The feasibility of an on campus biogas operation at the University of Waterloo.

Presented to Prof. Jim Robinson and WAT Green Advisor, Patti Cook
ERS 317

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1. Introduction

Currently only 1% of Ontario Power Generation's (OPG) is generated by green electricity (OPG 2005). In order to phase out nuclear power we feel that creating an Organics Processing Facility to create biogas will be more cost effective, cut down on landfill waste, generate a high-quality renewable fuel, and reduce carbon dioxide and methane emissions (biogasworks 2000). It is our intent to implement an Organics Processing Facility on the north campus of the University of Waterloo. By addressing the needs for alternative power generation the biogas operation would reduce emissions of methane and carbon dioxide, and would thereby meet the goals of the Kyoto protocol. By implementing this proposal the university would be saving money in the long-term, cutting down on campus waste, and setting a president for other universities to follow suit. Furthermore, it creates learning opportunities for various facilities such as: ES, Engineering, Business, and Biology to name a few. In order to evaluate the feasibility of creating a biogas operation on campus we looked at the economics, funding, and conducted various interview to surrounding food markets and restaurants. We also interviewed a number of local farmers to ask if they would be interested in the Biogas benefits though receiving fertilizer for their fields. Overall by creating a biogas operation on campus it is a beneficial situation for all stakeholders.

2. Background on biogas production

2.1 Biogas production

Biogas is a gas consisting of mainly methane and carbon dioxide. It is produced under anaerobic decomposition through three phases:

1. Hydrolysis: saprophytic bacteria converts complex organic compounds into less complex organic compounds, which are water-soluble
2. Acid formation: acid forming bacteria degrades organic compounds to volatile fatty acids and ammonia
3. Methane formation: methane forming bacteria utilizes these acids to form methane (CH_4) (Veziroglu, 1991)

The net formula for the biogas production is:

$$C_aH_bO_cN_d + {}^{(4a-b-2c+3d)}/4 \quad H_2O \rightarrow {}^{(4a+b-2c-3d)}/8 \quad CH_4 + {}^{(4a-b+2c+3d)}/8 \quad CO_2 + d \; NH_3.$$

(Veziroglu, 1991)

All kinds of organic waste can be used in a biogas plant such as: kitchen waste and garden waste, cattle dung and sewage. The efficiency of the biogas production is affected by the following factors: Carbon: Nitrogen-ratio, volatile solid content, loading rate, temperature, pH, toxicity, dilution, retention time and mixing. The Carbon: Nitrogen-ratio should be between 30:1 and 10:1 (“raw garbage” has 22-27:1). The volatile solids percent (VS) represent the portion of the matter being anaerobically decomposed. In the biogas plant, 0.25-0.70 m^3 biogas per kg volatile solids is produced. The loading rate should be in the range of 1-1.5 kg volatile solids/ m^3 digester/day, the pH should be between 7 and 7.4 and the dilution with water 1:1. (Veziroglu, 1991) The retention time for mesophilic digestion should be 30-60 days (Werner et al, 1989). Anaerobic decomposition is possible at three temperature ranges: psychrophilic (<30 ºC), mesophilic (30-40 ºC) and thermophilic (50-60 ºC). As can be seen in figure 1 biogas production increases with higher temperature and longer retention time.

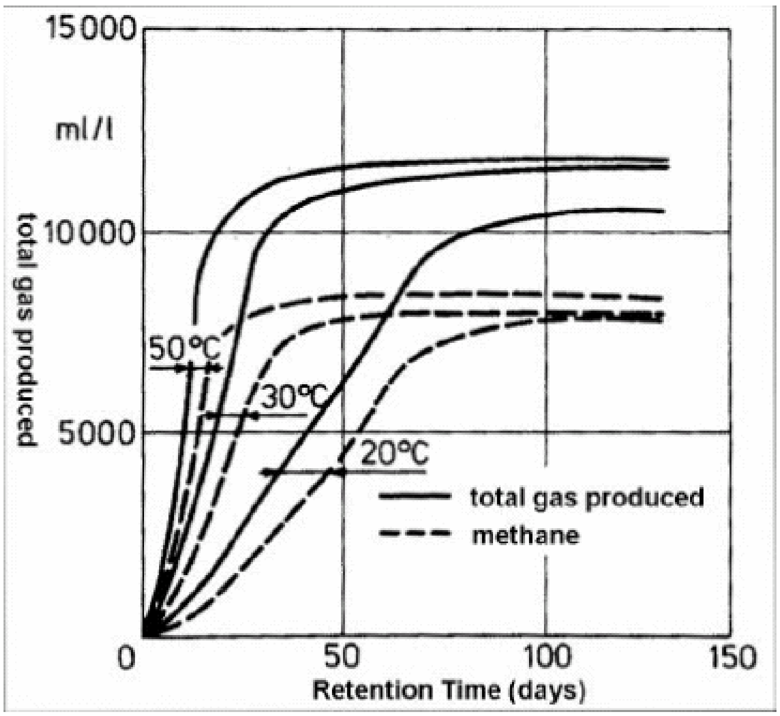

Figure 1: Gas yield of sewage sludge in function of retention time and temperature (Wellinger, 1999)

In Canada mesophilic degradation seems to be most feasible, since psychrophilic decomposition results in poor biogas production, while thermophilic is too expensive because of the heating costs. A decrease in gas production has been reported during the winter due to lower temperatures (Yadvika et al., 2004), so even a biogas plant with mesophilic bacteria would have to get heated in the winter months.

There are different techniques to enhance biogas production (Yadvika et al., 2004). These include: use of additives; recycling slurry; variation in operational parameters like temperature, hydraulic retention time (HRT) and particle size of the substrate; and the use of fixed film / biofilm. (Yadvika et al., 2004)

Different sources give different values for biogas production per amount of organic input: Veziroglu (1991) gives 0.45-0.65 m^3 gas produced per kg food waste with a methane content of 60-65 %. 1 m^3 biogas equals 5200-5900 kcal of heat energy which equals 1.25 kWh of electricity. (Veziroglu, 1991) Baier (2005) indicates that pure food residues with 30 % TR and 90 % oTR will give about 500-600 m^3 biogas per t oTR or 150-200 m^3 biogas per t waste. This biogas will have a methane content of 65-70 %. (Baier, 2005) Werner et al. (1989) give 0.3-0.6 m^3 biogas per kg VS. Hobsen (1993) points out that the biogas produced should get used in Combined Heat and Power units (CHP) to get the highest efficiency possible.

2.2 Bi-products from the biogas production:

The sludge is very rich in nutrients, which makes it a good fertilizer and dietary supplement to cattle and poultry feed. (Veziroglu, 1991) It has the original Nitrogen (N), Phosphorous (P), Potassium (K)-value, the C:N-ration is reduced and many of the nutrients have been mineralized, which increases the fertilizing effect (Werner et al, 1989). Also, the odor is markedly reduced. The slow decomposition preserves the fibred structure, which makes it a good soil conditioner, and leaves readily available ammonia nitrogen to plants. The sludge is free of weed seeds and pathogens. Salmonella, Shigella, Polivirus, Hookworm ova, and Schistosoma ova have a 100 % fatality rate after 10 days in a mesophilic digester (Werner et al, 1989). The sludge can then be used instead of synthetic fertilizer with co benefits such as reduced energy consumption, reduced air pollution etc. (Hobsen, 1993). The spent liquor can be disposed in a tank to be reused for fish cultures, irrigation, water plants etc. (Veziroglu, 1991)

2.3 The structure of a biogas plant:

A biogas plant consists of basically of two parts: the digestion chamber and the gas storage chamber. Most of the biogas plants have in addition a pre-chamber, where the different components get mixed, and a post-chamber, where the sludge "ripens". An example of a biogas plant is shown in figure 2. There are 2 different types of biogas plants: the batch digester, where the organic waste stays in the tank for some time and is then replaced after gas production; and the continuous digester, where new slurry is fed every day. The continuous type is more efficient with a higher gas production rate per digester volume. [1] In our case it would also be more feasible because waste accrues every day.

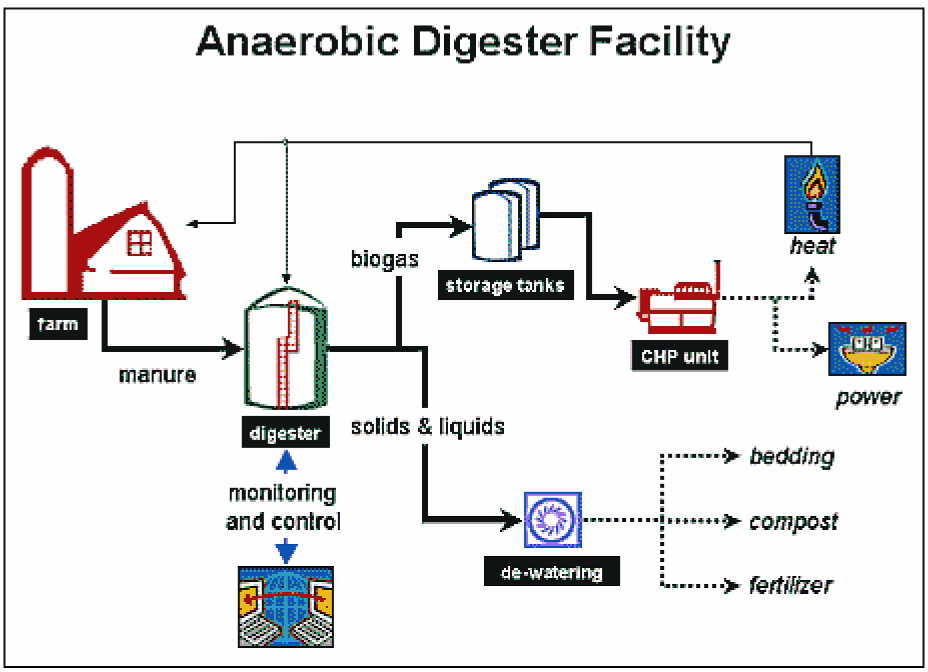

Figure 2: Flow chart of a biogas plant (Microgy)

2.4 Determining the size of the digester

The reactor dimensions and biogas potential depends on:

- The type of substrates to be digested
- The quantity of each in metric tonnes per year
- The total solid content in percentage
  Total solids content (TS) = 100(%)-water content (%)
- The organic content in percentage: Organic dry matter content is determined by incinerating the dried sample at 550°C for six hours and weighing the remaining ashes.

$$\text{Organic content (ODM)} = \frac{\text{(mass of TS(g)-mass of ashes (g)*100}}{\text{mass of TS(g)}}$$

(Renewable Energy Technologies, 2005)

The size of the digester (Vd) is determined by the retention time (RT) and the daily substrate input in m^3 (Sd). The following formula can be used in order to calculate the appropriate volume: Vd = Sd x RT (Werner et al, 1989).

For fruit and vegetable waste an average retention time of 40 days is needed. As can be seen in figure 1 is this also in the most efficient range. From the data collected (presented later in this document) a daily waste amount of 630 kg seems realistic for this project. The daily substrate input is about 1260 kg per day which equals 1.26 m^3 (630 kg biomass + 630 kg of water, because of 1:1 dilution). So the digester needs to have a volume of 50.4 m^3 (Vd = Sd x RT = 50.4 m^3).

Another way of calculating the digester size is by Load rate (Ld) which should not exceed 1.5 kg VS/m^3/day (Werner et al, 1989). The volatile solid content (VS) of fruit and vegetable waste is approximately 88 g/kg (Bouallagui et al., 2004). 630 kg of organic waste contain therefore about 55 kg VS/day. Therefore the digester volume needs to be at least 36.6 m^3.

Therefore it is recommended that a digester volume of 50 m^3would be adequate for this site.

2.5 Benefits

Biogas production has many benefits as a form of renewable energy production, sustainable waste management, and fertilizer production. In addition it is a closed loop system. The qualities of the sludge get significantly improved since the odor gets reduced, and weed seeds and pathogens get removed. All together biogas production contributes to a sustainable development.

Comparison biogas production – composting

An alternative to using organic waste for biogas production is composting. However, as indicated in table 1 biogas production has quite a few advantages over composting.

Table 1: Biogas versus compost

Biogas production	**Composting**
- converts organic waste into a valuable product (electricity, heat & fertilizer)	- converts organic waste into a valuable product (only fertilizer)
- uses the energy in the organic matter to produce electricity and heat	- does **not** use the energy
- reduces odor significantly	- can pose odor problems
- stabilizes sludge, mineralizes nutrients, and removes weed seeds and pathogens	- does **not** remove weed seeds and pathogens and does not mineralize nutrients
- helps reduce the CO_2-emission and thereby to reach goals set by the Kyoto protocol	- does **not** have an influence on CO_2-emission

2.6 Case Study: Field Trip

As of May 2004 the Dufferin Organics Processing Facility was officially opened and ready for processing. The facility is located 35 Vanley Crescent, which is in the Northwest end of Toronto (City of Toronto, 2005). During a site visit it was explained that the Dufferin operation is an experimental site in order to evaluate the amount of methane that can be taken from organic waste. This is the first step in a two-step study to convert organics into biogas (City of Toronto, 2005). As of right now, the site is processing 25,000 tonnes of waste per year, and 100 tonnes per day (City of Toronto, 2005). During our site visitation it was brought to out attention that there are three components to the overall material: solicited organic material, plastic bags, and contaminant materials.

The second stage is currently being completed at a privately owned facility located outside of Toronto, Ontario and the digested solids are being put to good use as feedstock for an aerobic composting process, which will produce marketable compost (City of Toronto, 2005).

The Dufferin site has also implemented the green bin program in the GTA, thus allowing the opportunity for residents to compost their organic waste. The green bin program was applied as a method to lower the amount of garbage created in the GTA (Site visit, 2005).

The following table, Table 2, presents the average operating results observed at the Facility from May 2004 to December 2004 (City of Toronto, 2005)

Table 2. Average Processing Results May 2004 to December 2004

Processing (tonnes per day)	95
Residue Rate (percent)	26%
Digested Solids Production (kg/tonne SSO)	266
Biogas Production (m3/tonne SSO)	125
Biogas Flow (m3/hr)	348
Biogas Quality (percent Methane)	55.6%
Biogas Energy Content (MJ/tonne SSO)	2467
Downtime (percent)	17%
Cost per tonne (based on 25,000 tonnes per year)	$121.23

(City of Toronto, 2005)

3. Methodologies

This project will be conducted by using a triangulation method consisting of: literature review, background research/case studies and direct interviews. The literature review and background research will provide an initial overview of biogas. These sources will describe what biogas is, how it is produced, and how it could be used. The literature review transcribes what studies have been done in reference to biogas and current projects using biogas technology. To increase the validity of the project, only recent journal articles were reviewed.

Background research and case studies were reviewed and will serve as a comparison to the potential UW project and provide information as to the size, capacity, and type of biogas plant that would best suit UW and the Region of Waterloo.

Interviews were conducted to several local potential donators of organic wastes including farmers, restaurants, and food markets. The interview questions were reviewed and passed by University of Waterloos Office of Research Ethics. Approval from the Research Ethics office was needed to interview businesses and farmers. Consent forms, interview questions, information form and feedback forms were created for Ethics clearance. These forms can be found in Appendix A through C.

Interview participants were selected from criteria which were based on the proximity of the participants to the potential plant, and the volume of wastes that could be collected. For example, only a few restaurants were contacted because those were directly adjacent to the university. Minimal waste could be collected from such operations as compared to farmers' wastes. Participants were contacted via telephone, or e-mail. A series of questions were asked regarding where the waste goes currently and whether they would be willing to donate their organic waste if it was picked up free of charge and the sludge donated to local agricultural farms. The collected data was taken and assessed to determine extra amounts of organic waste needed for the biogas plant. The economic feasibility of the biogas plant was conducted with all data collected. This will be followed by a discussion, recommendations and alternatives for the feasibility of this project.

This method of triangulation attempts to use the most recent and innovative technologies to minimize potential operational and start-up problems. This method also emphasizes the benefits a biogas operation would have on the local community and the University of Waterloo.

Literature Review

Literature found for biogas and other related topics were mainly from Europe. The use of biogas and other biofuels have yet to take hold in North America. One reason why it is not as widespread as it is in Europe is its reputation of instability during start-up and operation (Jantsch & Mattiasson, 2004). However, with the ratification of the Kyoto Protocol, which commits Canada to reducing its greenhouse gas (GHG) emissions by 20% by 2012, biogas seems a viable option (Warren, 2004). Biogas is a readily available resource that significantly reduces greenhouse-gas production as compared to the emission of landfill gas to the atmosphere (Murphy, McKeog, & Kiely, 2004).

One study investigated the reactivity of methane. It concluded that it has more than 20 times the global warming potential of carbon dioxide and that the concentration of it in the atmosphere is increasing with one to two per cent per year (Kumar et al., 2004). The article continues by highlighting that about 3 to 19% of anthropogenic sources of methane originate from landfills.

As Taleghani and Kia (2005) observed, the resource limitation of fossil fuels and the problems arising from their combustion has led to widespread research on the accessibility of new and renewable energy resources. Solar, wind, thermal and hydro sources, and biogas are all renewable energy resources. But what makes biogas distinct from other renewable energies is its importance in controlling and collecting organic waste material and at the same time producing fertilizer and water for use in agricultural irrigation. Biogas does not have any geographical limitations or requires advanced technology for producing energy, nor is it complex or monopolistic (Taleghani & Kia, 2005). Considering the ever increasing amount of organic waste the University of Waterloo produces, that is waste that can be utilized, biogas is a viable option.

Murphy, McKeog, and Kiely (2004) completed a study in Ireland analyzing the usages of biogas and biofuels. This study provides a detailed summary of comparisons with other fuel sources with regards to its effect on the environment, finical dependence, and functioning of the plant. One of the conclusions the study found was a greater economic advantage with utilizing biofuels for transport rather than power production; however, power generation was more permanent and has less maintenance demands.

Lissens et al. (2004) completed a study on a biogas operation to increase the total biogas yield from 50% available biogas to 90% using several treatments including: a mesophilic laboratory scale continuously stirred tank reactor, an up flow biofilm reactor, a fiber liquefaction reactor releasing the bacteria *Fibrobacter succinogenes* and a system that adds water during the process (Lissens, et al., 2004; and Lopes, Leite, & Prasad, 2004).

These methods were sufficient in bringing about large increases to the total yield; however, the study was under a very controlled method, which leaves room for error when used under varying conditions. However, Bouallagui et al. (2004) did determine that minor influxes in temperature do not severely impact the anaerobic digestion for biogas production. Another study by Thomsen et al. (2004) found that increasing oxygen pressure during wet oxidation on the digested biowaste increased the total amount of methane yield. Specifically, the yield which is normally 50 to 60% increased by 35 to 40% demonstrating the increased ability to retrieve methane to produce economic benefits (Thomsen et al, 2004).

One study looked at the feasibility for dairy cow waste to be used in anaerobic digestive systems. Because the animal's wastes are more reactive than other cow wastes, the study suggests dairy cow wastes should be chosen over other animal wastes (Carrasco et al., 2004).

Jantsch and Mattiasson (2004) discuss how anaerobic digestion is a suitable method for the treatment of wastewater and organic wastes, yielding biogas as a useful by-product. However, due to instabilities in start-up and operation it is often not considered. A common way of preventing instability problems and avoiding acidification in anaerobic digesters is to keep the organic load of the digester far below its maximum capacity. There are a large number of factors which affect biogas production efficiency including: environmental conditions such as pH, temperature, type and quality of substrate; mixing; high organic loading; formation of high volatile fatty acids; and inadequate alkalinity. These must be determined through monitoring the system. Taking pH samples for monitoring, which indicates the bicarbonate concentration, has in many cases been found to be a good variable to monitor. The study demonstrates the potential for monitoring anaerobic digesters, as it responds to the alkalinity in the digester, as well as being stable over a relatively long time span with few maintenance requirements (Jantsch & Mattiasson, 2004).

Meres, (2004) also looked into factors effecting biogas production. He found that in order to achieve optimum efficiency of utilization, it is of paramount importance that biogas production and composition is constant. Low air temperature and high cumulative precipitation, factors effecting biogas production, mainly decrease the permeability of the outer layers and do not significantly influence the biological processes in the entire waste mass. Low permeability of the outer layers lowers the biogas emission into the atmosphere, and may thus enhance the quality and volume of biogas getting to the installation. The other important climatic variable is the atmospheric pressure, which influences the vertical and lateral flow of biogas. High atmospheric pressure lowers the volume of biogas emitted to the atmosphere and increases the methane concentration of the biogas collected in the network (Meres, 2004).

Taleghani and Kia, (2005) outlined the economic, and social benefits of biogas production. The economic benefits were as follows:

1. Treatment of solid waste without long-term follow-up costs usually due to soil and water pollution
2. Increased local distribution of fertilizer, chemical herbicides, and pesticide demand
3. Generation of income through compost and energy sales (biogas/electricity/heat) to the public grid
4. Improved soil/agriculture productivity through long-term effects on soil structure and fertility through compost use
5. Reduction of landfill space and consequently land costs

The social and health effects associated with biogas include:

1. Creation of employment in biogas sector
2. Improvement of the general condition of farmers due to the local availability of soil-improving fertilizer
3. Decreased smell and scavenger rodents and birds

(Taleghani & Kia, 2005)

Overall commonalities in the literature suggest Europe and parts of middle-eastern nations, such as Iran, and India are far more interested in biogas production than Canada. However, this provides an excellent opportunity for Canada. Numerous studies have been conducted to increase the productive yield of methane and to work out several operational problems that other sites encountered. Canada can learn from their mistakes and begin biogas production to reduce the amount of GHG emissions they produce in coinciding with the Kyoto Protocol Accord.

4. Organic waste

4.1 On campus

Based on past WATGREEN projects, 6 tonnes of organic waste is produced on campus per year (the equivalent of 16 kg per day).

4.2 Off campus

Based on the information collected during interviews, the grocery stores will supply the plant with 3840.8 kg of organic waste per week (the equivalent of 548 kg per day) and the two restaurants (Mongolian Grill and East Side Mario's) will produce 66 kg of organic waste per day.

Mongolian Grill

According to Charles Bye, Kitchen Manager of Mongolian Grill, there is approximately 30 kg of food waste produced Monday and Tuesday. Wednesday, Thursday, and Sunday there is approximately 50-60 kg of food waste is produced each day. On Friday and Saturday the waste produced can reach up to 60-70 kg a day (see Table 2).

Currently, the organic food waste goes to the landfill and there is no recycling program in place. They are willing to contribute to the biogas plant as long as there are no extra associated costs and easy for them (Bye, 2005).

Table 2: Data collected from Mongolian Grill

Mongolian Grill	Kg	Avg. Kg
Sunday	50-60	55
Monday	30	30
Tuesday	30	30
Wednesday	50-60	55
Thursday	50-60	55
Friday	60-70	65
Saturday	60-70	65
	Total	**~355**

East Side Mario's

East Side Mario's manager, Dave Ambrose, explains that the restaurant produces approximately 30 lbs. of food waste from Sunday to Friday each day. On Saturday the waste can reach up to 60 lbs (see Table 3). There is not any composting system currently in place but East Side Mario's manager said that they are willing to contribute to the biogas plant as long as there are no extra costs and free pick up.

Table 3: Data Collected from East Side Mario's

East Side Mario's	Kg	Avg. Kg
Sunday	13.6	13.6
Monday	13.6	13.6
Tuesday	13.6	13.6
Wednesday	13.6	13.6
Thursday	13.6	13.6
Friday	13.6	13.6
Saturday	27.2	27.2
	Total	**108.8**

There is approximately 465 kg of food waste produced per week from these two restaurants. In total, there is about 24 tonnes of waste produced each year. If all restaurants in the plaza were to participate in this study, this number would be much higher (Ambrose, 2005).

5. Interview results

5.1 Restaurants in University Plaza

Mongolian Grill and East Side Mario's were interviewed to assess the number of food waste produced each week. These two restaurants were chosen with the assumption they generate the most waste out of all the restaurants at University Plaza because of their size. These restaurants are a representative of all restaurants in the plaza and one could estimate the number of waste the plaza produces each week. One must take into consideration that not all restaurants in the plaza would participate for their own reasons.

5.2 Farmers

In general, there was a negative response from the farmers. We contacted seven local farmers and inquired about their operation and whether or not they had extra manure or organic waste that they would be willing to supply us with. The farmers did not have enough extra waste and, therefore, were not willing to participate in our project. Cash crop farmers leave all their remains from the crop on the field so that it decomposes and creates nutrients in the field for the following year. Livestock farmers use the manure as a nutrient base and spread it over fields (Herrle, 2005). Each livestock farmer had enough land so that they did not have excess manure. When it was suggested that they receive the sludge produced from the plant they were also not interested.

5.3 Local Grocery stores

In total there were twenty stores identified viable for donating their organic waste for the UW feasibility biogas operation plant. These stores included: Zehrs, Sobeys, Price Chopper, Value-Mart and Food Basics. Store Managers were called, as identified in the methods section, and asked various questions about the organic waste that each store produces on a weekly basis.

Of the twenty stores, ten stores were available to answer questions. Nine of the ten stores currently used a private company that picked up the waste for a fee, and recycled that material. Actual usages of the waste were unknown by some store managers, whereas other believed the waste to go to various locations including: local farmers, composting facilities, or dog food producing plants. The remaining store that was not interested in the study feared of liability issues, and contaminant problems. The waste produced in that store contributes to the waste facility on Erb Street.

Of the nine interested stores, one was willing to donate the waste immediately to the proposed UW Biogas Operation, whereas eight other stores were locked into contracts. All store managers were interested in the project under the agreement that all organic wastes would be picked up free of charge, and the sludge would be donated to local agricultural farms as fertilizers. As mentioned above, eight stores were under contracts with various companies; however, since donating the waste would cut back costs for the individual stores, the managers were very receptive. Contract end dates varied from 2 to 5 years, and some were unable to disclose that information.

Of the nine stores available, each store produced a varying amount of wastes producing a total of 3840.8 kilograms per week. This number is subject to heighten during the summer because more produce is sold from local farmers.

Some limitations were found during the telephone interviews. Some stores were not allowed to disclose any information, others were unavailable to talk, and others did not return phone calls. Despite the 50% success rate of talking with stores, most managers were receptive to the idea and looked forward to hearing news of the new UW Biogas Operation on campus.

6. Economics

6.1 University expenses:

Garbage	
Pick-up fee -	$122,604.00
Tipping fee -	$91,786.50
GST -	+ $8,582.28
Total -	$205,808.22
(Cook, 2005)	

Electricity	
Cost -	8.2 ¢/kWh
Usage -	+78,000,000 kWh/year
Total -	$6,396,000/year in 2004
(Cook, 2005)	

Fertilizer	
Cost/bag -	$26.00
Amount used -	+480 bags (12 tonnes of fertilizers)
Total -	$12,480.00
(Hutten, 2005)	

Total Spending on Campus	
Garbage -	$205,808.22
Electricity -	$6,396,000/year in 2004
Fertilizer -	+$12,480.00
Total -	$6,614,288.22

6.2 Savings at the University of Waterloo:

1. Electricity:

0.5 m^3 biogas per kg food waste (Werner et al. 1989)

1 m^3 biogas = 5200-5900 kcal of heat energy = 1.25 kWh electricity

→ 0.625 kWh per kg food waste

→ 5.125 cent electricity saved per kg food waste

6 tons of food waste per year = 6,000 kg = 30,750 cents = **$ 307.50** saved per year

2. Garbage costs:

Each year the University spends $205,808 (Cook, 2005). About 33 % of this waste is organic waste (Cook, 2005). That makes **$ 68,602** saved. However, the cost of pick up and delivery to the biogas plant also needs to be considered.

3. Sludge:

The sludge could be used on campus instead of bought fertilizer. This will amount to a total savings of **$12,480.00** (Hutten, 2005).

4. Other

Other costs include plant supervision. In larger operations this can amount to $10, 000 to $20,000 annually (SERC, 2005). Therefore, there may be other costs such as wages that need to be considered. Pick up and delivery to the biogas plant also need to be considered. During the winter month there might be a need for heating the tank in order to keep the methane producing bacteria active (SERC, 2005). This means that the University will increase their spending on electricity. However, this cost will be compensated for the methane produced which can be used for energy.

This makes a total of $ 81,389.00 saved per year. This number does not include additional costs that might occur after the construction of the plant (i.e. wages, heating, and garbage pick-up).

The building cost of UW's biogas plant cannot be determined based on present data. This is due to the size of the biogas plant. Since there is a limited amount of waste collected (630 kg/day), the biogas plant would only need to be $50m^3$ in size.

6.3 Case Studies

Humboldt Dairy Farms

Costs for Building:

Plug Flow Digester (400 dairy cows)

Installation -	$200,000.00	to	$400,000.00
Maintenance (annually) -	+ $10, 000.00	to	+ $20,000.00
Total (first year) -	$210,000.00		$420,000.00

(SERC, 2005)

Savings:

In a digester of this size and type, 4 million to 6.4 million cubic feet of biogas and 124,000 to 198,000 kWh per year of electricity can be produced. This resulted in cost benefits of: $11,100 to $23,800 a year in avoided electrical costs; an annual income of $4,800 to $8,000 from fibers produced; and manure pit maintenance costs reduced by $9,000 per year. This makes a payback period of 5.6 years (SERC, 2005).

Texas Cow farms

Cost for Building:

The digester is 18 ft wide by 104 ft long and is V-shaped at bottom. It is 8 ft deep at the sides and 12 ft 10 in deep at centerline. This makes a liquid volume of 110,000 gallons = 416.4 m^3. This is for a farm of 400 cows. There is a 15 year life expectancy, expect the engine is expected to last for five years (Engler 2003.).

Table 4: Cow Manure Energy Analysis

	110,000 gallon facility **(Cow Manure)**	
Construction cost range	$149,700.00	
O & M range	$23911/year	
Electricity Revenue (@6.7¢/kWh)	$14,300.00	

(Engler 2003.)

Seattle has also created a biogas plant. Refer to the following tables for the costs and savings (Uhlar-Heffner pg. 40).

Table 5: Economic Analysis for Seattle anaerobic digestion prototype facility

	39,000 Tonnes per Year Facility **(Commercial Food Scraps Only)**	
Construction cost range	$ 8.4 million to $9.9 million	
O & M range	$1.9 million to $2.2 million/year	
Electricity Revenue	$245,000 to $325,000	

(Uhlar-Heffner pg. 40)

Table 5 (continued): Economic Analysis for Seattle anaerobic digestion prototype facility

	51,000 Tonnes per Year (Commercial and Residential)
Construction cost range	$9.4 million to $11.1 million
O & M range	$1.6 million to $1.7 to million/ yea
Electricity Revenue	$245,000 to $325,000

(Uhlar-Heffner pg. 40)

There is also the cost of a generator that needs to be considered. In general, a 25 kW generator costs $96,000.00 but has the highest installed cost/kW of installed generating capacity. Generators that are greater then 25 kW costs approximately $300,000.00 but has the lowest cost/kW of installed electric generating capacity (Lusk 1998).

Efficiency:

With every tonne of manure put in the digester there will be a return of approximately 30 cubic meters of biogas product. However, when the manure is blended with oils and other food wastes there is a return of 200 cubic meters per tonne. Therefore, it is beneficial to mix food waste with manure and oils (Lusk 1998).

7. Subsidies/Funding:

Canada is fortunate enough to have a well established funding program subsidizing clean energy projects. In many respects, this varies from the American funding programs. Unlike the United States, the major Canadian clean energy funds tend to operate nationally, with division of responsibilities lying in the type of projects they support (Fitzgerald et al, 2004). To contrast this, the American government relies on geographic boundaries. Another difference between American and Canadian funding programs is the broader scope of Canadian projects. This calls for more initiative and allows many different projects get underway rather than just a narrow specific type. Lastly, Canadian projects rely on partnerships between numerous parties such as federal and municipal governments, as well as private and academic partnerships (Fitzgerald et al, 2004).

One such organization to give out funding is the Federation of Canadian Municipalities (FCM 2005), who is "dedicated to improving the quality of life in all communities by promoting strong, effective and accountable municipal government" (FCM, 2005). They created the Green Municipal Funds to increase investment in environmental projects among Canadian municipalities and their public or private sector partners. The two programs are The Green Municipal Enabling Fund, and The Green Municipal Investment Funds.

The Green Municipal Enabling Fund gives out grants for feasibility studies and field tests of renewable energy products. Projects can be funded up to 50% of their costs for a maximum total of $350,000 (Fitzgerald et al., 2004). To be eligible for this funding, the project has to entail an on-site energy generation and cogeneration biomass projects which will meet a community's needs. The Wastewater Treatment Biogas Cogeneration Plant in Red Deer Alberta has received $60,000 for the construction of a cogeneration facility and wastewater treatment centre (Fitzgerald et al., 2004). The plant is now fueled by biogas, which eliminates the loss of this gas to the atmosphere and eliminates the usage of natural gas within the plant (Fitzgerald et al, 2004).

The second type of funding that FCM provides is the Green Municipal Investment Funds which acts as a loan for companies. FCM lends funds to municipalities at the Government of Canada bond yield minus 1.5% annually with terms of 4 to 10 years (Fitzgerald et al., 2004). They lend to private sector partners of municipalities and can cover up to 25% of project. The project must have an investment return of 10 years or less, except for extreme circumstances (Fitzgerald et al., 2004). The Waste Wood Biomass Utilization in Revelstoke, British Columbia received both a loan and a grant, each worth $1,348,000 (Fitzgerald et al., 2004). Funding covered half of the cost of the construction of a new heating plant and district heating system. This project would not have been feasible without the financial assistance of FCM.

Another funding program, The Sustainable Development Technology Canada (SDTC) will pay for 35% of the project costs and up to 50% of the project costs.

In order for our project to receive funding from either source, there would need to be a significant contribution to the community. Perhaps, this has been accomplished because the project is already connected to the University of Waterloo community, which impacts the overall community of Kitchener-Waterloo. The Green Municipal Enabling Fund would be most beneficial to our project as we may never have enough money to pay back the FCM.

8. Limitations

From our research we have found that there are several limitations for the production of a biogas plant. These include: time constraints; lack of organic waste in order to make it profitable; not enough interest; location; costs – not enough government subsidies so that there is a large initial price; and lack of initiative by the university. Firstly, time constraints are an issue because there are only four months to conduct the entire feasibility study which included the background research, interviews, and analysis among others. If this project were to take place it would require much more in depth research.

Another limitation to the project is the lack of organic waste accumulated on campus. There are only six tonnes accumulated on campus. In order to make the biogas plant the most efficient there would need to a total of 5000 tonnes more waste collected per year (Mulert 2005). However, we have tried to offset this limitation by extended our waste collection to off campus restaurants, grocery stores, and farms.

We also found that there was not much interest in participating in a biogas plant. The farmers do not accumulate enough extra waste to supply our biogas plant and it would be an extra hassle for it to be collected and transported to our on campus biogas plant. Although grocery stores did seem interested, they were limited by contracts they had signed for garbage collection. This is just a temporary limitation because they would be willing to participate once the contracts expire. Several of the restaurants were interested in our proposal; however, others did not have time to work with us and learn about the project. The location of the biogas plant is also an issue. The community may not support the construction of a biogas plant due to concern of odor. Also, the location was not convenient for the farmers because they would have to transport their waste into town. Costs of construction are also a major limitation. There are not large enough subsidies to offset the initial price of construction. There would not be the support needed from the school to build a biogas plant without larger subsidies. There would need to be more initiative from the university.

9. Recommendations

There are several recommendations that can be implemented to increase the amount of food waste for the biogas plant. Most of these recommendations for improvement focus on local community contributions. It would be beneficial if the City or Region of Waterloo setup a compost program for residential areas. Food waste from all commercial areas within the City or the Region would also generate a substantial amount for the biogas plant. Also, creating incentives for all area farmers to contribute would add more organic waste to the biogas plant.

Community awareness and promotion is another recommendation to educate the community about biogas technology. People who understand the concept of biogas would most likely help by contributing waste to the plant.

The City or Region of Waterloo may want to have a joint project with the University since they are involved. This would provide extra resources and alleviate costs to the University. The City or Region could find land and transportation of food waste to the biogas plant. The University could take part in design of the biogas plant since there is an abundant source of faculty and students from engineering, environmental, and science faculties. This could also lead to new technologies discovered through innovative thinking from the University body.

Additional government funding would also reduce construction and operational costs. This would promote a greener image of Canada as a supporter of Kyoto Protocol.

10. Conclusions

Using the decided method of analysis, the UW biogas feasibility operational plant was discovered to be not feasible. This small scale operation required large amounts of organic waste, which is much larger than could be potentially accumulated by local restaurants, farmers, and grocery stores. As discussed in the limitation section, there were gaps in our interviews from people who were not interested participating in our study.

Despite the unfortunate conclusion that a biogas operation is currently not feasible, the outlook is not hopeless. The increased frequency and popularity of biogas operations throughout Europe and Asia, as outlined in the literature review, are helping to add awareness of this green energy source globally by decreasing costs and potential operational and start-up problems. New technologies and innovations must occur in order for Canada's to reach their commitment of reducing greenhouse gas emissions. Biogas is a viable option for renewable energies while reducing the amount of greenhouse gas emissions created. As awareness becomes more heightened in Canada, perhaps the University of Waterloo in partnership with the Region of Waterloo will embrace the benefits of biogas renewable energy.

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Appendix A – Ethics – General Information

A. GENERAL INFORMATION

1. Title of Project: University of Waterloo Biogas Feasibility Study

2. a) Principal and Co-Investigator(s) N/A

3. Project Supervisor(s)

Name	Department	Ext:	e-mail:
Jim Robinson	Environment & Resource Studies	2706	jrobin@watserv1.uwaterloo.ca

4. Student Investigator(s)

Name	Department	Ext:	e-mail:	Local Phone #:
Sara Holzman	Environment & Resource Studies		sholzman@fes.uwaterloo.ca	880-8099
Christine Maass	Environment & Resource Studies		chrismaa@student.matnat.uio.no	725-0849
Torry Reid	Environment & Resource Studies		torry.reid@gmail.com	
Leo Lau	Geography		solidification@hotmail.com	501-8531
Laurel McCarthy	Environment & Resource Studies		lemccart@fes.uwaterloo.ca	880-8099
Breanne Card	Environment & Resource Studies		beecard@fes.uwaterloo.ca	880-8099

5. Level of Project: Undergraduate Course **Specify Course:** ERS 317

Non-Theses Course Projects:

Research Project/Course Status:

6. Funding Status: N/A

7. Is this research a multi-center study? NA
If Yes, what other institutions are involved:
NA

8. Has this proposal been submitted to any other Research Ethics Board/Institutional Review Board? N/A

9. For Undergraduate and Graduate Research:

Has this proposal received approval of a Department Committee? N/A

10. a) Indicate the anticipated commencement date for this project: 1/4/2005

b) Indicate the anticipated completion date for this project: 4/8/2005

B. SUMMARY OF PROPOSED RESEARCH

1. Purpose and Rationale for Proposed Research

a. Briefly describe the purpose (objectives) and rationale of the proposed project and include any hypothesis (es)/research questions to be investigated. Where available, provide a copy of a research proposal:

We want to look at whether it is possible to use the food waste from the University of Waterloo to produce biogas. This biogas could then be used in a Combined Heat and Power unit to produce electricity and heating for the University. The sludge could be used as a fertilizer on campus or could be sold.

The feasibility of the plant is mainly determined by economics, and since it seems to be to little food waste on campus, we would like to look into whether it is possible to mix the organic waste from campus with the organic waste from nearby grocery-stores, restaurants or farms.

b. In lay language, provide a one paragraph (approximately 100 words) summary of the project including purpose and basic methods:

C. DETAILS OF STUDY

1. Methodology/Procedures

a. Which of the following procedures will be used? Provide a copy of all materials to be used in this study.

Interview(s) (in person)
Interview(s) (by telephone)

b. Provide a brief, sequential description of the procedures to be used in this study:

First we want to provide the participants with information about biogas production from organic waste. Then we want to ask them how much organic waste they produce annually and how they dispose it currently. The third question bulk is about whether they would be interested in converting their waste to biogas, and if not, why not.

c. Will this study involve the administration of any drugs? N/A

2. Participants Involved in the Study

a. Indicate who will be recruited as potential participants in this study.
Non-UW Participants:
Adults

b. Describe the potential participants in this study including group affiliation, gender, age range and any other special characteristics. If only one gender is to be recruited, provide a justification for this:

1. Management staff of grocery-stores & restaurants

2. Farmers from the Waterloo-region

c. How many participants are expected to be involved in this study? 1. about 10 2. about 10

3. Recruitment Process and Study Location

a. From what source(s) will the potential participants be recruited?
KW residential community
Businesses, industries

b. Describe how and by whom the potential participants will be recruited. Provide a copy of any materials to be used for recruitment (e.g. posters(s), flyers, advertisement(s), letter(s), telephone script):

Hello, We are students at the University of Waterloo, in Waterloo Canada and are studying in the Department of Environment and Resource Studies. This is a multi-disciplinary program that focuses on environmental systems, policies, and frameworks. As part of our waste Management class, we have been instructed to complete a project involving a waste management initiative involving our campus. We want to look at whether it is possible to use the food waste from the University of Waterloo to produce biogas. This biogas could then be used in a Combined Heat and Power unit to produce electricity and heating for the University. The sludge could be used as a fertilizer on campus or could be sold. The feasibility of the plant is mainly determined by economics, and since it seems to be to little food waste on campus, we would like to look into whether it is possible to mix the organic waste from campus with the organic waste from nearby grocery-stores, restaurants or farms. We would be very interested in speaking to your company, to learn how much and what types of organic waste you dispose of, and if you'd be interested in alternative to your current methods of disposal. Our research advisor is Jim Robinson, and can be reached at (519) 888-4567 ext: 2706, or jrobin@watserv1.uwaterloo.ca. This project has been reviewed and received ethics clearance through the Office of Research Ethics at the University of Waterloo. Thank you for your interest, and we look forward to hearing from you, and are anticipating a visit to your intentional community. If you have any questions, please do not hesitate to call or e-mail one of us.

Sincerely,

Christine Maas chrismaa@student.matnat.uio.no

Tory Reid torry.reid@gmail.com

Leo Lau solidification@hotmail.com

Sara Holzman sholzman@fes.uwaterloo.ca

Laurel McCarthy lemccart@fes.uwaterloo.ca

Breanne Card becard@fes.uwaterloo.ca

c. Where will the study take place? Off campus: direct contact at their place

4. Compensation of Participants
Will participants receive compensation (financial or otherwise) for participation? No

5. Feedback to Participants

Briefly describe the plans for provision of feedback. Where feasible, a letter of appreciation should be provided to participants. This also should include details about the purpose and predictions of the study, and if possible, an executive summary of the study outcomes. Provide a copy of the feedback letter to be used.

University of Waterloo

March 2, 2005

Dear Mr Jones,

We would like to take this opportunity and formally thank you for your assistance in our research project concerning a feasibility study for creating a biogas plant at the University of Waterloo. Your information to us has been deemed very valuable and useful in the continuation of our study.

This project has been reviewed by, and received ethics clearance through, the Office of Research Ethics. In the event you have any comments or concerns resulting from your participation in this study, please contact Dr. Susan Sykes at 519-888-4567, Ext. 6005. Our research advisor is Professor Jim Robinson and can be reached at (519) 888-4567 ext: 2706, or jrobin@watserv1.uwaterloo.ca.

A summary of our findings can be made available to you through e-mail upon your request. Thank you for your assistance, and we look forward to hearing from you.

If you have any questions, please do not hesitate to call or e-mail one of us.

Sincerely,

Christine Maas chrismaa@student.matnat.uio.no
Tory Reid torry.reid@gmail.com

Leo Lau solidification@hotmail.com
Sara Holzman sholzman@fes.uwaterloo.ca
Laurel McCarthy lemccart@fes.uwaterloo.ca
Breanne Card becard@fes.uwaterloo.ca

D. POTENTIAL BENEFITS FROM THE STUDY

1. Identify and describe any known or anticipated direct benefits to the participants from their involvement in the project:
They could get involved in a more environmental friendly and more economic solution of organic waste disposal, or at least get information about it (eductional benefit).

2. Identify and describe any known or anticipated benefits to the scientific community/society from this study:
It seems to us that biogas production from organic waste is a undervalued source of energy in Canada. If our study shows that it is possible to produce biogas and get all the co-benefits assosiated with is, it might lead to enhanced use og anaerobic decompostion of food waste.

E. POTENTIAL RISKS TO PARTICIPANTS FROM THE STUDY

1. For each procedure used in this study, describe any known or anticipated risks/stressors to the participants. Consider physiological, psychological, emotional, social etc. risks/stressors.
No known or anticipated risks
Although, biogas production seems to be a mainly unknown procedure, will ensure that the participants will be given sufficient information about the process to prevent emotional/psychological stress due to the uncertainities one might face.

2. Describe the procedures or safeguards in place to protect the physical and psychological health of the participants in light of the risks/stresses identified in E1:
WE would provide the participants with adequate information material to be able to make an informed decision, which propably will reduce stress.

F. INFORMED CONSENT PROCESS

Researchers are advised to review the Sample Materials section of the ORE website

1. What process will be used to inform the potential participants about the study details and to obtain their consent for participation?
Information letter with verbal consent.

2. If written consent cannot/will not be obtained from the potential participants, provide a justification for this.

3. Does this study involve persons who cannot give their own consent (e.g. minors)? No

---

G. ANONYMITY OF PARTICIPANTS AND CONFIDENTIALITY OF DATA

1. Describe the procedures to be used to ensure anonymity of participants and confidentiality of data both during the research and in the release of the findings.
No data will be released without prior consent.

2. Describe the procedures for securing written records, video/audio tapes, questionnaires and recordings.
There will be no information that will be considered confidential and will in any way harm any of our participants. In any way, upon finishing the project, we will dispose of interview notes.

3. Indicate how long the data will be securely stored and the method to be used for final disposition of the data.
Paper Records
Data will be retained until completion of the course.
Electronic Data
Data will be retained until completion of the course.
Location: Filing cabinet, Computer files

4. Are there conditions under which anonymity of participants or confidentiality of data cannot be guaranteed? No

---

H. DECEPTION

1. Will this study involve the use of deception? N/A

Researchers must ensure that all supporting materials/documentation for their applications are submitted with the signed, hard copies of the ORE form 101/101A. Note that materials shown below in bold are required as part of the ORE application package. The inclusion of other materials depends on the specific type of projects.

Researchers are advised to review the Sample Materials section of the ORE web site:
http://www.research.uwaterloo.ca/ethics/human/informed_consent.asp

Please **check** below all appendices that are attached as part of your application package:

- Recruitment Materials: A copy of any poster(s), flyer(s), advertisement(s), letter(s), telephone or other verbal script(s) used to recruit/gain access to participants.
- Information Letter and Consent Form(s)*. Used in studies involving interaction with participants (e.g. interviews, testing, etc.)
- Information/Cover Letter(s)*. Used in studies involving surveys or questionnaires.
- Data Collection Materials: A copy of all survey(s), questionnaire(s), interview questions, interview themes/sample questions for open-ended interviews, focus

group questions, or any standardized tests.
- Feedback letter *

* Refer to requirements for content under Elements for Information Letters and Consent Forms, including suggested wording:
http://www.research.uwaterloo.ca/ethics/human/samples/ElementsInfoLtrConsentForm1.htm

Please note the submission of incomplete packages may result in delays in receiving full ethics clearance.
We suggest reviewing your application with the Checklist For Ethics Review of Human Research Applications
to minimize any required revisions and avoid common errors/omissions.
http://www.research.uwaterloo.ca/ethics/form101/checklist.htm

Appendix B- Consent Form

University of Waterloo

March 2, 2005

Dear _______

This letter is an invitation to consider participating in a study we are conducting as part of our Undergraduate degree in the Department of Environment and Resource Studies at the University of Waterloo under the supervision of Professor Jim Robinson. We would like to provide you with more information about this project and what your involvement would entail if you decide to take part.

The purpose of this study is to conduct a feasibility study for creating a biogas plant at the University of Waterloo. Biogas production is the process of taking organic waste and converting it into methane gas. This methane gas can be used to create electricity and heat. The solid by product (after the biogas process) could be used as a fertilizer on campus or could be sold. From our research, we have determined that there must be a large amount of organic waste to generate biogas. Therefore, we are asking businesses throughout the area if they would contribute to the biogas plant if one were to be constructed.

Participation in this study is voluntary. It will involve an interview of approximately one hour or less in length to take place in a mutually agreed upon location. You may decline to answer any of the interview questions if you so wish. Further, you may decide to withdraw from this study at any time without any negative consequences by advising the researcher. Shortly after the interview has been completed, we will send you a copy of the transcript to give you an opportunity to confirm the accuracy of our conversation and to add or clarify any points that you wish. We ask your permission to use quotations from your interview and to name you and your community in the report. If however, you wish to remain anonymous, we will respect your wishes. Data collected during this study will be retained for one year in a locked office in my supervisor's lab. Only researchers associated with this project will have access. There are no known or anticipated risks to you as a participant in this study.

If you have any questions regarding this study, or would like additional information to assist you in reaching a decision about participation, please contact us.

You can also contact our supervisor, Professor Jim Robinson at (519) 888-4567 ext 2706, or jrobin@watserv1.uwaterloo.ca.

We would like to assure you that this study has been reviewed and received ethics clearance through the University of Waterloo's Office of Research Ethics. However, the final decision about participation is yours. If you have any comments or concerns resulting from your participation in this study, please contact Dr. Susan Sykes of this office at (519) 888-4567 Ext. 6005.

I hope that the results of my study will be of benefit to those organizations directly involved in the study, as well as to the broader research community.

I very much look forward to speaking with you and thank you in advance for your assistance in this project.

Yours Sincerely,

Christine Maas chrismaa@student.matnat.uio.no

Tory Reid torry.reid@gmail.com

Leo Lau solidification@hotmail.com

Sara Holzman sholzman@fes.uwaterloo.ca

Laurel McCarthy lemccart@fes.uwaterloo.ca

Breanne Card becard@fes.uwaterloo.ca

CONSENT FORM

I have read the information presented in the information letter about a study being conducted by Christine Mass et al. of the Department of Environment and Resource Studies at the University of Waterloo. I have had the opportunity to ask any questions related to this study, to receive satisfactory answers to my questions, and any additional details I wanted.

I am also aware that excerpts from the interview may be included in the report to come from this research, with the understanding that the quotations will be attributed to me, or if I prefer, used anonymously.

I was informed that I may withdraw my consent at any time without penalty by advising the researcher.

This project has been reviewed by, and received ethics clearance through, the Office of Research Ethics at the University of Waterloo. I was informed that if I have any comments or concerns resulting from my participation in this study, I may contact the Director, Office of Research Ethics at (519) 888-4567 ext. 6005.

With full knowledge of all foregoing, I agree, of my own free will, to participate in this study.

☐YES ☐NO

I agree to be named as a participant in the final research report and for quotations from my interview to be used in the report and attributed to me

☐YES ☐NO

I agree to the use of anonymous quotations in the report.

☐YES ☐NO

Participant Name: ____________________________ (Please print)

Participant Signature: ____________________________

Witness Name: ________________________________ (Please print)

Witness Signature: ______________________________

Date: ____________________________

Appendix C- Questions for Interviews

GROCERY STORE

1) What do you currently do with your organic waste? Where does it go? Do you pay for the removal, and if so, does the company pick it up for you?
2) Would you be interested in giving it away for biogas production?
3) Would you be willing to pay for the transportation to this plant?
4) How much organic waste in tonnes do you collect in a week?

RESTAURANTS

5) What do you currently do with your organic waste? Where does it go? Do you pay for the removal, and if so, does the company pick it up for you?
6) Would you be interested in giving it away for biogas production?
7) Would you be willing to pay for the transportation to this plant?
8) How much organic waste in tonnes do you collect in a week?

FARMERS

9) What do you currently do with your organic waste? Where does it go? Do you pay for the removal, and if so, does the company pick it up for you?
10) Would you be interested in giving it away for biogas production?
11) Would you be willing to pay for the transportation to this plant?
12) How much organic waste in tonnes do you collect in a week?
13) Would you be interested in constructing a biogas operation on your property in order to get benefits of free energy?

Appendix D: Information sheet for the interview participants

Biogas production from organic waste

Biogas production is the process of taking organic waste, putting it into a closed tank and leaving it there for 30-50 days.

When organic matter is left without oxygen, methane gas is formed. This gas can be burned similar to natural gas to produce electricity and heat.

As a by product, a nutrient rich sludge is formed, which can be used either as a fertilizer or as a dietary supplement to cattle and poultry feed.

Through the biogas production process the odor is significantly reduced, and the sludge is free of weed seeds and pathogens. If the sludge is used as a fertilizer, this can reduce weed problems and thereby pesticide use. If it is used as a dietary supplement, this can reduce the need for the use of antibiotics.

All kind of organic waste is feasible for the use in a biogas plant, but the best results are achieved by mixing food waste with animal dung.

Using organic waste to produce biogas is a closed cycle:
You use food waste & animal dung to produce energy and fertilizer. The fertilizer can then be used to produce food again, and the waste is used for the production of energy and fertilizer again...

Biogas production versus composting

Biogas production	**Composting**
- converts organic waste into a valuable product (electricity, heat & fertilizer)	- converts organic waste into a valuable product (only fertilizer)
- uses the energy in the organic matter to produce electricity and heat	- does **not** use the energy
- reduces odor significantly	- can pose odor problems
- stabilizes sludge and removes weed seeds and pathogens	- does **not** remove weed seeds and pathogens
- helps reduce the CO_2-emission and thereby to reach goals set by the Kyoto protocol	- does **not** have an influence on CO_2-emission