding	$30,000	$30,900	$31,827	$32,782	$33,765
Gate fee	$46,000	$47,380	$48,801	$50,265	$51,773
Total	$243,911	$248,050	$252,281	$256,608	$261,031
* Electricity sold at	$0.081	per kWh			
Expenses					
Genset Maintenance	$29,428	$30,311	$31,220	$32,157	$33,121
Diesel/Oil	$16,000	$16,480	$16,974	$17,484	$18,008
Lab Analysis	$1,500	$1,545	$1,591	$1,639	$1,688
AD plant electricity	$4,120	$4,244	$4,371	$4,502	$4,637
Insurance	$3,748	$3,861	$3,977	$4,096	$4,219
General Maintenance	$29,986	$30,885	$31,812	$32,766	$33,749
Labour	$8,760	$9,023	$9,293	$9,572	$9,859
Debt service	$217,581	$217,581	$217,581	$217,581	$217,581
Total	$311,122	$313,929	$316,819	$319,796	$322,863
Net cash flow	-$67,212	-$65,879	-$64,538	-$63,189	-$61,832

8.6.3. Cashflow analysis –threshold energy price with gate fees

The case farm project with significant gate fee revenue scenario would be marginally profitable with a minimum energy resell price of $120 per MWhe. Note that GHG carbon credits were not accounted for since the market is still quite uncertain.

Table 17 -Economic analysis for the threshold energy price with gate fees

	Year 1	***Year 2***	***Year 3***	***Year 4***	***Year 5***
Revenue/Savings					
Electricity*	$235,423	$237,777	$240,155	$242,557	$244,982
Heat Savings	$4,000	$4,120	$4,244	$4,371	$4,502
GHG Carbon Credits	$0	$0	$0	$0	$0
EcoEnergy Incentive	$0	$0	$0	$0	$0
Manure spreading	$5,000	$5,150	$5,305	$5,464	$5,628
Bedding	$30,000	$30,900	$31,827	$32,782	$33,765
Gate fee	$46,000	$47,380	$48,801	$50,265	$51,773
Total	$320,423	$325,327	$330,332	$335,438	$340,650
* Electricity sold at	$0.120	per kWh			
Expenses					
Genset Maintenance	$29,428	$30,311	$31,220	$32,157	$33,121
Diesel/Oil	$16,000	$16,480	$16,974	$17,484	$18,008
Lab Analysis	$1,500	$1,545	$1,591	$1,639	$1,688
AD plant electricity	$4,120	$4,244	$4,371	$4,502	$4,637
Insurance	$3,748	$3,861	$3,977	$4,096	$4,219
General Maintenance	$29,986	$30,885	$31,812	$32,766	$33,749
Labour	$8,760	$9,023	$9,293	$9,572	$9,859
Debt service	$217,581	$217,581	$217,581	$217,581	$217,581
Total	$311,122	$313,929	$316,819	$319,796	$322,863
Net cash flow	$9,301	$11,399	$13,512	$15,642	$17,788

8.6.4. Cashflow analysis –threshold energy price without gate fees

To run profitable anaerobic digestion plants for energy resell alone, it would require electricity resell price of approximately $145 per MWhe. This scenario, with a long-term fixed price of energy supporting anaerobic digestion without having to rely on gate fees, would significantly reduce project risk.

Table 18 -Economic analysis for the threshold energy price without gate fees

	Year 1	***Year 2***	***Year 3***	***Year 4***	***Year 5***
Revenue/Savings					
Electricity*	$284,470	$287,314	$290,187	$293,089	$296,020
Heat Savings	$4,000	$4,120	$4,244	$4,371	$4,502
GHG Carbon Credits	$0	$0	$0	$0	$0
EcoEnergy Incentive	$0	$0	$0	$0	$0
Manure spreading	$5,000	$5,150	$5,305	$5,464	$5,628
Bedding	$30,000	$30,900	$31,827	$32,782	$33,765
Gate fee	$0	$0	$0	$0	$0
Total	$323,470	$327,484	$331,562	$335,706	$339,915
* Electricity sold at	$0.145	per kWh			
Expenses					
Genset Maintenance	$29,428	$30,311	$31,220	$32,157	$33,121
Diesel/Oil	$16,000	$16,480	$16,974	$17,484	$18,008
Lab Analysis	$1,500	$1,545	$1,591	$1,639	$1,688
AD plant electricity	$4,120	$4,244	$4,371	$4,502	$4,637
Insurance	$3,748	$3,861	$3,977	$4,096	$4,219
General Maintenance	$29,986	$30,885	$31,812	$32,766	$33,749
Labour	$8,760	$9,023	$9,293	$9,572	$9,859
Debt service	$217,581	$217,581	$217,581	$217,581	$217,581
Total	$311,122	$313,929	$316,819	$319,796	$322,863
Net cash flow	$12,347	$13,556	$14,743	$15,909	$17,052

8.7. Environmental and social impact assessment

Based on an interview with the permitting office of the Chilliwack municipality. The most important social and environmental concerns, in order of priority, were:

- Odours
- Truck traffic
- Air pollutant emissions

The benefits of anaerobic digestion in reducing air emissions were discussed earlier in this document and should not present a barrier to the realization of this project.

Assuming 20-tonnes per load of off-farm waste, this would result in approximately 2-trucks per week throughout the year and should not raise truck traffic concerns in an agricultural community.

The dumping and mixing of off-farm waste in the mixing pit could result in odour issues. To mitigate potential problems it would be recommended for the mixing pit to be as air tight as possible and equipped with a bio-filter to scrub any odours produced.

Potential zoning issues relative to the generation and resale of energy on farm land were discussed. The municipality of Chilliwack does not perceive this as a problematic issue as long as the core business remains agricultural.

According to the farm owner, the construction and operation of an anaerobic digester should not present issues with the local community. In fact, he believes the community may be interested in using the heat from the electric generator to heat the local primary school at a discount.

Furthermore, it is believed that this project would be embraced firmly by the community if it could demonstrate responsible manure management practices, odour reductions and increased profitability for the farm.

8.7.1. Estimated project emissions

Assuming that all biogas produced in this project is combusted in a specialized lean burn biogas engine, the following greenhouse gases and air pollutant emissions should be expected:

Table 19 - Biogas engine emissions

	Emission Factor (EF)	EF Units	Yearly emissions* (kg/yr)	
Air pollutants				
NOx	540	g/GJ	12,296	
SO_2	19	g/GJ	433	
NMVOC	14	g/GJ	319	
CO	273	g/GJ	6,216	
TSP	2.63	g/GJ	60	
PM10	451	mg/GJ	10	
PM2,5	206	mg/GJ	5	
Greenhouse gases				
CO_2	83.6	kg/GJ	1,904	tonnes CO_2 equiv/year
CH_4	323	g/GJ	154	tonnes CO_2 equiv/year
N_2O	0.5	g/GJ	4	tonnes CO_2 equiv/year
		Total	**2,062**	

*Assuming a biogas energy production of: 22,771 GJ

Using the IPCC Reference Manual [54], we calculated a potential greenhouse gas offset value of approximately 850 tonnes of CO2 equivalent per year for this operation of 250 milking cows..

8.7.2. Farm nutrient management

By importing high energy off farm waste material, the producer increases the nutrient load on his farm. The table below evaluates the impact of bringing off-farm waste on the farm nutrient balance.

Table 20 - Nutrient impact estimation

Manure	Mass *(tonnes/year)*	N *(kg/t)*	Annual N *(tonnes/year)*	P *(kg/t)*	Annual P *(tonnes/year)*	K *(kg/t)*	Annual K *(tonnes/year)*
Cow Slurry	11 330	2	22.66	0.5	5.67	2	22.66
Off-farm	**Mass** *(tonnes/year)*	**N** *(% dw)*	**Annual N** *(tonnes/year)*	**P** *(% dw)*	**Annual P** *(tonnes/year)*	**K** *(% dw)*	**Annual K** *(tonnes/year)*
Fat, Oil & Grease (36% DM)	2 300	0.03	2.48	0.001	0.00828	0	0

[33]

If the producer focuses on importing high energy material such as fat, oil and grease which is rich in carbon, this should minimize import of excess nitrogen. In this scenario, the increase in nutrient load would only be 10% for nitrogen and negligible for phosphorous and potassium.

8.8. Project implementation steps

The following are steps that a biogas project developer would have to follow to bring a project to successful completion.

8.8.1. Project development plan

Any serious developer should invest in the production of a planning document that encompasses a business plan to analyze the project economic viability, preliminary engineering calculations and layout and the gathering of documentation necessary for permitting. The case farm study chapter and the supporting documents attached in the appendices should be sufficient to support a project developer through permitting and financing of this project.

8.8.2. Permitting & BC Hydro SOP application

The biogas project developer needs to apply for permits with the local municipality and the Ministry of Environment.

Chilliwack required permits:

- Building permit to ensure building code is respected
- Siting permit to ensure land use rules and building setbacks are respected

Appendix L presents the City of Chilliwack building permits and inspections brochure guidelines that would apply to the construction of an AD plant.

Ministry of Environment required permit:

- Approval to bring in off-farm waste on-to the farm for processing

Regional District

- Petition to amend Solid- or Liquid Waste Management Plan

The biogas project developer should, in parallel, apply to the Standing Offer Program. BC Hydro recommends that the developer contacts the BC Hydro interconnection team to begin interconnection study procedures. This is a technical study on the impact of pushing power into the local power grid that is to be completed at the cost of the developer.

8.8.3. Energy contract

Once the interconnection study is complete and the proper permits are in place, the developer has to complete the Standing Offer review process which, if successful, will conclude with an electricity purchase agreement (EPA) with BC Hydro. See figure 13 for a flow chart of the process.

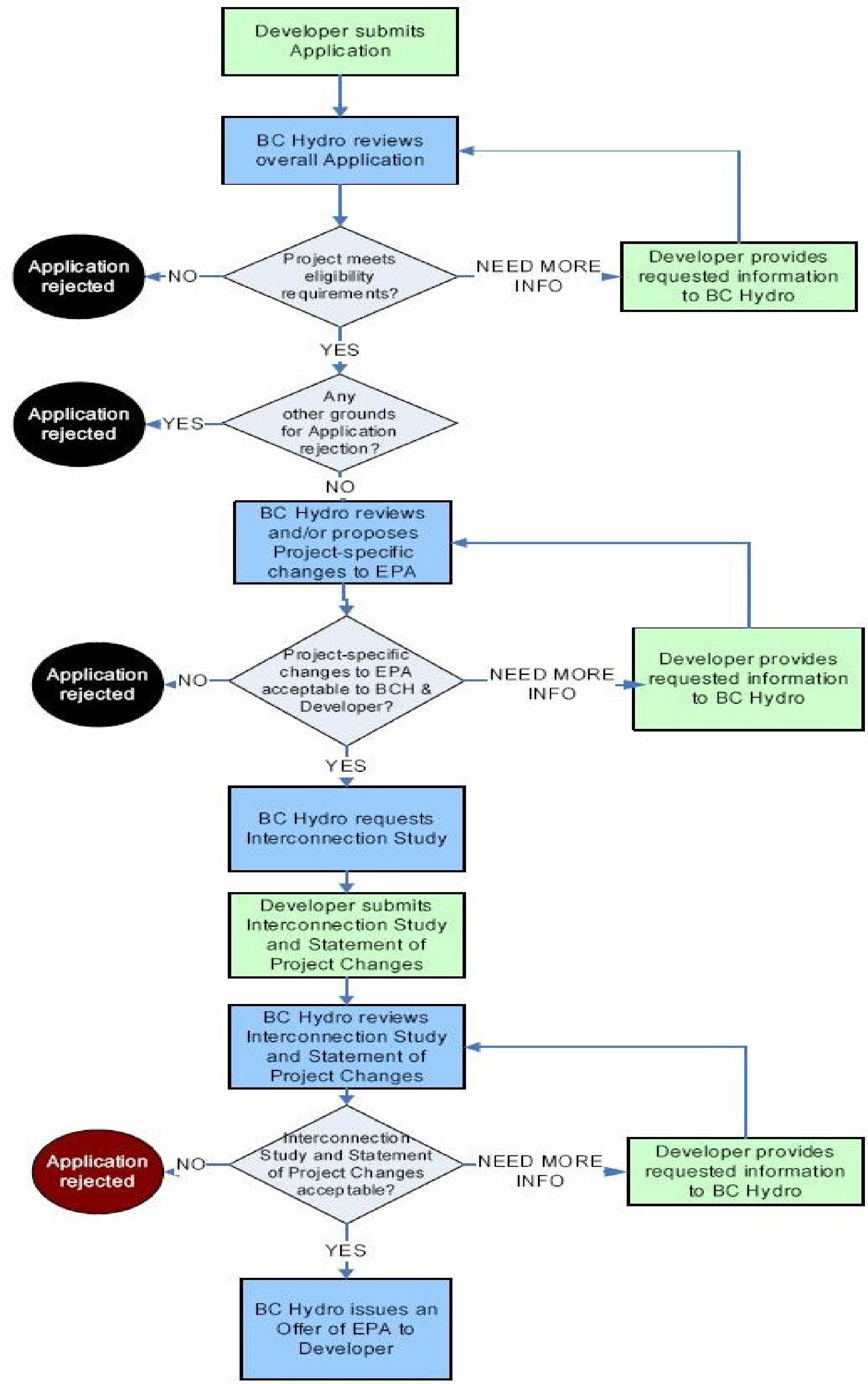

Figure 13 - Standing Offer Program application flow chart

8.8.4. Financing

With a 20 to 40-year BC Hydro EPA in hand, the developer can now negotiate financing for the project. Farm Credit Canada has expressed their interest in financing such projects.

8.8.5. Construction

With financing in place, construction can proceed. Experience has shown that permitting, energy contract negotiations and financing can take 12 to 18 months to complete. A well-planned and managed construction schedule should take approximately 3 months to complete.

8.8.6. Commissioning

Once the project is constructed, the biogas plant is started and unforeseen design or implementation mistakes are corrected. Biogas plant manufacturers guarantee certain biogas throughput for one year after which they are released from their obligations.

8.9. Potential realization barriers

As it stands, the case farm barriers are:

- Price of power sold under the Standing Offer Program
- Lack of clear regulations for importing off-farm waste
- Potential emission and nutrient management concerns from the Ministry of Environment.
- Lack of definition of on-farm biogas production as a normal farm practice

Overall, all government agencies concerned have showed interest and enthusiasm and have expressed their interest in making projects like this work.

9. Policy Recommendations

Given the above sections of this report and the comments of Steering Committee members, Electrigaz has formulated a set of policy recommendations that would enable a successful development of anaerobic digestion in BC. These may or may not reflect the opinions/positions of individual Steering Committee members.

9.1. Energy Policies

It is required that:

BC Hydro is engaged to revise its Standing Offer Program to:

- Determine a fair feed-in tariff for each renewable energy sector. The current "one-size-fits-all" feed-in tariff favours lower cost technologies such as run of the river hydro and wind power.

  Anaerobic digestion feed-in tariff recommendations:

<250 kW	$150/MWh
250 kW -500 kW	$145/MWh
>500kW	$130/MWh

- Remove the clause that forces IPPs to sell their environmental attributes to BC Hydro.

It is recommended that:

BC Utilities Commission and BC Hydro are encouraged to establish a program for electricity, similar to the gas market, which allows IPPs to sell power directly to end customers by using the BC Hydro network and billing system. This program could be limited to power generated from biomass produced in BC (pine beetle, manure, landfills, etc.)

BC Utilities Commission mandate is redefined to ensure that all energy decisions are weighted against long term environmental sustainability principles.

9.2. Environmental Policies

It is required that:

Clear rules and regulations are established for importing off-farm wastes onto farms for anaerobic digestion treatment.

It is recommended that:

The development of anaerobic digestion is recognized and supported as a near term practical solution to greenhouse gas reduction, air quality and water quality improvements.

Legislation is put forward to force diversion of organic material away from landfills over time.

Authorizations are provided for anaerobic digestion projects only if a comprehensive nutrient management plan is established by a qualified agronomist.

9.3. Agriculture and Land Use Related Policies

It is required that:

Biogas energy production is recognized as a standard farm practice and the BC Land Commission Act and the Agricultural Land Reserve Use rules and regulations be modified to reflect this reality.

It is recommended that:

A program is created to offer financial support for agricultural producers in the development of biogas projects.

9.4. Economic Development Policies

It is recommended that:

A program is developed to give access to low interest rate loans or loan guarantees to bio-energy developers.

9.5. Taxation Related Policies

It is recommended that:

Tax credits are provided to all of those who pay a premium to power their homes and businesses with BC made renewable energy products.

9.6. BC General Leadership & Governance

It is recommended that:

The BC government, Metro Vancouver and FVRD take the leadership in recognizing anaerobic digestion as a simple, proven and practical solution to renewable energy supplies and regional environmental concerns.

The BC government powers all of its government buildings and vehicles with bio-energy such as "cowpower", "moothane", ethanol and/or bio-diesel. This could be done outside the framework of the BC Utilities Commission by paying direct incentives to bio-energy producers.

The Olympic Games be powered with green, clean energy produced in BC.

10. Conclusion

The majority of organic waste produced in the Fraser Valley originates from the agricultural and food processing sectors. Almost all organic waste from residential, commercial and institutional sources ends up in landfills and sewage treatment facilities, fuelling air and water quality concerns.

Anaerobic digestion is a mature and proven technology that will thrive under the right market conditions. Anaerobic digestion is a technology that addresses odour and waste management issues, establishes a diverse supply of renewable firm power and addresses local and global environmental concerns.

Policies supporting anaerobic digestion will empower rural communities to develop a biogas industry that would create jobs, improve the agriculture industry's image and generate significant rural economic returns.

Under current provincial environment and energy policies, anaerobic digestion cannot develop to its full potential.

At a minimum, improvement of BC Hydro's standing offer program and policies allowing off-farm waste to be processed in on-farm anaerobic digesters will be required to enable a biogas industry in British Columbia.

It is in the hands of BC policy makers to enable the development of an anaerobic digestion industry in BC by paving the way through innovative policies.

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Appendices

Appendix A	Province of BC, Environmental Management Act. Ministerial Order # M176
Appendix B	Organic Waste Survey Summary Table
Appendix C	Anaerobic Digesters Technical Sheets
Appendix D	Biogas Conversion Technologies
Appendix E	Net Metering Brochure
Appendix F	BC Hydro Standard Offer Program
Appendix G	National Pollutant Release Inventory
Appendix H	German Renewable Energy Law (EEG)
Appendix I	Ontario – Optional On-farm Treatment Technologies
Appendix J	Case Farm Economic Pro-forma
Appendix K	Case Farm Study Equipment List
Appendix L	City of Chilliwack Building Permits Brochure