

8. Environmental Benefits of Anaerobic Digestion

8.1 Overview

Anaerobic digestion of organic waste generated within the City of Toronto has a number of environmental benefits including:

- Diversion of organic waste from landfill to a technology where the gas potential of the waste is realized in 3 weeks rather than 30 years or more in a landfill;
- The methane that would be produced by AD plants in Toronto will be collected and managed in an environmentally sound manner, by using it as a natural gas substitute either directly, or in the production of hot water, steam or electricity. When combusted, the methane is converted to CO₂, which is much less damaging as a greenhouse gas (methane is 21 times more powerful than CO₂ as a greenhouse gas);
- The methane produced in the digester will be used as an energy source. If it displaces oil, natural gas or coal, used for the generation of electricity, this waste management approach has significant greenhouse gas benefits;
- AD plants need smaller footprints than aerobic facilities of the same capacity, therefore they cause less displacement of land from other purposes. AD facilities with very large capacity (100,000 to 200,000 tonnes per year) can be located on a 3 ha site, therefore it is viable to locate AD plants in the Portlands area;
- Anaerobic digestion of organic municipal waste lowers the requirement for landfill capacity, and preserves existing landfill capacity for other wastes where diversion options are less viable, thereby resulting in reduced environmental displacement impacts of landfill;
- When the material is directed to an AD facility for conversion to gas, this results in a reduction in the amount of waste trucked to distant landfill, thereby reducing transportation emissions;
- Diversion of organic waste from landfill reduces the production of leachate in landfills. It also specifically lowers the generation of acidic leachate (produced in the digestion process which occurs in landfills) which increases the amount of metals in landfill leachate. All of these impacts are reduced substantially when organic waste is kept out of the landfill and directed to either AD or composting.
- The compost product produced through the anaerobic digestion of organic waste is a valuable soil amendment; when added to soil it can improve plant growth, reduce soil erosion and nutrient runoff, alleviate soil compaction, and help soil retain water. In addition, there is evidence that compost can suppress diseases and ward off pests².

² EPA (Environmental Protection Agency), May 2000: The value of Recovered Organic Materials. Solid Waste and Emergency Response 5306W. Available at: <http://www.epa.gov/region09/waste/solid/compost.pdf>

- Compost can also reduce the need for artificial fertilizers, which are derived from natural gas, result in water contamination, and deplete soil health. Further, greenhouse gases are created during their production and nitrous oxide (N₂O) is released during tillage. This harmful practice can be replaced, in part, by returning nitrogen bound in organic waste to the soil.
- The quantifiable benefits of displacing artificial fertilizer include reducing the significant CO₂ emissions associated with their manufacture, and reducing the N₂O emissions released through their use.

A further discussion of some of the more relevant environmental benefits of anaerobic digestion follows.

8.2 Waste Diversion Impacts

Anaerobic digestion can ideally be applied to any biodegradable fraction of the municipal waste stream. Counting paper, food and leaf and yard waste, the total biodegradable fraction of the Toronto waste stream is over 50%. The practicality of how much of this total is realistically divertible depends on the system chosen to collect the waste and send it to the digester, combined with the end markets available for the final product. Source-separated organics systems typically provide a much cleaner feedstock (below 10% unintentional material), and high end markets are available to absorb the finished materials. Other sources of biodegradable waste contain a higher percentage of non-biodegradable materials (up to 30% assumed in this study), and the resulting finished compost may not be as readily absorbed by high end markets. In addition, in the Toronto system, source separated leaf and yard waste from single family homes will be collected separately for open windrow composting and will not be digested. The diversion impact of the four AD plant scenarios under consideration in this study are presented in Table 8.1 below.

Table 8.1
Impact of Four Potential AD Plants on Diversion of Toronto Waste

AD Plant Scenario	Net Tonnes Diverted Per Year	Percentage of Toronto Diversion Goal Achieved By This Plant ³
100,000 tpy; 30% unintentional	76,300	5.1%
100,000 tpy; 10% unintentional	91,000	6.1%
200,000 tpy; 30% unintentional	152,600	10.2%
200,000 tpy; 10% unintentional	182,000	12.1%

³ Based on a total waste generation of 1,500,000 tonnes per year, which represents all waste managed by the City of Toronto, including residential, industrial, commercial and institutional waste, and waste from Agencies, Boards, and Commissions (ABCs).

Diverted amount = 100% – (residue quantity / total quantity to plant)%

8.3 Greenhouse Gas Impacts

AD facilities are designed to promote rapid anaerobic decomposition of solid waste; the resulting methane is used as an energy source, from which electricity (and sometimes steam or hot water) is produced. Relatively little information is available on the greenhouse gas emissions and sinks from the AD process for both source separated organics (SSO) and other wastes since relatively few AD facilities for municipal waste have been in operation for more than a few years.

There are three categories of potential GHG emissions or sinks/offsets from AD facilities:

- methane emissions,
- electricity and thermal energy production offsets, and
- soil carbon sequestration.⁴

AD facilities are designed and operated to capture methane, thus it is reasonable to assume that methane emissions are negligible. Electricity offsets (the emission impact of displacing the requirement to generate electricity) and soil carbon sequestration are described below.

The eCO₂ (equivalent carbon dioxide) emission impacts of the proposed Toronto AD plants were calculated using emission factors developed in an Environment Canada study⁵. These emission factors were combined with material mass balance flows for various scenarios, such as plant capacity, either 100,000 tonnes of material or 200,000 tonnes, and non-biodegradable material levels of 10% and 30% of the feedstock (before digestion).

Two sets of emission factors were used: with and without a “sink effect” or carbon sequestration, which is a significant factor in climate change and emission trading discussions for Canada⁶. A stock that is taking-up carbon is called a "sink" and one that is releasing carbon is call a "source." Global carbon is held in a variety of different stocks. Natural stocks include the terrestrial system, the oceans and the atmosphere. In the terrestrial system carbon is sequestered in rocks and sediments, in forests, and in soils. Non-natural stocks include long-lived wood products and landfills (with and without landfill gas recovery). Over time, carbon is transferred from one stock to another. Fossil fuel burning, for example, shifts carbon from fossil fuel deposits to the atmospheric stock.

The effect of soil carbon sequestration in the AD emission calculations was taken into account in the model used in a recent Environment Canada report⁷.

⁴ The AD process also generates CO₂ emissions from decomposition of organic inputs. The CO₂ generated in this manner is considered to be from biogenic, sustainably harvested sources and is not counted in emission inventories developed using the International Panel on Climate Change (IPCC) protocols and methods, and it is therefore not addressed in this analysis.

⁵ Environment Canada *Determination of the Impact of Waste Management Activities on Greenhouse Gas Emissions*. ICF Consulting with Torrie Smith Associates and Enviro RIS, March 30, 2001.

⁶ Because Canada has significant forest and swamp resources, which are carbon sinks

⁷ Environment Canada *Determination of the Impact of Waste Management Activities on Greenhouse Gas Emissions*. ICF Consulting with Torrie Smith Associates and Enviro RIS, March 30, 2001.

Municipal organic waste that is digested anaerobically is typically sent to aerobic composting to further stabilize the organic materials and produce a compost suitable for sale. This will also be the case for the AD facilities assessed in this study. The composted digestate will be applied to gardens and landscaping applications as a soil amendment. This will result in some carbon storage or carbon sink impacts, all of which impact net carbon emissions. The composting process and landspreading of the finished compost are included in the model used for the analysis of net greenhouse gas impacts of AD carried out for this study.

It is not known the extent to which nitrous oxide emissions resulting from the reduced need for application of artificial fertilizers are addressed in the composting calculations embedded in the Environment Canada model. Therefore, a separate calculation of the potential magnitude of this emission source is included in Appendix D. This amount is not included in the estimates presented in this chapter because of the risk of double counting.

If the proposed AD facilities generate electricity, they offset the use of other fuels or energy sources at electric generating stations. This analysis uses the standard IPCC protocol of assuming that natural gas is the marginal fuel that is offset by energy produced by AD facilities⁸.

The biogas from anaerobic digesters is generally upgraded for energy use by removing moisture and other contaminants. This gas can be used as a substitute for natural gas, either in boilers producing hot water and steam for industrial processes or to generate electricity. Options for the use of the gas at the Portlands facility are discussed in Chapter 9. Energy is needed for the anaerobic digestion process (heating, mixing, drying, etc.) and is usually supplied from the biogas product. It is estimated in this study that 22% of in-plant energy generation is required to meet in-plant needs for dry AD processes, and 37% is required for the wet processes, therefore about 63% to 78% of the energy generated by the AD facility is available for export or sale.

A model developed by Environment Canada⁹ was used to estimate GHG impacts of AD facilities of different sizes. The model does not have separate input parameters for wet and dry AD processes, therefore the “generic” AD module of the model was used. The greenhouse gas estimates are based on the tonnes of each material which actually reach the digester, rather than simply the input tonnage to the plant. The values in the Environment Canada model use relative yield data for CH₄ and CO₂ for different materials taken from Barlaz¹⁰, calibrated to actual data (reported in the literature) on the overall yield of methane at AD facilities using municipal organic waste as the feedstock.

Table 8.2 shows the estimated reduction of eCO₂ emissions in tonnes per year for both the 100,000 and 200,000 tonne anaerobic digestion plants digesting organics with ten percent unintentional materials and using emission factors that consider a “sink” effect or carbon sequestration.

⁸ Standard protocol used by both Environment Canada and IPCC in climate change analyses.

⁹ Environment Canada *Determination of the Impact of Waste Management Activities on Greenhouse Gas Emissions*. ICF Consulting with Torrie Smith Associates and Enviros RIS, March 30, 2001.

¹⁰ Barlaz, M.A. *Biodegradative Analysis of Municipal Solid Waste in Laboratory-Scale Landfills*; USEPA 600/R-97-071, 1997

Table 8.2
Tonnes Of eCO₂ Emissions for 10% Unintentional Material, Carbon Sequestration Included

PLANT INPUT	EMISSION FACTOR	PLANT CAPACITY	
		100,000T/Y	200,000 T/Y
	tonnes eCO ₂ per tonne of material to digester	eCO ₂ tonnes	eCO ₂ tonnes
Paper	(0.2632)	(2,106)	(4,211)
Food Waste	(0.1945)	(12,448)	(25,281)
Animal Waste	(0.1945)	(1,556)	(3,112)
Sanitary Waste	(0.2632)	(2,632)	(5,264)
Other	(0.2484)	0	0
TOTAL		(18,740)	(37,868)

Brackets indicate a negative number or a reduction in emissions.

Table 8.3 shows the reduction of eCO₂ emissions in tonnes for both 100,000 and 200,000 tonne anaerobic digestion plants digesting organics with thirty percent unintentional materials and using emission factors that consider a “sink” effect or carbon sequestration.

Table 8.3
Tonnes Of eCO₂ Emissions For 30% Unintentional Material, Carbon Sequestration Included

MATERIAL	EMISSION FACTOR	PLANT CAPACITY	
		100,000 t/y	200,000 t/y
	tonnes eCO ₂ per tonne of material to digester	eCO ₂ tonnes	eCO ₂ tonnes
Paper	(0.2632)	(9,740)	(19,480)
Food Waste	(0.1945)	(6,418)	(12,835)
Animal Waste	(0.1945)	(681)	(1,361)
Sanitary Waste	(0.2632)	(1,053)	(2,105)
Other	(0.2484)	(497)	(993)
TOTAL		(18,389)	(36,774)

Table 8.4 shows the reduction of eCO₂ emissions in tonnes for both 100,000 and 200,000 tonne anaerobic digestion plants digesting organics with ten percent unintentional materials and using emission factors that do not consider a “sink” effect or carbon sequestration.

Table 8.4
Tonnes Of eCO₂ Emissions For 10% Unintentional Material,
Carbon Sequestration Excluded

MATERIAL	EMISSION FACTOR	PLANT CAPACITY	
		100,000t/y	200,000 t/y
	tonnes eCO ₂ per tonne of material to digester	eCO ₂ tonnes	eCO ₂ tonnes
Paper	(0.1914)	(1,531)	(3,062)
Food Waste	(0.1945)	(12,448)	(24,896)
Animal Waste	(0.1945)	(1,556)	(3,112)
Sanitary Waste	(0.1914)	(1,914)	(3,828)
Other	(0.1716)	0	0
TOTAL		(17,449)	(34,898)

Table 8.5 shows the reduction of eCO₂ emissions in tonnes for both 100,000 and 200,000 tonne anaerobic digestion plants digesting organics with thirty percent unintentional materials and using emission factors that do not consider a “sink” effect for carbon sequestration.

Table 8.5
Tonnes Of eCO₂ Emissions For 30% Unintentional Material,
Carbon Sequestration Excluded

MATERIAL	EMISSION FACTOR	PLANT CAPACITY	
		100,000 t/y	200,000 t/y
	tonnes eCO ₂ per tonne of material to digester	eCO ₂ tonnes	eCO ₂ tonnes
Paper	(0.1914)	(7,081)	(14,164)
Food Waste	(0.1945)	(6,418)	(12,835)
Animal Waste	(0.1945)	(681)	(1,361)
Sanitary Waste	(0.1914)	(766)	(1,531)
Other	(0.1716)	(343)	(686)
TOTAL		(15,289)	(30,577)

In all cases, higher net emission reductions are achieved by considering the sink effects of the AD process. Paper waste materials play an important role when carbon sequestration is factored in. The digestion of paper products produces much more methane and CO₂ due to its high carbon content. The compost product returns carbon to the soil when used as a soil amendment.

Table 8.6 summarizes net greenhouse gas impacts of the two sizes of AD plants, with and without carbon sequestration.

The impact of carbon sequestration calculations on carbon emission credits has not been fully resolved as rules governing how carbon emission credits are estimated are still under discussion.

Table 8.6
Summary of Greenhouse Gas Impacts of AD Plants With and Without Carbon Sequestration
 (tonnes eCO₂/year)

	100,000 t/y		200,000 t/y	
	10% Residue	30% Residue	10% Residue	30% Residue
No Carbon Sequestration	17,450	15,300	34,900	30,600
Including Carbon Sequestration	18,700	18,400	37,900	36,800

8.4 Other Air Emission Impacts of Anaerobic Digestion

Sufficient information is not available on other emissions from anaerobic digestion of municipal organic waste to include these estimates in this section at this time. These data will be available when the AD module of the IWM model, which is under development at this time, is complete. This model is likely to provide specific information on emissions from anaerobic digestion of the following parameters: SO_x for acid gases, PM-10, NO_x and THC as smog precursors, heavy metals (mercury, lead and cadmium), trace organics (dioxins and furans, NMVOCs) and chlorides (HCl).

European research has identified a number of environmental benefits of anaerobic digestion related to odour generating compounds. VOCs (volatile organic compounds) are broken down in the anaerobic digester, and exhaust from the digester is combusted in a controlled environment. The VOC content of digested material after aerobic curing is about 3 g/tonne of material processed, compared to a level of 558 g/tonne processed after aerobic composting. Ammonia, which is another odour causing compound, is about 97 mg/L in material which has been digested compared to 160 mg/L in aerobically composted material.

8.5 Impacts of Reduced Transportation to Landfill

Directing material from Toronto to a digester in the Portlands area avoids the need for transportation of the waste 600 km to a landfill in Michigan. The net impact of anaerobic digestion therefore needs to take the reduction in landfill transportation into account. This is somewhat offset by the need to truck digestate from each digester to an aerobic composting facility for final curing. Table 8.7 shows the number of truck trips and distance involved, assuming that each truck carried 30 tonnes of material, that the return journey to landfill is 1,200 km, and that the return journey to the composting site is 200 km. The table shows that the

overwhelming impact is the savings in transportation of garbage to a landfill 600 km from Toronto by truck.

Table 8.7
Reduced Transportation Requirements Resulting From AD Facilities in Portlands Area

AD Facility Design	Avoided Landfill Tonnes/yr	Avoided Truck Trips @ 1200km rtn	Avoided Truck Km/yr	Tonnes Trucked to Aerobic Composting	Incurred Truck Trips at 200km rtn	Incurred Composting Trucking km/yr	Net Reduction in Truck Transport km/yr
100,000t/y; 10% unintentional	91,000	3,034	3.64 million	55,635	1,854	370,900	3.269 million
100,000t/y; 30% unintentional	66,700	2,223	2.668 million	38,486	1,282	256,600	2.411 million
200,000t/y; 10% unintentional	182,000	6,068	7.28 million	111,270	3,708	740,800	6.538 million
200,000t/y; 30% unintentional	152,600	4,446	5.336 million	76,972	2,564	513,200	4.822 million

The environmental benefit of an AD facility located in Toronto with respect to reduced trucking requirements are shown in the following four tables, one for each AD facility design. These estimates were developed using the following emission factors per km of truck travel, assuming that each truck carries 30 tonnes of material:

Greenhouse gases:¹¹

CO₂ 1.094 kg/km

Acid Gases:¹²

SO_x 0.002 kg/km

Smog Precursors:

PM-10 0.001 kg/km

NO_x 0.0045 kg/km

Trace Organics:¹³

Dioxins and furans 2.5 x 10⁻¹⁰ kg/km

NMVOC 0.002 kg/km

¹¹ Emission factors for greenhouse gases are from Jaques, 1992: *Canada's Greenhouse Gas Emissions*.

Environmental Protection and Conservation. EPS 5/AP/4. Environment Canada. Ottawa Ontario

¹² Emission factors for acid gases, smog precursors (except for NO_x) and NMVOC are from U.S. EPA, 1997.

Application of Life Cycle Management to Evaluate Integrated Solid Waste Management Strategies. National Risk Management Research Laboratory, Air Pollution Prevention and Control Division. NO_x emission factor from EPA AP-42 pending Vol.II App H

¹³ Emission factors for dioxins and furans are from American Petroleum Institute and Engine Manufacturers Association, 1996: *A Study to Quantify On-Road Emissions of Dioxins and Furans* Prepared by the Energy and Environmental Dept., Desert Research Institute, Reno Nevada

Estimates shown in Table 8.8 were developed assuming each truck carries 30 tonnes of material.

Table 8.8
Avoided Transportation Emissions For Different Scenarios

Plant Capacity		100,000t/y	100,000t/y	200,000t/y	200,000t/y
Unintentional Material		10%	30%	10%	30%
Truck Km Avoided		3,269,000	2,411,000	6,538,000	4,822,000
	Emission Factor (kg/km)	Emission Reduction (tonnes)	Emission Reduction (tonnes)	Emission Reduction (tonnes)	Emission Reduction (tonnes)
Greenhouse Gases					
CO ₂	1.094	3576	2637	7152	5275
Acid Gases					
SO ₂	0.002	7	5	13	10
Smog Precursors					
PM-10	0.001	3	2	6	5
NO _x	0.0045	14	11	29	22
Trace Organics					
NM VOC	0.002	7	5	13	10

Avoided dioxin and furan emissions are estimated at 817 milligrams and 1634 milligrams for the 100,000 and 200,000 tonne plants with 10% residue, and 602 and 1204 milligrams for the 100,000 and 200,000 tonne plants with 30% residue, respectively.

The City of Toronto's estimated municipal eCO₂ emissions for 1990 and 1998 are shown in Table 8.9 below.

Table 8.9
City of Toronto eCO₂ emissions, 1990 and 1998¹⁴

Source	eCO ₂ emissions 1990 (tonnes per year)	eCO ₂ emissions 1998 (tonnes per year)
Street Lighting	53,144	39,286
Fleets	82,906	58,173
Water/Sewage	212,725	186,464
Buildings	309,168	343,420
Waste	1,660,000	140,000
Total	2,317,943	767,343

It should be noted that the City has exceeded the original goal of 20% reduction in GHG emissions if waste related activities are included. The substantial reduction in waste related emissions is as a result of installation of landfill gas recovery facilities at City sites. However, in most of the planning carried out by the city, waste related activities are often separated from other activities in order to evaluate the impacts of waste and non-waste related activities separately.

Table 8.10 summarizes all GHG emission impacts of the four AD plants evaluated in this study. It is not possible to compare these to a specific goal, as the City has not set a specific goal measured as tonnes of CO₂ emissions to be avoided. However, the table illustrates that the AD plants would reduce all GHG emissions from waste activities by 13% to 30% from 1998 levels, depending on the scenario chosen.

The greenhouse gas emission reductions from a Portlands AD plant including plant processing, transport and carbon sequestration are presented in Table 8.10 below.

Table 8.10
Summary of Greenhouse Gas Impacts of AD Plants Including Transport and Carbon Sequestration (tonnes eCO₂/year)

100,000 t/y		200,000 t/y	
10% Residue	30% Residue	10% Residue	30% Residue
21,050	17,950	42,050	35,900

8.6 Wastewater Discharge Impacts

Table 8.11 shows the effluent quality estimated for the Dufferin anaerobic digestion pilot plant, which is assumed to be typical of an AD process. Although of high strength, the wastewater

¹⁴ *Moving Beyond Kyoto: Toronto's Emission Reductions 1990-1998 and the Future Outlook* prepared for Toronto Atmospheric Fund by Enviro RIS and Torrie Smith Associates; February, 2002

produced by AD plants can be treated on-site to Toronto sewer use by-law limit requirements by technologies which are currently available.

Table 8.11
Typical Anaerobic Digestion Facility Effluent Characteristics

PARAMETER	UNIT	MIN.	MAX.	AVERAGE	BY-LAW LIMIT
Total Solids	mg/L	7,500	10,500	9,000	
Suspended Solids	mg/L	1,000	2,000	1,500	350
Total COD	mg/L	3,000	7,000	5,000	
Soluble COD	mg/L	1,500	4,000	2,500	
BOD ₅	mg/L	500	1,500	1,000	300
Ammonium	mg/L	400	1,600	600	100 (TKN)
Nitrate	mg/L	0	0	0	100 (TKN)
Total phosphorus	mg/L	40	300	10	1.0
Soluble phosphorus	mg/L	14		14	
Phosphate-phosphorus	mg/L	13		13	
Chloride	mg/L	600	2,000	1300	
Sulphate	mg/L	<1	3	<1	
Sulphide	mg/L		2	2	
Aluminum	mg/L		0.25	0.25	50
pH		6.5	8.0	7.8	
Conductivity	mS/cm	5.5	17	11.25	

Table 8.12 shows the amount of wastewater generated in cubic meters per day and tonnes per year for different anaerobic digestion scenarios.

Table 8.12
Amount Of Wastewater Discharged By AD Facilities

100,000 tonne Dry Plant, 10% Unintentional Material	200,000 tonne Dry Plant, 10% Unintentional Material	100,000 tonne Wet Plant, 30% Unintentional Material	200,000 tonne Wet Plant, 30% Unintentional Material
91,000 tonnes to digester	182,000 tonnes to digester	66,700 tonnes to digester	132,400 tonnes to digester
105 m ³ /day wastewater	210 m ³ /day wastewater	67 m ³ /day wastewater	134 m ³ /day wastewater

The totals are a relatively modest amount, compared to over 800,000 cubic metres per day treated at the Toronto Ashbridges Bay plant, where the wastewater would be treated.

8.7 Energy Displacement Impacts

Anaerobic digestion is a net energy-producing process. The plant electrical and heat requirement (“parasitic load”) is about 22% of the energy produced for dry processes, with 78% available for export as either a natural gas substitute or as other forms (discussed below). In the case of wet anaerobic processes, the parasitic load is about 37% of plant production, with 63% of plant energy production available for export. The higher plant energy requirement for the wet process is related to the need to heat large amounts of water in the digesters.

Estimating the potential value of surplus energy is dependent on a wide range of variables. Actual data from existing operating plants is required to confirm values, and will be available from the Dufferin facility over time. Factors that influence energy production include:

- **Feedstock selection:** SSO contains a higher proportion of easily digested organic waste, but mixed waste contains more paper, which depending on its quality is also a digestible source of gas (e.g. fine papers are readily digestible and high gas producers¹⁵);
- **Plant operation:** High rates of annual biogas production will depend on the efficient operation of the digestion reactor.
- **Local market conditions:** Access to potential buyers and a distribution system as well as local prices for methane gas, steam and electricity will also affect the revenue potential for any AD plant considered. In this case, the site in the Portlands has Boralex as a potential customer, or possibly the Ashbridges Bay Treatment Plant or the OPG Hearn plant. Another possibility is onsite co-generation of electricity and heat for sale to the electric grid and local district heating.

Generally, there are four options for using excess energy from AD plants:

- **clean** the biogas to extract the methane gas, which can then be exported off-site and sold as a substitute for natural gas;
- **burn** the methane gas in an internal combustion engine to produce electricity for sale off-site while collecting heat from the engine’s exhaust and cooling system to produce steam or hot water;
- **burn** the methane gas in a boiler to produce steam for use onsite and sale off-site, or
- **convert** methane gas into compressed natural gas (CNG) for use as a fuel source for light and heavy-duty vehicles. Vehicles powered by CNG, such as municipal buses, offer a number of

¹⁵ Barlaz, M.A. *Biodegradative Analysis of Municipal Solid Waste in Laboratory-Scale Landfills*; USEPA 600/R-97-071, 1997

positive environmental benefits including reduced noise levels and cleaner emissions compared to diesel-powered vehicles. Operators of CNG-powered vehicles have reported that vehicle maintenance costs are 40-50% lower than diesel fuel¹⁶.

In all cases, methane from the digester replaces the need for power from other sources. Section 8.3 discusses the net greenhouse gas benefits of displacing energy sources from a typical Canadian mix. Other benefits include the reduced demand for new power generating facilities and the displacement of environmental impacts associated with their construction.

¹⁶ *Energy Efficiency in Ontario – Framework for Government of Ontario’s Submission to VCR Inc and a Continuous Improvement Strategy*; Report to Ontario Ministry of Environment and Energy, Enviro RIS in association with Woodrising Consulting Inc, Lourie and Love Environmental Management Consulting Inc and Ian Malcolm Associates, June, 2000

9. Description of Energy Transmission System

9.1 Overview

This section presents the amounts of biogas and energy produced by each of the four plant scenarios. The known and assumed treatment requirements for the biogas are described, according to the possible end uses of the biogas. The transport of biogas offsite would be achieved by means of a pipeline, the options for which are described in section 9.4. Cost estimates for onsite handling and treatment of biogas and offsite transport are presented in Section 9.5.

9.2 On-Site Production of Biogas

The quantity of biogas produced by the facility will be dependent on the type of waste stream and the quantity processed. The potential biogas yields are presented in Table 9-1.

Table 9.1
Biogas Yields for Processing Scenarios

Plant Scenario	Biogas Gross Yield, m ³ /yr
100k tpy, 30% unintentional, wet mesophilic	8,960,000
100k tpy, 10% unintentional, dry thermophilic	9,620,000
200k tpy, 30% unintentional, wet mesophilic	17,920,000
200k tpy, 10% unintentional, dry thermophilic	19,240,000

Volumes at 0^o C, 1 atm. pressure.

The gross biogas yield from a facility processing a waste stream with 10% unintentional material is higher than the energy yield for the 30% unintentional material waste stream. This is due to the fact that approximately 90% of the material is going to the digester as opposed to 70%, as is the case for the more highly contaminated waste stream.

The biogas could be transported via gas pipeline to the Boralex facility for use in Boralex's proposed combined-cycle co-generation unit. Alternate possibilities are transport to the Ashbridges Bay Treatment Plant for use in their boiler, transport to a future Hearn generating facility, or installation of an onsite co-generation system to provide electricity to the electrical grid and possibly heat to industrial neighbours.

The potential energy yield for each of the four scenarios was calculated on a gross energy value basis, not taking conversion efficiencies into account, to allow direct comparison to natural gas prices. The amount of biogas consumed to meet plant heat requirements (accounting for 80% conversion efficiency in a boiler) is subtracted from the gross energy production to determine the net energy available for offsite use.

It is assumed that the facility would have an onsite boiler using biogas to produce heat, as otherwise the costs of buying energy to meet the plant's heat requirements would likely exceed the amount of revenue from selling the equivalent amount of gas to the offsite user. Since there is no onsite electrical generation, the plant's electrical requirements would have to be met by purchased electricity.

Table 9.2
Energy Yields for Processing Scenarios

Plant Scenario	Gross Energy Production (as Biogas) GJ/yr	Plant Heat Energy Consumption, GJ/yr	Net Energy for Export (as Biogas) GJ/yr
100k tpy, 30% unintentional	174,000	36,000	138,000
100k tpy, 10% unintentional	187,000	15,000	172,000
200k tpy, 30% unintentional	348,000	72,000	276,000
200k tpy, 30% unintentional	374,000	29,000	345,000

The plant energy consumption for heat is higher for the plant processing a waste stream with 30% unintentional material. This is due to the fact that a wet digestion technology is proposed for this waste stream, while a dry technology is proposed for the 10% unintentional material stream. Wet digestion requires more heat than dry digestion because it uses more liquid, which results in more mass to be heated.

The avoided cost of natural gas purchased by Boralex was calculated based on a natural gas price of \$6/GJ, which includes estimated handling and transport costs added on to the base natural gas price of \$4.70 at the Alberta Plant Gate¹⁷, current as of 1 Apr. 2002. If there is no green energy credit available for the use of biogas at the end user's site, then the biogas would likely need to be sold at a price below that of natural gas. However, if green energy credits are available, the biogas may fetch a premium. Therefore the possible revenues for the AD plant are presented in Table 9.3, based on selling biogas at a 15% discount and a 15% premium over the price of natural gas, to indicate the range into which revenues would likely fall.

¹⁷ Gilbert Laustsen Jung Associates Ltd, 2002. Product Price and Market Forecasts for the Canadian Oil and Gas Industry: Quarterly Update. <http://www.GLJA.com>

Table 9.3
Energy Value for Processing Scenarios

Plant Scenario	Net Energy for Export GJ/yr	Natural Gas Burner Tip Price \$/GJ	Natural Gas Value, \$/yr	Value of Biogas with 15% Premium \$/yr	Value of Biogas with 15% Discount \$/yr
100k tpy, 30% unintentional	138,000	\$6.00	\$827,000	\$951,000	\$703,000
100k tpy, 10% unintentional	172,000	\$6.00	\$1,035,000	\$1,190,000	\$880,000
200k tpy, 30% unintentional	276,000	\$6.00	\$1,654,000	\$1,902,000	\$1,405,000
200k tpy, 10% unintentional	345,000	\$6.00	\$2,070,000	\$2,381,000	\$1,760,000

Three of the proposed plant scenarios could potentially generate revenues of over \$1,000,000 per year by sale of biogas to the Boralex facility or another end user. However, this is dependent on the end user being able to accept the biogas, which has higher levels of moisture and non-fuel contaminants than natural gas.

The other possibility for biogas utilization would be co-generation of electricity and heat by an on-site co-generation facility. This would avoid the expense and uncertainty of a pipeline from the anaerobic digestion plant site to the proposed Boralex facility. The energy inputs and outputs of the two possible options of Off-Site Gas Export and On-Site Co-Generation are presented in Figures 9.1 and 9.2 for each of the two possible waste stream scenarios.

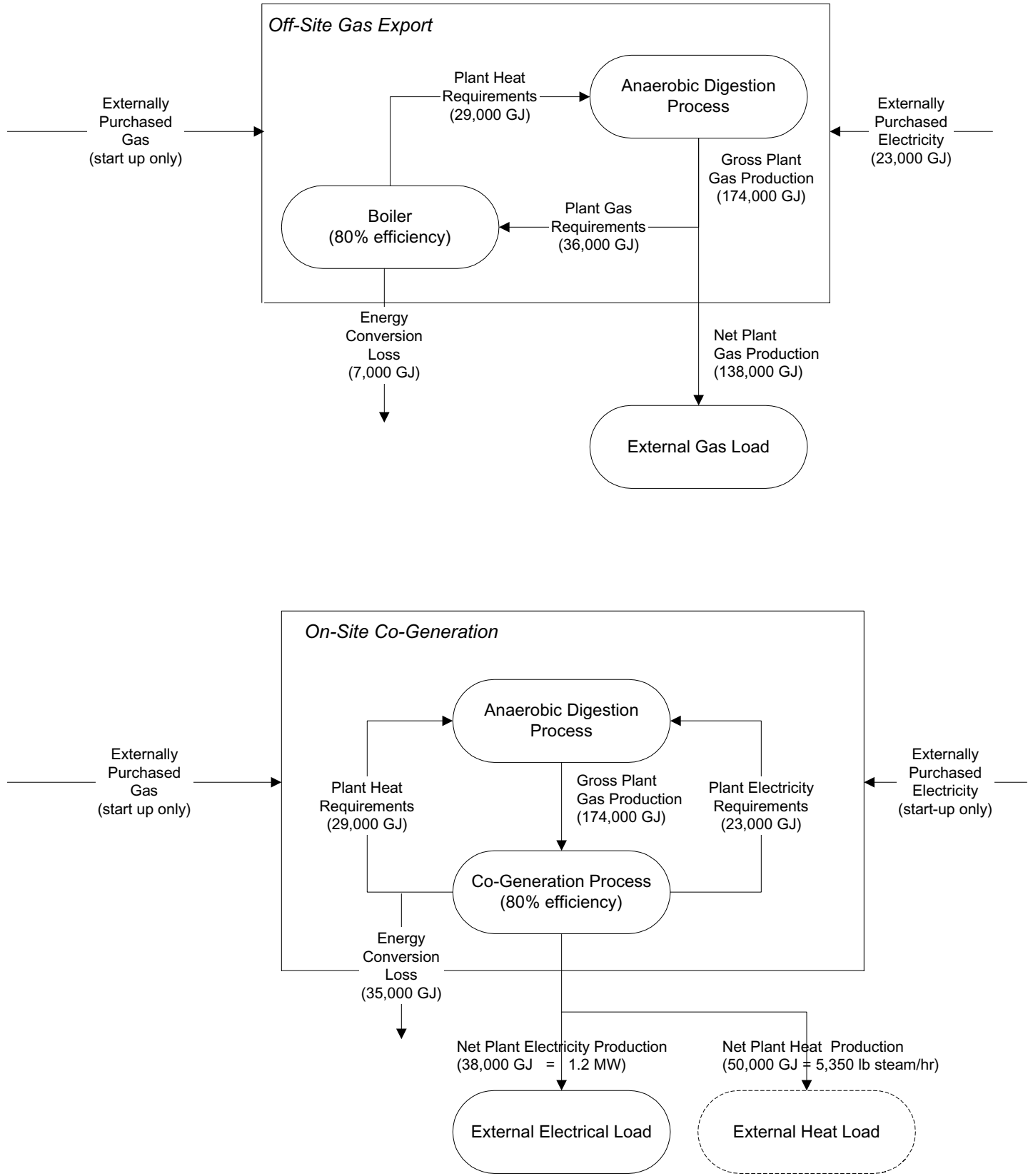


Figure 9.1: Energy Balance
Wet Mesophilic Single-Stage Plant, 100,000 tpy
(30% Unintentional Material)

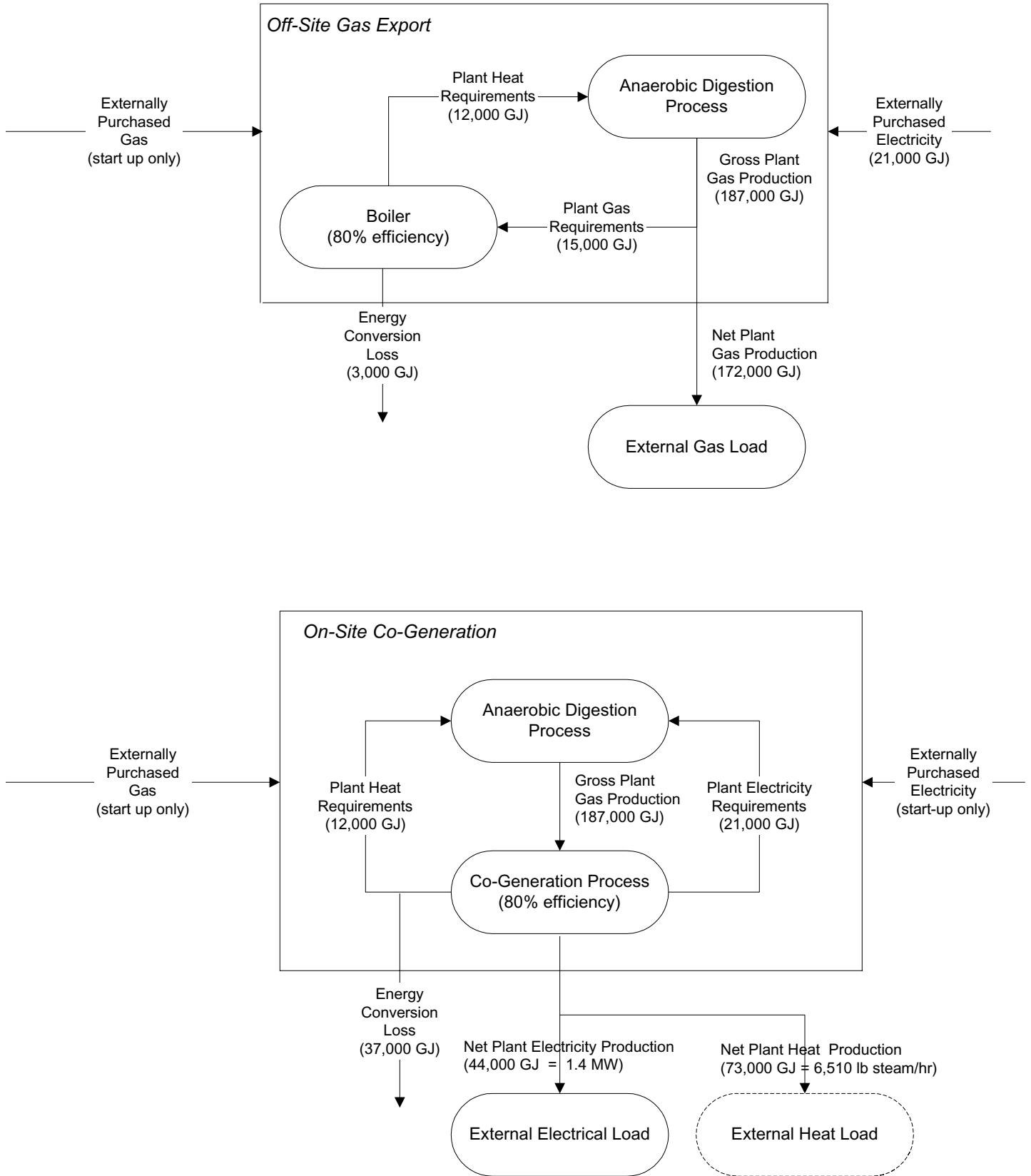


Figure 9.2: Energy Balance
Dry Thermophilic Single-Stage Plant, 100,000 tpy
(10% Unintentional Material)

9.3 On-Site Treatment of Biogas

9.3.1 Biogas Profile

The quality of the gas (ie., levels of contaminants) may vary slightly for different feedstocks, but for the purposes of this project it was assumed that the biogas from all four scenarios would be of the same quality, within the accuracy range used for this study.

Biogas from the digester will have contaminants such as hydrogen sulphide and moisture, which may need to be removed before compression and transmission of the gas to the Boralex facility, the proposed end-user.

Table 9.4 presents a profile of the expected composition of the biogas, based on the gas profile prediction from the Dufferin pilot facility combined with gas profile information from other technology suppliers.

Table 9.4
Biogas Composition

Components of Dry Biogas	Unit of Measurement	Average	Minimum	Maximum
Methane	Vol. %	55	52	70
Carbon Dioxide	Vol. %	45	30	48
Hydrogen Sulphide	Ppm		50	2,500
Total chlorine	mg/m ³	0.6	0.02	1.2
Total fluorine	mg/m ³	<0.1	<0.03	0.2

The biogas also contains water, to a level of approximately 100% humidity. The main parameters of concern are moisture and hydrogen sulphide, both of which are major causes of corrosion in biogas utilization equipment.

It should be noted that although maximum expected H₂S levels of up to 2,500 ppm were given in information from European technology suppliers and are therefore used in the table, actual levels from the operating AD facility in Newmarket have been substantially lower. Levels of H₂S in the influent stream to the co-generation unit have generally been recorded in the 50-60 ppm range. The Newmarket plant does not have a scrubber for hydrogen sulphide.

9.3.2 Treatment Requirements

The biogas will need some level of treatment prior to compression. The extent of treatment required is largely dependent on the end use of the gas. A boiler is much more tolerant of contaminants such as moisture and H₂S than a gas turbine. The required gas pressure also varies according to the end use. A gas turbine requires gas at a much higher pressure than a boiler.

Borex Requirements

The proposed Borex facility will be a combined-cycle co-generation gas turbine, fueled by natural gas supplied by Enbridge Consumers Gas. The Enbridge gas is much lower in contaminants than biogas from the proposed AD facility would be, and is supplied to the site at a pressure of 200-250 pounds per square inch (psi).

Use in Gas Turbine

If biogas from the AD facility were to be used in the gas turbine, it would be necessary to remove most of the moisture and hydrogen sulfide, to minimize corrosion and other impacts on the equipment, which is designed for natural gas use. The equipment requirements for the incoming gas stream in terms of contaminant levels were not yet available from Borex at the time of writing at this study. However, it is known that there would be treatment necessary; equipment descriptions and cost estimates are covered subsequently in this chapter.

The cost estimate for the proposed Portlands plant includes a hydrogen sulphide removal system should one prove necessary to meet Borex's requirements. However, this is a high-cost item, and it would likely be more economically feasible to install another burner at the Borex facility that was designed to handle biogas.

The biogas would need to be compressed for use in the turbine. There will be compression equipment at the facility, into which biogas from the AD facility could be fed, provided it had been cleaned up to a level acceptable for the equipment. Biogas would need to be supplied to the compression equipment at the same pressure as natural gas from Enbridge, which comes onto the site at 200-250 psi. Therefore, it would have to be compressed at the AD plant site from the pressure at which it comes out of the digester, which is less than 1 psi.

Use in Boiler

There will be an auxiliary boiler at the Borex facility which will also use natural gas as the main fuel. The biogas could be used as a supplementary fuel source for the boiler. This has substantial cost advantages with respect to treatment and compression equipment, because a boiler is much less sensitive to sulfide and moisture levels in the fuel, and also can operate at a much lower input gas pressure.

Gas treatment for H₂S and moisture may not be required by the boiler. However, the Borex facility's Certificate of Approval (Air) will specify quality requirements for the fuel to be used, and this standard would likely determine the extent of gas cleanup required for use at the Borex facility. Toronto Hydro Energy Services and Borex are commencing the application process later this year, and the gas quality requirements will be determined as an outcome of that process. Results will not be available within the timeline of this study.

A gas pressure of 30 psi would be sufficient for the boiler, which is much less costly to achieve than the 200 psi necessary for Borex's onsite compression equipment.

On-site Use

If the biogas were to be used for onsite co-generation, a generator of the type used in landfill gas and wastewater treatment plant applications would be used. These generators are designed for digester and landfill gas, and are less sensitive to moisture and sulfides.

Compression equipment would still be required to boost the gas pressure to the level required by the generator.

Generating electricity and process heat onsite would eliminate the need to purchase electricity and heat for the plant. The facility under consideration is large enough to produce enough biogas to be of interest to an energy developer, who could install a co-generation system at the facility at no cost to the facility, and would then sell electricity and heat back to the facility. This is beneficial for the energy developer as they would receive fuel at no cost and could sell electricity to the electrical grid. The co-generation system at the existing AD facility in Newmarket Ontario is operated under this model.

Transmission to ABTP

The Ashbridges Bay Treatment Plant has an onsite boiler, and recently built a new digester gas control building containing biogas compression equipment. It may be possible to feed biogas from the AD facility into the existing digester gas utilization system at the ABTP, since the gas from the proposed facility would have a similar profile to the digester gas currently firing the boiler.

Compression would be needed to optimize the pipeline volume required, and would likely be to 30 psi.

9.3.3 Treatment and Compression Equipment

General descriptions of the biogas treatment and compression equipment required are provided in this section.

Emergency Flare and Pressure Relief Equipment

To conform with CAN/CGA-B105-M93, the federal code applicable to digester gas installations, the following pieces of equipment would be necessary:

- Emergency Flare
- In-line Flame Arrester
- Back Pressure Regulator
- Pressure Relief Valve & Flame Arrester assembly on the roof of each digester
- 3-way plug valve for PRV assembly
- Manometer

Biogas would be directed to the emergency flare only when not being fed into the gas pipeline or used onsite for energy generation or gas mixing of the digesters (during maintenance downtime or emergencies). The biogas would be flared off when gas in the system reached a pressure of 15" water column.

Emergency pressure relief valves on the roofs of the digesters act as a backup to the flare to prevent pressure buildup in the digesters if gas cannot be flared due to obstructions in the gas piping or the flare being out of service.

Sulfur Removal

The removal of H₂S would be by means of a scrubber that uses iron to oxidize the sulfide to elemental sulfur, which precipitates out of the gas stream. The scrubber reduces the sulfide concentration by over 90%, and a removal rate of up to 99% is claimed by some manufacturers.

Sulfur removal would not be required if the biogas were to be used in a boiler at the Boralex facility, the ABTP, or onsite. An onsite co-generation system may also be able to handle the untreated biogas if the unit was designed for biogas.

Moisture Removal

A knockout pot would remove any liquid water in the biogas by gravity, due to its larger diameter. For transmission of the biogas by pipeline, a desiccant dryer or a dryer that chilled the gas would be necessary for removal of water vapour from the biogas.

Moisture removal would be required for transmitting the biogas offsite and for use in the Boralex gas turbine. Utilization of the gas in a boiler may not require moisture removal.

Pressurization

To boost the biogas pressure to the 200 psi required at the Boralex co-gen unit, a large two-stage compression system would be required.

If the final use of the biogas was to be the Boralex auxiliary boiler or the ABTP boiler, compression of the gas to 30 psi would be sufficient and necessary for transport of the biogas through the pipeline. Compression to 30 psi is also necessary for the gas mixing used by the wet mesophilic digestion technology.

9.4 Biogas Transmission System

The pipeline distance and preliminary costs were estimated for transmission of biogas via pipeline from each of the two technically feasible sites (Sites A and B) to the location of the proposed Boralex facility.

9.4.1 Piping System Options

The following discussion is non site-specific and describes the type of piping to be used for the various delivery pressure scenarios.

Two main options for the transmission of the digester gas to the Boralex site were considered. The first is the transmission of high pressure gas at approximately 1380 kPa (200 psig) and the second using low pressure gas at approximately 210 kPa (30 psig). The high pressure system is for use of the biogas in the gas turbine, while the low pressure system is for use of the biogas in the auxiliary boiler.

For the high pressure case the piping system considered was 75 mm black steel pipe with a high density polyethylene (HDPE) jacket and provided with passive corrosion protection. The pipe joints would be welded in the field and the pipe would be laid in a shallow trench approximately 1 m deep. Sacrificial zinc anodes would be installed at selected intervals beside the pipe for corrosion protection.

For the low pressure cases the piping system considered was 150 mm “Wehogas” HDPE pipe. This type of pipe is the standard in this area for all gas distribution pipe for service under 690 kPa (100 psig). This would be installed directly into a trench also at approximately 1 m depth.

9.4.2 Pipe Routing Discussion

The following discussion applies to both of the main piping systems proposed.

The routing of transmission piping to the two plant site locations were reviewed to develop cost estimates for the piping systems.

For Site A the route proposed is east from the plant to Logan Avenue, south along Logan to Commissioners Street, east along Commissioners to just west of Carlaw Avenue and then south to the Boralex site. A review of the PUCG drawings for this route shows that there is ample room in the road allowance for the piping and a minimum of existing services crossing the road allowance.

For Site B the route proposed is north from the plant to Commissioners Street and west to the west side of Carlaw Avenue and then south to the Boralex site. A review of the PUCG drawings for this route shows that there is ample room in the road allowance for the piping, however, there a number of services to be crossed at Carlaw and to the east of Carlaw.

When considering installation costs it is important to note that since this pipeline is in the Portlands, it is likely that the excavation for parts or all of this pipeline will involve the removal of contaminated soil. Contaminated soil has a disposal cost of approximately \$55/tonne if it meets Regulation 347 requirements, or up to \$200/tonne if it does not. Data on the levels of contamination throughout the Portlands is incomplete and the soil conditions would probably not be known for all of the pipeline route. Therefore, it would be necessary to carry out a soil sampling and testing program, plus continuous supervision by a person knowledgeable about contaminated soil during the excavation. This would be in addition to the normal excavation and construction supervision costs.

For the estimate it was assumed that the excavated material was not suitable for backfill and therefore would be removed from the site at a cost of \$55/tonne for 90% of the soil, and \$200/tonne for the other 10% of the soil. Backfill materials include sand bedding for the pipe and the remainder of the excavation filled with unshrinkable fill and finished with asphalt. Figure 9.3 is a diagram of a cross-section of pipe, including the trench and backfill.

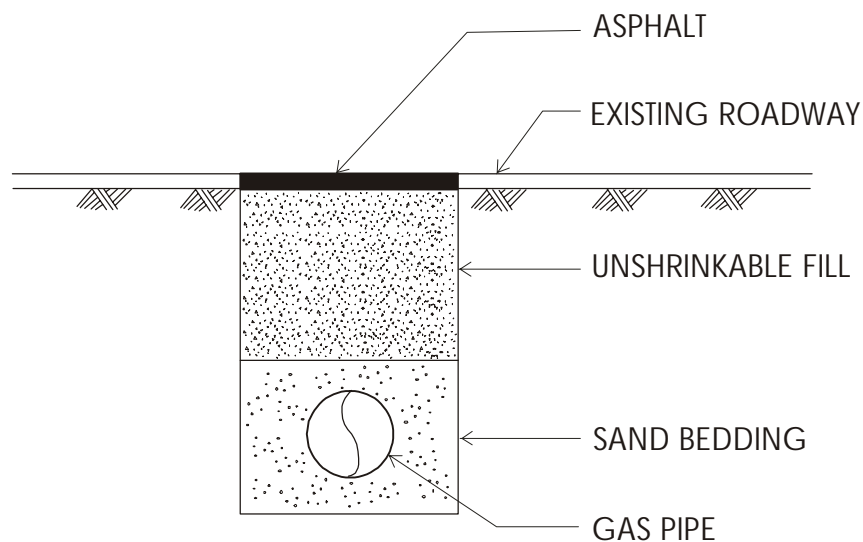


Figure 9.3: Cross-Sectional Diagram of Biogas Transmission Piping Installation

9.4.3 Operational Requirements

The pipeline would require monitoring for corrosion and moisture buildup. Corrosion monitoring would consist of periodic monitoring of the sacrificial zinc anodes to monitor the rate of degradation, likely on a yearly basis. This would not require removal of the pipe or opening of the pipe.

One potentially problematic issue is the condensation of moisture in the pipeline. The biogas will go through a knockout device to remove all liquid water before transmission through the

pipeline. However, there would be water vapour remaining in the gas stream which would be condensed when the gas cooled during the journey to the Boralex facility. Therefore it would be necessary to install a more extensive moisture removal system, such as a desiccant dryer or a system to lower the dewpoint to remove water vapour from the gas stream before entering the pipeline.

9.5 Cost Estimates

Cost estimates for biogas handling, treatment and transmission are presented on the following pages. A total of four different end-use options are considered, as the end use of the biogas has a significant impact on price, since the treatment requirements are different for the different options.

The two pipe types for the two possible pipeline pressure ratings are very close in cost. The differences in costs are that the steel pipe is more expensive to buy and assemble but is considerably cheaper to install as the excavation will be smaller and the backfilling requirements are much less rigorous.

The operational cost of the pipeline would be an annual corrosion monitoring allowance.

The total costs would be the sum of the costs for Safety and Gas Conditioning Equipment, plus the Total for Option 1, Option 2, or Option 3, depending which final use of the biogas was chosen.

The capital costs for biogas utilization equipment for a 100,000 tpy plant would be from \$1,069,000 to \$1,976,000, depending which gas utilization option was chosen. The operating costs would be from \$48,000 per year to \$82,000 per year, depending on which gas utilization option was chosen.

The capital costs for biogas utilization equipment for a 200,000 tpy plant would be from \$1,717,000 to \$3,458,000, depending which gas utilization option was chosen. The operating costs would be from \$74,000 per year to \$137,000 per year, depending on which gas utilization option was chosen.

The cost estimates for the other gas utilization options are very approximate, as these costs are provided only as a basis of comparison against which to make decisions on the feasibility of piping the biogas to the Boralex facility. It is uncertain whether Boralex will be willing or able to take on the extra operational demands of using biogas to meet a small percentage of their fuel requirement (engine and pipeline maintenance etc.), and therefore other options for use of the biogas should be considered.

Another option for use of the biogas is the installation of a co-generation unit at the facility by an energy systems supplier. The capital and operating costs of the unit may be covered by the supplier, in exchange for ownership of the gas for the purpose of selling electricity to the electrical grid and possibly process heat to local users. The facility would buy power from the power system supplier to meet its own electrical and heat requirements, likely at a price less than it would pay to purchase energy from an offsite supplier. The Dufferin pilot facility does not have a co-generation system due to its small volumes of gas, but the proposed Portlands facility would have sufficient volumes of gas to justify a co-generation unit.

An on-site co-generation unit would eliminate the regulatory and operational issues associated with exporting biogas offsite. A preliminary estimate of the revenues that could be gained by selling electricity to the grid at a price of 6 cents/kwh is presented in Table 9.5 below. If the unit were to be installed by an energy developer at no cost to the AD facility, these revenues would go to the energy developer. If a co-generation unit were installed as part of the AD facility, these revenues would go to the facility but the capital and operating costs of the co-generation unit would also need to be covered by the facility.

At an electricity price of 6c/kwh, the revenues from the sale of electricity would be less than potential revenues from the sale of biogas. However, selling biogas is dependent on having an end user willing and able to accept the biogas, which includes meeting regulatory requirements at the user’s site, and the regulatory, operational and financial implications of building a pipeline to the site.

Table 9.5
Potential Electricity Revenues

Net Electricity for Sale (kwh/yr)	Electricity Price (cents/kwh)	Electricity Revenue (\$/yr)
10,640,218	6	\$638,000
12,258,030	6	\$735,000
21,280,437	6	\$1,277,000
24,516,059	6	\$1,471,000

Table 9.6
Capital Cost Estimate - Biogas Cleanup and Transmission System

	<u>100,000 tpy facility</u>	<u>200,000 tpy facility</u>
<u>Safety and Gas Conditioning Equipment</u>		
Flare	180,000	180,000
Overpressure Control Valve	22,000	44,000
Flame Arresters (2)	38,000	76,000
Rooftop Pressure Relief Valves (6)	34,000	68,000
Manometers (2)	3,000	6,000
sub total:	<u>277,000</u>	<u>374,000</u>
Unforeseen and Estimating Allowance (20%):	55,400	74,800
Engineering & Contract Administration (13%):	43,000	58,000
Total:	375,400	506,800
<u>Process Heat Generation</u>		
Boiler		
(installed cost for 100 hp and 200 hp, respectively)	sub total:	180,000
Unforeseen and Estimating Allowance (20%):	36,000	52,000
Engineering & Contract Administration (13%):	28,000	41,000
Total:	244,000	353,000
<u>Gas Utilization Option 1: Boralex Co-Generation Unit</u>		
<i>Gas Conditioning Equipment</i>		
Dessicant Dryer	200,000	400,000
High-Pressure Compressor	330,000	660,000
(H ₂ S Scrubber, if required)	300,000	600,000
<i>High-Pressure Pipeline for Transmission to Boralex Co-Gen (200 psi)</i>		
Site A pipeline (730 m)	125,000	187,500
Site B pipeline (1093 m)	187,000	280,500
sub total Option 1:	<u>955,000</u>	<u>1,847,500</u>
or	1,017,000	1,940,500
Unforeseen and Estimating Allowance (20%):	191,000	369,500
Engineering & Contract Administration (13%):	149,000	288,000
Total Option 1:	1,357,000	2,598,000
<u>Gas Utilization Option 2: Boralex Auxiliary Boiler</u>		
<i>Gas Conditioning Equipment</i>		
Dessicant Dryer	200,000	400,000
Compressor	70,000	140,000
<i>Low-Pressure Pipeline for Transmission to Boralex Boiler (30 psi)</i>		
Site A pipeline (730 m)	136,000	204,000
Site B pipeline (1093 m)	204,000	306,000
sub total Option 2:	<u>406,000</u>	<u>744,000</u>
or	474,000	846,000
Unforeseen and Estimating Allowance (20%):	81,200	148,800
Engineering & Contract Administration (13%):	63,000	116,000
Total Option 2:	618,200	1,110,800
<u>Gas Utilization Option 3: Ashbridges Bay Boiler</u>		
<i>Gas Conditioning Equipment</i>		
Dessicant Dryer	200,000	400,000
Compressor	70,000	140,000
<i>Low-Pressure Pipeline for Transmission to ABTP (30 psi)</i>		
Site A pipeline (730 m)	261,000	391,500
Site B pipeline (1093 m)	61,000	91,500
sub total Option 3:	<u>531,000</u>	<u>931,500</u>
or	331,000	631,500
Unforeseen and Estimating Allowance (20%):	66,200	126,300
Engineering & Contract Administration (13%):	52,000	99,000
Total Option 3:	449,200	856,800

Table 9.7
Operating Cost Estimate - Biogas Cleanup and Transmission System

	<u>100,000 tpy facility</u>	<u>200,000 tpy facility</u>
<u>Safety and Gas Conditioning Equipment</u>		
Total Capital Investment:		
100k tpy plant:	277,000	
200k tpy plant:	374,000	
Yearly Maintenance Allowance 4% of TCI:	11,000	15,000
Unforeseen at 10%:	1,000	2,000
Estimating Allowance at 10%:	1,000	2,000
Yearly Operating Cost, Safety Equipment:	13,000	19,000

Process Heat Generation

Total Capital Investment:		
100k tpy plant:	180,000	
200k tpy plant:	260,000	
Yearly Maintenance Allowance 4% of TCI:	7,000	10,000
Unforeseen at 10%:	700	1,000
Estimating Allowance at 10%:	700	1,000
Yearly Operating Cost, Safety Equipment:	8,400	12,000

Gas Utilization Option 1: Boralex Co-Generation Unit

Total Capital Investment:		
100k tpy plant:	1,017,000	
200k tpy plant:	1,940,500	
Yearly Maintenance and Replacement Allowance 4% of TCI:	41,000	78,000
Yearly Pipeline Corrosion Monitoring	<u>10,000</u>	<u>10,000</u>
subtotal, Option 1:	51,000	88,000
Unforeseen at 10%:	5,000	9,000
Estimating Allowance at 10%:	5,000	9,000
Yearly Operating Cost, Option 1:	61,000	106,000

Gas Utilization Option 2: Boralex Auxiliary Boiler

Total Capital Investment:		
100k tpy plant:	474,000	
200k tpy plant:	846,000	
Yearly Maintenance and Replacement Allowance 4% of TCI:	19,000	34,000
Yearly Pipeline Corrosion Monitoring	<u>10,000</u>	<u>10,000</u>
subtotal, Option 2:	29,000	44,000
Unforeseen at 10%:	3,000	4,000
Estimating Allowance at 10%:	3,000	4,000
Yearly Operating Cost, Option 2:	35,000	52,000

Gas Utilization Option 3: Ashbridges Bay Boiler

Total Capital Investment:		
100k tpy plant:	331,000	
200k tpy plant:	631,500	
Yearly Replacement Cost, 4% of TCI:	13,000	25,000
Yearly Pipeline Corrosion Monitoring	<u>10,000</u>	<u>10,000</u>
subtotal, Option 3:	23,000	35,000
Unforeseen at 10%:	2,000	4,000
Estimating Allowance at 10%:	2,000	4,000
Yearly Operating Cost, Option 3:	27,000	43,000

10. Regulatory and Approvals Requirements

10.1 Overview

This chapter includes a summary of the main regulatory considerations associated with meeting applicable codes and standards and securing the necessary approvals for the facility and its associated transport systems.

10.2 Environmental Assessment Act

The Environmental Assessment Act (EAA) requires that subject projects must go through an individual Environmental Assessment, which is a major undertaking involving studies of all potential impacts of the project on the surrounding environment including impacts to air, land and water, wildlife, human welfare and economic implications.

The first step in the EA process is the completion, and subsequent approval by the Minister of the Environment, of the Terms of Reference (ToR). The EA submitted for approval must be prepared in accordance with the approved ToR. The following information is required in the ToR:

1. Description and purpose of the undertaking being considered;
2. Description of the environment and potential effects;
3. Alternatives (both alternatives to the undertaking and alternative methods of carrying out the undertaking);
4. EA Work Plan;
5. EA Consultation Plan;
6. Other Approvals; and
7. Consultation to develop Terms of Reference and future consultation on the EA.

The Terms of Reference does provide an opportunity for some of the issues (e.g., “alternatives to” that are examined) to be scoped prior to commencing the preparation of the EA. For the AD facility, justification could be provided in the ToR for scoping the alternatives (both alternatives to and alternative methods). Since the ToR are approved by the Minister assurances are provided to the proponent of the information and level of study (including the consultation activities) required for the EA, including the level of scoping.

In the terminology of the Act¹⁸, the environmental assessment must consist of:

- “(a) a description of the purpose of the undertaking;
- (b) a description of and a statement of the rationale for,
- (i) the undertaking,
 - (ii) the alternative methods of carrying out the undertaking, and
 - (iii) the alternatives to the undertaking;

¹⁸ Ontario Ministry of the Environment. Environmental Assessment Act R.S.O. 1990, c. E-18;

(c) a description of,

(i) the environment that will be affected or that might reasonably be expected to be affected, directly or indirectly,

(ii) the effects that will be caused or that might reasonably be expected to be caused to the environment, and

(iii) the actions necessary or that may reasonably be expected to be necessary to prevent, change, mitigate or remedy the effects upon or the effects that might reasonably be expected upon the environment, by the undertaking, the alternative methods of carrying out the undertaking and the alternatives to the undertaking;

(d) an evaluation of the advantages and disadvantages to the environment of the undertaking, the alternative methods of carrying out the undertaking and the alternatives to the undertaking; and

(e) a description of any consultation about the undertaking by the proponent and the results of the consultation. 1996, c. 27, s. 3.”

Although the opportunity exists for scoping of the alternatives and other possible issues, an individual EA can still be costly in terms of time and money. It is difficult to accurately predict the costs and schedule required for an EA, as depending on a number of factors including the level of public opposition, new requirements and new studies can be added while the ToR are being developed (prior to approval). There is an extensive public consultation component (during development of both the ToR and the EA) which can delay approval of the project if not all members of the public are satisfied with the results of studies done under the ToR and possibly the EA.

A waste processing facility is subject to the EAA if over 200 tonnes per day leaves the facility destined for disposal¹⁹. In accordance with the materials mass balances given in Chapter 4, a total of up to 28,215 tonnes per year would be sent to disposal (solid residuals with no recyclables recovery) for a 100,000 tonne per year plant. For a 200,000 tonne per year plant, this figure would be 56,430 tonnes.

Based on 250 operating days per year (5 days/week), a 100,000 tpy plant has 113 tonnes per day of residue, which is below the threshold that triggers an EA. However, a 200,000 tonne per year plant would have twice that amount, or 226 tonnes per day. If the plant was operated six days per week rather than five, the total daily amount of waste leaving the site would be only 188 tonnes per day, which is beneath the EAA trigger. However, it is so close to the trigger that the Ministry would most likely require an individual EA to be carried out.

The calculation of less than 200 tonnes per day of residuals leaving the site does not include digestate leaving the site, as this is intended to be cured and used as compost. It should be noted, however, that if the intended use of the compost is for landfill cover then the MOE considers this to be deemed “for disposal” and the compost would have to be considered as part of the 200 tpd

¹⁹ Ontario Ministry of the Environment. “Guide for Applying for Approval of Waste Disposal Sites: Sections 27, 30, 31 and 32, *Environmental Protection Act* R.S.O. 1990. Environmental Assessment and Approvals Branch, November 1999. Appendix 1

disposed from the site. This could be the case for a facility processing organics with up to 30% unintentional material.

A second trigger for whether a project is subject to the EAA is the dollar value of the project. Regulation 334 of the Environmental Assessment Act²⁰ stipulates that an undertaking is subject to the EAA if it has an estimated cost of over \$3,500,000.

This dollar figure does not include costs for:

“(a) the acquisition of land,
(b) feasibility studies and design carried out for the undertaking,
(c) the operation of the undertaking,
(d) a building, the construction of which is regulated by the Building Code Act,
(e) any furnishings, equipment, facilities or machinery ancillary to a building described in clause (d), whether contained in it or not, or
(f) any facilities or machinery contained in a building described in clause (d), whether ancillary to it or not. O. Reg. 456/93, s. 2 (1).”

Based on this definition, the estimated cost of the project would not exceed \$3,500,000 since a large amount of the total capital cost will be buildings, process equipment contained within the buildings, and process equipment outside of the building which may be deemed to be ancillary to the building.

City of Toronto staff has consulted with MOE staff on whether the undertaking is subject to the EAA; at this point it is unknown whether the 200,000 tpy plant would be subject or not. Before proceeding with the project, it would be necessary to get definite clarification from the Ministry of Environment on this issue.

It is also possible for the public to request a site specific EAA designation of the facility. It is intended that the public consultation carried out as part of the approvals process for the facility, and subsequent actions to address concerns identified, would be sufficient to satisfy the public that an EA was not necessary.

10.3 Environmental Protection Act

10.3.1 Certificate of Approval for Waste Processing at the AD Facility Site

The anaerobic digestion facility will need to obtain a Certificate of Approval for waste processing. If the facility is to be located on Site A, adjacent to the existing transfer station, it may be possible to apply for an amendment to the Commissioners' St. site to extend the area covered by the C of A to include Site A. This would likely be less time-consuming and costly than a full application for a new waste processing facility.

The Ministry of the Environment's Guide for Applying for Approval of Waste Disposal Sites has the following definition of a waste processing site:

²⁰ Ontario Ministry of the Environment. Environmental Assessment Act, Revised Regulations of Ontario, Regulation 334, Amended to O. Reg. 390/01.

“A Waste Processing Site (WPS) is a site that manages or prepares waste for subsequent reuse or disposal. Centralized composting facilities receiving waste (ie. leaf and yard or the wet component of municipal solid waste) from various sources (ie. towns, municipalities, etc.) and are required to fulfil the waste processing requirements (also see section on Composting).

Waste processing sites, from both the private and public sectors, are subject to Part V, Section 27 and 32 of the EPA. Approval under Section 9 of the EPA is required for air emissions from any processes or venting.”²¹

An application for approval of a WPS under Part V of the EPA must be accompanied by three documents:

- Design and Operations Report, including site plans, maps, diagrams and detailed descriptions of the site, processes, specifications for all storage containers, waste quantities and handling procedures, record keeping and reporting procedures, site operations and staff training, and details of emergency planning;
- Drainage Study, including surface drainage and stormwater management calculations, effluent quality and quantities and written approval from the municipality for discharges to the sanitary sewer; and
- Financial Assurance information for the implementation of remedial measures in the event of a spill, fire or waste abandonment.

The relevant section of the MOE document is excerpted in Appendix C.

The issuing of a Certificate of Approval is also dependent on whether the public consultation requirements of the Environmental Bill of Rights (EBR) have been met, if the facility approval is a prescribed instrument under the EBR. This would require posting on the EBR site for a minimum of 30 days, and would be required if the undertaking is not subject to the Environmental Assessment Act (EAA). However, the undertaking is exempted from the EBR public participation requirement (under EPA) if it is subject to an Environmental Assessment under the EAA, as the EA would be posted.

10.3.2 Certificate of Approval of a Waste Management System for Digestate Transport

The transportation of uncured digestate from the anaerobic digestion facility to an offsite location for final composting will require an Application for Approval of a Waste Management System, which applies to “transportation systems which do not involve land spreading of biosolids or other organic wastes”.

The application must include information on the applicant (the City of Toronto); the site to receive the waste, the waste to be handled (digestate), the method of operation, vehicle information, emergency procedures, and other approvals associated with the undertaking.

The relevant section of the MOE document is excerpted in Appendix C.

²¹ Ontario Ministry of the Environment. “Guide for Applying for Approval of Waste Disposal Sites: Sections 27, 30, 31 and 32, *Environmental Protection Act* R.S.O. 1990. Environmental Assessment and Approvals Branch, November 1999.

10.3.3 Certificate of Approval for Waste Processing for the Final Composting Location

The offsite composting location for the digestate will also need to have a Certificate of Approval for waste processing, as it would fall under the same requirements as the AD facility site, as outlined in Section 10.2. The location of the curing facility is unknown at this point. The most desirable option would be for the digestate to be taken to an existing facility that already has a C of A. If the facility's existing C of A does not currently cover the type and volume of waste coming from the AD facility, it may need to be amended to allow the processing of the digestate. This process, however, is simpler and faster than applying for a new Certificate of Approval.

It should be noted that there are currently no facilities in operation in Ontario that process the volume of feedstock considered in this study.

10.3.4 Certificate of Approval (Air) for the AD Facility

The facility will require a Certificate of Approval (Air) under Section 8 of the Environmental Protection Act (Form 1147 4/76). Regulation 346, the general air management regulation, sets standards for acceptable levels of airborne emissions (stack or fugitive), noise, and odour.

The three emission points at the facility will be the flare, the boiler and the biofilter. If an onsite co-generation unit were installed, the stack from this unit would also be an emission point. The proposed plan to send biogas directly to the Boralex facility would mean that emissions from the generation of energy from the biogas would be covered under the Boralex facility's Certificate of Approval. It will be necessary to ensure that the Boralex C of A (Air) allows for the combustion of biogas.

Toronto Hydro Energy Services and Boralex are currently in the C of A process for the facility. It is unknown whether the application addresses the issue of feeding biogas to the facility.

10.4 Ontario Interim Guidelines for Compost

The goal for the production and composting of digestate from the AD facility is to produce a compost that can be marketed in Ontario. This requires that the compost meets Ontario standards for unrestricted use, as set out in the Ministry of the Environment's Interim Guidelines for the Production and Use of Aerobic Compost in Ontario. These Guidelines are under Part V of the Environmental Protection Act and Ontario Regulation 347 governing the disposal and processing of wastes at waste disposal sites for which Certificates of Approval are required.

The guideline contains some operational requirements for temperature and oxygen levels to be maintained during the composting process. The main operational requirement is the pathogen reduction requirement, which demands that compost be maintained at a temperature of at least 55⁰ C for at least 15 days for static pile and windrow composting, and at least 3 days for in-vessel composting.

One of the principal purposes of the guideline is to distinguish between a composted "product" and a "waste". Composted material that fails to meet the Interim Guidelines requirements is considered a waste under Regulation 347, with restrictions on the location and manner it can be used; Certificates of Approval will be required for its transport and for the sites on which it is to

be used. Compost that meets the requirements is a product that has no restrictions on where and how it is used, and does not require C of A's for its transportation or final use.

To assess the quality of the compost product, the Guidelines include a set of standards for metals, organic chemicals, non-biodegradable particulate matter and stability. Guidelines for particle size, mineral content, organic matter content, Carbon:Nitrogen ratio, salinity, pH, moisture content and organic matter reduction are also provided as general measures of compost quality, but are not used in the determination of an unrestricted use product.

Metals

The Guidelines state that to be classified as an unrestricted use product, the metal content of finished compost must not exceed the concentrations given in the table below, reproduced from the Guidelines. Concentrations are calculated on a dry weight basis.

Table 10.1
Interim Guidelines Standards for Metals Content in Unrestricted Use Compost

Metal	Concentration (mg/kg dry wt)
Arsenic	10
Cadmium	3
Chromium	50
Cobalt	25
Copper	60
Lead	150
Mercury	0.15
Molybdenum	2
Nickel	60
Selenium	2
Zinc	500

It is expected that the metals content requirements will be the most difficult standards to meet. They are quite stringent and some facilities composting fractions of the municipal solid waste stream have been able to consistently produce a product that meets the standards.

Anaerobic digestion does not remove metals from feedstocks, and metals do not significantly partition into the wastewater stream, due to their low solubility at the pH range of 6-8 typical of AD. Therefore, any metals in the incoming feedstock that are not removed in the mechanical pre-processing stages will end up in the compost.

Compost from an operating facility in Europe has been shown to comply with the MOE compost guidelines for cadmium, nickel and zinc, but requires metal removal treatment to bring it into

compliance for chromium, copper and lead (the other metals were not tested)²². This facility digests “rest waste”, which is the residue after recyclables and kitchen organics have been removed from the waste stream. This waste stream would be fairly high in metals.

Compost from another operating facility in Europe has been shown to meet MOE standards for all metals except for mercury, which at 0.2 mg/kg dry weight is just over the MOE standard of 0.15 mg/kg dry weight²³. This facility digests biowaste (household organics) with solid and liquid foodwaste from commercial sources. This waste stream would not have a high metals content in the feedstock.

The metals content in the final product is primarily determined by the incoming feedstock, and there are not yet operational examples of the processing of these two waste streams by AD in Toronto or elsewhere in North America. Therefore, it is difficult to predict whether the compost will meet the Interim Guidelines. It is expected that the compost produced from the waste stream with no more than 10% unintentional material would have a good chance of meeting the standard, while the compost from the 30% unintentional material stream may not meet the standard. It may be possible to blend this product with leaf and yard waste compost, which is generally low in metals content, to bring it into compliance with the Guidelines.

Organic Chemicals

The Guidelines also contain a standard of 0.5 mg/kg dry weight for PCB. However, it is not expected that this standard will be difficult to meet, as the feedstock will not contain significant amounts of organic chemicals. Compost from a European facility had a PCB level of 4 ug/kg, or less than 1% of the maximum level²⁴.

Non-Biodegradable Particulate Matter

The Guidelines also stipulate that the finished compost must contain “no material of a size of shape that reasonably can cause human or animal injury, or damage to equipment.” It also sets a non-biodegradable particulate maximum of particles greater than 8 mesh screen size as follows:

Table 10.2
Interim Guidelines Standards for Non-Biodegradable Particulate Matter in Unrestricted Use Compost

Parameter	Concentration (mg/kg dry wt)
Plastic	1.0
Other (total)	2.0

²² Results of testing of compost from Organic Waste Systems Bassum facility, presented in De Baere and Boelens, Rest or Mixed Waste Sorting-Digestion-Separation for the Recovery of Recyclables and Energy. ORBIT 99 proceedings.

²³ Results of testing of compost from BTA Kelheim facility, presented in Kubler et al., Full Scale Co-Digestion of Biowaste and Commercial Organic Waste.

²⁴ Results of testing of compost from BTA Kelheim facility, presented in Kubler et al., Full Scale Co-Digestion of Biowaste and Commercial Organic Waste.

Stability

The Guidelines stipulate that the compost must either be cured for a six-month period, or stability tested to ensure that it is mature. There is no specific maturity level given in the Guidelines, and therefore compost stability is not used in determining an unrestricted use product. The 20-30 day curing time following anaerobic digestion proposed for the facility was deemed to be suitable in European experience.

10.5 Ontario Guidelines for the Utilization of Biosolids and Other Wastes On Agricultural Land

Digestate from the facility processing waste with up to 30% unintentional material would not be likely to meet the MOE Interim Guidelines for Unrestricted Use compost. An alternative option for this digestate would be to manage it within the City's direct land application program for biosolids. Under this option, the digestate would need to meet the requirements set out in the Ontario Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land²⁵.

An application for land spreading of digestate must include "analyses that identify the components which benefit crop production and pose minimal risk to:

- Plant growth;
- Crop quality;
- Public and animal health; and
- Quality of the Environment."

The allowable metals content of land applied biosolids is a function of the nitrogen to metals ratio. Table 10.3 is reproduced from Table 1 of the Guideline.

²⁵ Ontario Ministry of the Environment and Ontario Ministry of Agriculture, Food and Rural Affairs, 1996. "Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land".

Table 10.3
Biosolids Utilization Guidelines Criteria for Metal Content in Sewage Biosolids

1	2	3	4	5
Metals	Anaerobic Biosolids		Aerobic, Dewatered and Dried Biosolids and Other Wastes	
	Minimum Ammonium + Nitrate Nitrogen to Metal Ratios		Maximum Permissible Metal Concentrations (mg/kg of solids)	
	Present Requirements	Long-term Targets	Present Requirements	Long-term Targets
Arsenic	100	480	170	35
Cadmium	500	4200	34	4
Cobalt	50	220	340	77
Chromium	6	32	2800	530
Copper	10	45	1700	380
Mercury	1500	8400	11	1.4
Molybdenum	180	1700	94	1.2
Nickel	40	210	420	80
Lead	15	75	1100	220
Selenium	500	2800	34	6
Zinc	4	20	4200	840
<p>a. Acceptability of biosolids will be judged on the basis of the average concentrations of nitrogen, metals and solids during the preceding 12 months.</p> <p>b. All dewatered and dried biosolids must meet the appropriate biosolid criteria before dewatering and drying.</p> <p>c. The long term targets are based on the assumption that metal additions to soil from waste materials is undesirable and that application rates of metals should be reduced in the future.</p>				

The allowable limit of land application of materials under the Biosolids Utilization Guideline is also a function of the metal content in the soils. Table 10.4 is reproduced from the Guideline.

Table 10.4
Biosolids Utilization Guidelines Criteria for Metal Content in Soils

1	2	3	4	5	6
Metal	Mean Metal Content in Uncontaminated Ontario Soils (mg/kg)	Maximum Permissible Metal Content in Soils Receiving Waste Materials (mg/kg)	Maximum Permissible Metal Addition to Uncontaminated Soil (kg/ha)	Maximum Permissible Metal Application per 5 years (kg/ha)	Minimum Number of Years to Reach Max. Recommended Metal Content in Soil
Arsenic	7	14	14	1.40	50
Cadmium	0.8	1.6	1.6	0.27	30
Cobalt	5	20	30	2.70	55
Chromium	15	120	210	23.30	45
Copper	25	100	150	13.60	55
Mercury	0.1	0.5	0.8	0.09	45
Molybdenum	2	4	4	0.80	25
Nickel	16	32	32	3.56	45
Lead	15	60	90	9.0	50
Selenium	0.4	1.6	2.4	0.27	45
Zinc	55	220	330	33.00	50

- a. Based on dry weight at 105 C.
- b. Columns 4 and 6 take into account the mean metal content of uncontaminated soils (see column 2). These numbers are examples because most soils are unlikely to have exactly the mean metal contents listed in column 2.
- c. Based on anaerobic biosolid applications providing 135 kg/ha of ammonium plus nitrate nitrogen, or aerobic biosolids applications providing 8 tonnes of dry solids per hectare per 5 years, as outlined in these Guidelines. The number of years is rounded to the nearest five.
- d. Column 4 divided by column 6 will give metal application for one year. To obtain the figures in column 5 the yearly metal application figures are multiplied by 5.

The Biosolids Utilization Guidelines also contain criteria for sodium and requirements for minimum separation distances from watercourses, residential areas, and height above the water table.

10.6 Nutrient Management Act

There is currently legislation (Bill 81) being debated that will potentially lead to the harmonization of quality standards for all materials to be applied to agricultural land. The

legislation will likely be called the Nutrient Management Act. The Act had not yet been finalized at the time of writing of this report, but is expected to become law by the summer of 2002.

It is expected that the new legislation will regulate land application on a site-specific, case-by-case basis, via the requirement for nutrient management plans.

10.7 Biogas Transmission Rights

If the biogas is to be piped to an offsite user, there may be an issue of ownership rights. Enbridge Consumers Gas has the rights for distribution of all natural gas in its franchise areas. This would not normally extend to biogas, but in the case of Toronto specifically, Consumers Gas had acquired the rights to the producer gas that was formerly used in the city, with the result that it may hold the rights to any kind of gas distributed in the Portlands. Therefore, it may be necessary for Enbridge to own and operate any offsite distribution system for biogas. This issue would require further investigation if the City were to proceed with this option.

10.8 Biogas Pipeline Standards and Codes

For the handling and transport of biogas from the AD facility site to the Boralex facility or any other potential end user, all codes and standards relevant to the processing, handling and transport of digester gas must be followed.

Design requirements for biogas have evolved over the past 25 to 30 years. Current codes and regulations place particular emphasis on life safety and minimizing fire and explosion hazards.

The following is a list of applicable codes and standards:

- The Ontario Building Code
- The Ontario Fire Code
- The Ontario Health and Safety Act
- CAN/CGA B105-M93 Code for Installation of Digester Gas and Landfill Gas Systems (to be changed in next edition to CAN/CSA B149.6)
- The Ontario Technical Standards and Safety Act 2000, O. Reg. 210, Oil and Gas Pipeline Systems
- NFPA 820 Standard for Fire Protection in Wastewater Treatment and Collection Facilities
- NFPA 101 Life Safety Code
- NFPA 68 Guide for Venting of Deflagrations
- C22 Canadian Electrical Code Part 1, Safety Standards for Electrical Installations

The design of the biogas handling and transport system must follow the requirements of these codes. In developing the description of a pipeline transport system in Chapter 9, it was assumed that piping materials and procedures would be the same as those used by Enbridge Consumers

Gas, which deals extensively with gas pipelines and is required to be in compliance with these standards for all installations.

The engineer responsible for the detailed design of the project will be required to ensure that the installation is in compliance with the codes and standards listed above.

11. Conclusion and Recommendations

The results of this feasibility study are summarized in Table 11.1, which presents the approximate costs and outputs of energy and materials of a proposed anaerobic digestion plant in the Portlands, processing each of the four projected waste streams.

Table 11.1
Data Summary Table – Portlands Anaerobic Digestion Plant Scenarios

	30% Unintentional Material (100,000 tpy)	30% Unintentional Material (200,000 tpy)	10% Unintentional Material (100,000 tpy)	10% Unintentional Material (200,000 tpy)
Process (Single Stage)	Wet / Mesophilic	Wet / Mesophilic	Dry / Thermophilic	Dry / Thermophilic
Products:				
Biogas (m ³)	8,960,000	17,920,000	9,620,000	19,261,000
Digestate (tonnes)	49,000	98,000	56,000	112,000
Wastewater (m ³)	21,000	42,000	33,000	66,000
Plant:				
Capital Cost	\$36,385,000	\$66,200,000	\$32,420,000	\$58,690,000
Annual Capital Charge (8% interest, 20 years for buildings & tanks, 15 years for equipment)	\$3,979,079	\$7,266,523	\$3,558,311	\$6,478,099
Annual Operating Cost	<u>\$6,440,000</u>	<u>\$11,500,000</u>	<u>\$5,470,000</u>	<u>\$9,580,000</u>
Total Annual Plant Cost	\$10,419,079	\$18,766,523	\$9,028,311	\$16,058,099
Energy Utilization System:				
Capital Cost	\$1,976,400	\$3,457,800	\$1,976,400	\$3,457,800
Annual Capital Charge (8% interest over 20 years)	\$201,395	\$352,350	\$201,395	\$352,350
Annual Operating Cost	<u>\$82,400</u>	<u>\$137,000</u>	<u>\$82,400</u>	<u>\$137,000</u>
Total Annual Energy Utilization System Cost	\$283,795	\$489,350	\$283,795	\$489,350
Possible Revenues:				
Gas Sales Revenue (\$6/GJ)	(827,000)	(1,654,000)	(1,035,000)	(2,070,000)
GHG Credit Revenue (\$2/tonne eCO ₂)	(36,800)	(73,600)	(37,400)	(75,800)
Net Annual Cost (Plant Plus Pipeline Less Revenues)	\$9,839,074	\$17,528,273	\$8,239,706	\$14,401,649
Net Cost Per Tonne	\$98	\$88	\$82	\$72

The table shows that a plant in the Portlands could cost from \$72 to \$98 per tonne to process organic waste, depending upon the size of the plant and the waste stream to be processed.

The specific assumptions on which these unit costs are based are as follows:

Plant Location:	Site A
Energy Utilization:	Gas piped offsite for use at Boralex facility.
AD Plant Energy Sources:	Biogas used for in-plant heat requirements, electricity purchased from outside sources.
Plant & Transmission System Capital Cost Amortization:	Capital costs amortized at an 8% interest rate, over 20 years for the plant buildings and tankage, 15 years for plant equipment (the average useful life – some equipment lasts more than 15 years, while some lasts less), and 20 years for the energy utilization system.
Revenue Assumptions:	Gas selling price \$6.00 / GJ Plant greenhouse gas emissions reduction credit (including carbon sequestration): \$2.00 / tonne eCO ₂
Capital and Operating Costs:	As per details in Report. Note: parts replacement cost is included in operating costs.
Digestate Management Costs (Transportation & Windrow Composting):	Digestate from 10% unintentional material: \$30 / tonne of digestate Digestate from 30% unintentional material: \$35 / tonne of digestate
Residue Disposal Cost:	\$65 / tonne.

The costs are lowest for the facilities processing an organics stream with no more than 10% unintentional material, at \$88/tonne and \$77/tonne, respectively, for the 100,000 tonne-per-year and 200,000 tonne-per-year facilities. This is partly due to the lower front-end contaminant removal costs involved in processing the more purely organic stream, and partly due to the lower tankage volume and energy requirements of a dry process versus a wet process.

11.1 Anaerobic Digestion in the Portlands

The results of this study show that there are sites in the Portlands that are technically suitable for an anaerobic digestion facility. Two of these are City-owned sites located adjacent to existing waste management or wastewater treatment sites. These sites are:

1. Site A
2. Site B

These sites have been found in this study to be the most technically favourable sites in the Portlands for a possible AD facility.

11.2 Accuracy of Cost Estimates

These detailed cost estimates represent the best available data on anaerobic digestion costs, but due to the lack of North American operating data, there are still many areas of uncertainty. Another factor affecting the cost estimates is the uncertainty with respect to the end user of the biogas. It is unlikely that further studies would shed more light on possible costs with any greater certainty than the results presented in this report. The only way to get more accurate cost estimates would be to put out a competitive Request for Proposals to technology vendors and evaluate their submissions.

It should be noted, however, that responding to an RFP is a very expensive process for bidders, and they should be given some idea of the prices that the City is willing to consider. The project team recommends that the City of Toronto put out a competitive RFP, and state within the RFP the upper price limit for a tipping fee that the City would be willing to consider. That way, bidders will have some idea of the scope from the outset and can assess at the outset whether they will be able to meet the City's price expectations.

11.3 Land Use for Waste Management

Clause No. 7 of the Policy and Finance committee report entitled "Environmental Task Force – Environmental Plan Clean, Green and Healthy – A Plan for an Environmentally Sustainable Toronto" was adopted by City Council on April 11, 2000. This document recommends the following for the City of Toronto:

- Reduced greenhouse gas air emissions (recommendation 22);
- Support green power (recommendation 30);
- Promote the use of district heating and cooling (recommendation 32);
- Promote the development of Green Industry (recommendation 38).

Building an anaerobic digestion plant in the Portlands would support all of these objectives, by preventing landfill emissions from organic waste that would otherwise be landfilled and displacing energy generation from fossil fuel sources, providing green power, and supplying an energy source to fuel district heating and cooling equipment.

It should be noted, however, that the "Making Waves" Secondary Plan for the Central Waterfront does not specifically note that waste management facilities are permitted. There are various clauses within the Plan which suggest that "green" industries may be developed within the area. The Plan also states that "a comprehensive set of environmental performance standards for public and private infrastructure, buildings and activities including, but not limited to, energy efficiency, reduction of CO₂ emissions, water conservation, clean air and the three Rs (reduce, reuse and recycle)" will be encouraged. It is expected that not only will many of the existing municipal facilities and green industries be maintained, but that more may actually locate to this area. Having noted this, however, it is to be expected that the siting of some of these facilities

will have to be carefully reviewed in the context of the TWRC's mandate and that performance criteria will be employed to minimize negative impact from the facilities.

11.4 Plant Sizing

This study focused on two possible quantities of waste to be processed: 100,000 tonnes per year and 200,000 tonnes per year. As explained in Chapter 2, most currently operating facilities in Europe are processing waste streams of 50,000 tonnes per year or less. There are not yet any 100,000 tonne-per-year facilities operating in Europe, although several are currently in the construction or commissioning stages. Therefore it is noted that none of the technologies are proven at the scale of 100,000 tonnes. There are no 200,000 tonne-per-year facilities under construction or in commissioning.

Due to the lack of operating facilities at this scale, it may be most effective to proceed with the smaller size, that of 100,000 tonnes per year, at least initially. It may be difficult to get the 200,000 tonnes of suitable waste required to run the larger facility within the catchment area of the facility. Also, the permitting requirements for the smaller facility would also be more expeditious, as it is extremely likely that an individual EA would be required for a 200,000 tonne-per-year facility. Public consultation would be required as part of the application for a Certificate of Approval for a 100,000 tonne-per-year facility, but this would be less costly than the more extensive individual EA.

11.5 Biogas Energy Utilization

This study included an assessment of the costs and technical requirements of sending biogas from the proposed anaerobic digestion plant to the proposed Boralex co-generation facility. It should be noted, however, that Toronto Hydro Energy Services Inc. and Boralex have not made a commitment at this time to accept biogas from the facility. It is expected that the amount of biogas produced by the AD facility would be sufficient to meet less than 10% of the Boralex facility's natural gas requirement. There would be numerous financial and operational issues involved with using biogas at the Boralex facility, including amending the Boralex plant's Certificate of Approval to allow for processing of biogas and equipment upgrades to handle biogas, which has more moisture and non-fuel contaminants than natural gas. It is uncertain whether Boralex would be willing or able to take on the regulatory and operational costs of using biogas to meet a tenth of its energy requirements.

An energy utilization system that includes an onsite boiler and flare, with a pipeline to convey biogas from the proposed AD plant to the Boralex facility would cost between \$1,976,000 and \$3,458,000, depending on the size of the plant, which site was chosen and whether the gas was transported at high or low pressure. This is a first order estimate. Potential difficulties could be encountered in the trench excavation, as the soil conditions throughout the Portlands are not well known. An extensive soil sampling and testing regime would need to be carried out prior to excavation, and if a contaminated "hot spot" were encountered during excavation, the installation activities would need to stop until all contaminated soil was removed. This could add a substantial cost to the project.

The quantity of biogas produced at the proposed anaerobic digestion plant would be sufficient for consideration of the installation of a standalone co-generation unit at the facility. This would

have advantages in providing power to meet the facility's own heat and electrical requirements, which then would not have to be purchased at retail prices. It would also avoid the regulatory issues and financial risks associated with building a pipeline from the plant to the proposed Boralex facility, and would not depend on acceptance of the gas by the Boralex facility. The existing private anaerobic digestion facility at Newmarket has a co-generation unit that is owned and operated by the engine supplier, which has the potential to sell power to the electrical grid using biogas from the AD plant. The co-gen owner also can sell electricity and heat back to the AD plant at a rate lower than that at which the plant would have to purchase it from the grid. This may be a possibility that the City of Toronto could consider for the utilization of biogas from a facility in the Portlands.

The Ashbridges Bay Treatment Plant could also be considered as an end user of the biogas, since it already has an energy generation system (boiler) designed for digester gas, which is very similar to biogas from anaerobic digestion. Utilization of the biogas at the ABTP could be much less problematic than use of the biogas at the Boralex facility, and this possibility should also be considered.

11.6 Emission Reductions

There would be significant greenhouse gas emissions reductions resulting from an AD plant. However, emission credit revenues, if any, are not likely to be sufficient to have a significant effect on the overall economics of a plant in the Portlands, as evidenced by Table 11.1.

11.7 Strategic Direction for Waste Management

The variables with respect to uncertainties such as the end user of the biogas, and whether the City will expand its Dufferin pilot AD facility to 100,000 tonne-per-year capacity, lend uncertainty to the planning process for a facility in the Portlands. The first step in moving forward with such a facility is to address these unknowns and make decisions on the direction the City wishes to take.

If the City is to concentrate capacity at the Dufferin facility, a facility in the Portlands would not be required for the next few years, and therefore further investigation of this possibility is not warranted. If, however, the City decides to pursue the Portlands AD option, then it is necessary to move forward with the next steps, which include public consultation and solicitation of proposals. The prerequisite to any further action on a Portlands facility is that the City make the decision on which direction it wishes to take for the processing of organics in Toronto.

11.8 Recommendations

The purpose of this project is to develop cost estimates and identify the energy and environmental benefits of several anaerobic digestion facility options. The information developed in this study can then be incorporated into other energy-related feasibility studies. (Note: the purpose of this project is not to assess the overall feasibility of an AD facility in the Portlands.) Given this background, the following recommendations are provided:

1. The City should determine whether to move forward with a Portlands AD facility, or to concentrate organics processing capacity at the Dufferin site. This would be done after a comparison of waste management system costs with and without an AD facility in the Portlands was carried out. The remaining recommendations are contingent on a decision being made to pursue the Portlands option.
2. The options for biogas use in the Portlands should be investigated with respect to which options are most viable. This would include discussions with Toronto Hydro (regarding Boralex), the City's wastewater division (regarding Ashbridges Bay), Ontario Power Generation (regarding reopening of the Hearn plant), and energy developers (regarding onsite co-generation). Following these investigations a decision should be made to focus planning efforts on one of these options.
3. If the City plans to proceed with a facility in the Portlands, it should immediately initiate a comprehensive public consultation program on the proposal to ensure that interested stakeholders are informed about the project and have an opportunity to provide input during the early planning stages of the project.
4. The City should focus planning efforts on a 100,000 tonne-per-year facility in the Portlands, which could later be expanded to 200,000 tonnes per year if conditions are favourable. The smaller plant is recommended due to concerns regarding the quantity of organic material that will be available to the facility, lack of operating data for very large scale facilities, and a less complex permitting and approvals process.
5. The City should investigate the options available for secondary management (i.e., off-site windrow composting) of digestate from an AD facility in the Portlands or elsewhere.
6. If an anaerobic digestion plant is to be built in the Portlands and following the selection of an appropriate site, the City should issue a competitive Request for Design, Build, Own and Operate Proposals from potential suppliers. The RFP should include an upper maximum price per tonne that the City is willing to pay, on a put-or-pay basis, at such a facility.