UBC Social Ecological Economic Development Studies (SEEDS) Student Report

An Investigation of Biodiesel Application in the UBC Boiler

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AN INVESTIGATION OF BIODIESEL APPLICATION IN THE UBC BOILER

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ABSTRACT

The formal report discusses biodiesel as an alternative fuel source that can be used in UBC to realize a more sustainable source of energy that can help direct the university into a more eco-friendly community. The university is currently one of the leaders in sustainable development and establishing the Centre for Interactive Research on Sustainability (CIRS) building in UBC, which is the greenest building in North America, shows the university's commitment to sustainable living.

The report examines the social, environmental and economic aspect of implementing biodiesel as the main fuel source for the UBC boiler. The production of biodiesel and its price using waste cooking oil are also analyzed to confirm the feasibility of biodiesel use in UBC. By taking into account the cost effectiveness, energy density and availability of raw materials, it can be determined how economical and reasonable it is to use biodiesel in heating oil to heat up UBC buildings. The capital cost to establish the infrastructure and equipments needed for the system that uses heating oil also needs consideration.

Furthermore, to establish biodiesel as the best renewable fuel source, biodiesel's environmental and social impact need to be more evident. Biodiesel should be able to convince the community that investing in biodiesel is worth it. Using the data gathered from several research papers, it is evident that biodiesel has major advantages in terms of reducing carbon emission. However, with the current heating system established in the UBC boiler, it is hard to justify the cost of switching to biodiesel since the heating system has been in use for several years. Consequently, overhauling the heating system requires huge capital that will never be recovered when biodiesel is used.

Table of Contents

LIST OF FIGURES

LIST OF TABLE

GLOSSARY

Glycerin:	A highly hygroscopic (absorbs moisture in the air) material; by-product in transesterification
Methanol:	Simple alcohol used in the Transesterification process
Methyl Ester:	A type of fatty acid; also known as biodiesel
Transesterification:	A process of exchanging organic group R’’ of an ester with the organic group R’ of an alcohol; often catalyzed adding acid or base catalyst

LIST OF ABBREVIATION

ASTM:	American Society for Testing and Materials
B5:	5% Biodiesel and 95% Diesel Fuel
B20:	20% Biodiesel and 80% Diesel Fuel
B100:	100% Biodiesel
CO:	Carbon Monoxide
NO:	Nitric Oxide
NO_2:	Nitrogen Dioxide
NO_x:	Nitrogen Oxides
PM:	Particular Matter
PPM:	Parts Per Million
SO_2:	Sulfur Dioxide

1.0 INTRODUCTION

For our project report, we decided to do research on the feasibility of using higher levels of blends in UBC's heating oil operations. Biodiesel is one of the forms of alternative energy that is most commonly discussed and can potentially be a viable option to supplant petroleum. It is being promoted because of its potential to power the world with lower emissions level than petroleum, hence, help the environment tremendously. It is through this belief that a variety of biodiesel applications are continued to be explored. In our report we chose to research biodiesel applications in heating oil. Biodiesel is a common application in this field and several states has mandated a minimum of 2% biodiesel be included in all petroleum based heating oil. We believe that this is just the minimum and it is reasonable to surmise that it is potentially more economically viable to use heating oil at around 10% blend of biodiesel. Throughout our report we will investigate the viability of this application in UBC. We will first explore the general points of biodiesel, exploring its production process, economics, environmental effects, and social effects. Later on we move on to exploring the application of biodiesel's application in heating oil. After gathering all the information needed, we tried to understand the optimal plan for UBC to use biodiesel in heating oil applications.

2.0 BIODIESEL ANALYSIS

With sustainability becoming a much more important issue, it makes sense for us to discuss other forms of alternative energies. We chose to discuss the alternative energy biodiesel. Biodiesel like petroleum can be used to generate great amounts of energy, but biodiesel can do it in a much cleaner fashion, with costs that appear to be manageable. The process of making biodiesel is also very simple and can easily be adopted by the masses. Due, to this factor biodiesel could become a much more important commodity in the future. Below we explore the four main factors that involve biodiesel: production, economics, environmental and social.

2.1 Biodiesel Production

The basis for producing biodiesel is adding fats and oils with alcohol to create a chemical reaction. These chemicals react to produce fatty acid methyl ester and glycerin; ester is the fuel used as biodiesel. The chemical process is illustrated below in (Figure 1). This product results in the production of one hundred pounds of biodiesel and ten pounds of glycerin, if we originally have one hundred pounds of fat and oil and ten pounds of alcohol

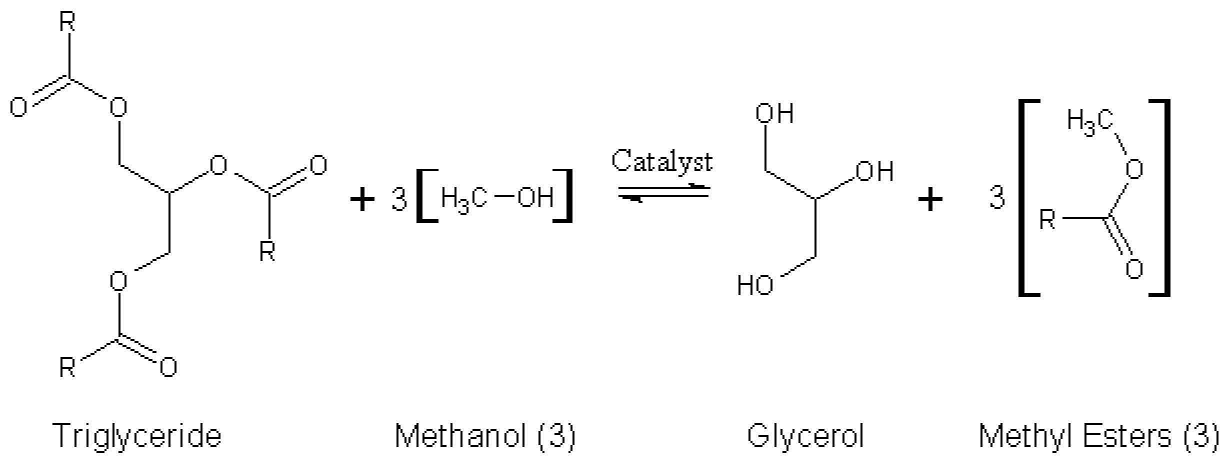

Figure 1 - Chemical Reaction to Produce Ester (Biodiesel)

There are three main ways to produce biodiesel and they are base catalyzed transesterification of the oil, direct acid catalyzed transesterification of the oil and conversion of the oil to its fatty acids and then to biodiesel. Today, the most commonly used processes for producing biodiesel is the base catalyzed transertification of the oil. We choose this process because it is performed in low temperature and pressure situations, it yields high conversion rates at 98% with minimal side reactions and reaction time, it is a direct conversion with no intermediate compound, and no exotic materials of conversion are needed. This process will be the topic of discussion because it is currently the most common process.

In using base catalyzed transesterification of the oil for biodiesel production there are six main steps that must be completed. They are mixing of alcohol and catalysts, reaction, separation alcohol removal, glycerin neutralization and methyl ester wash.

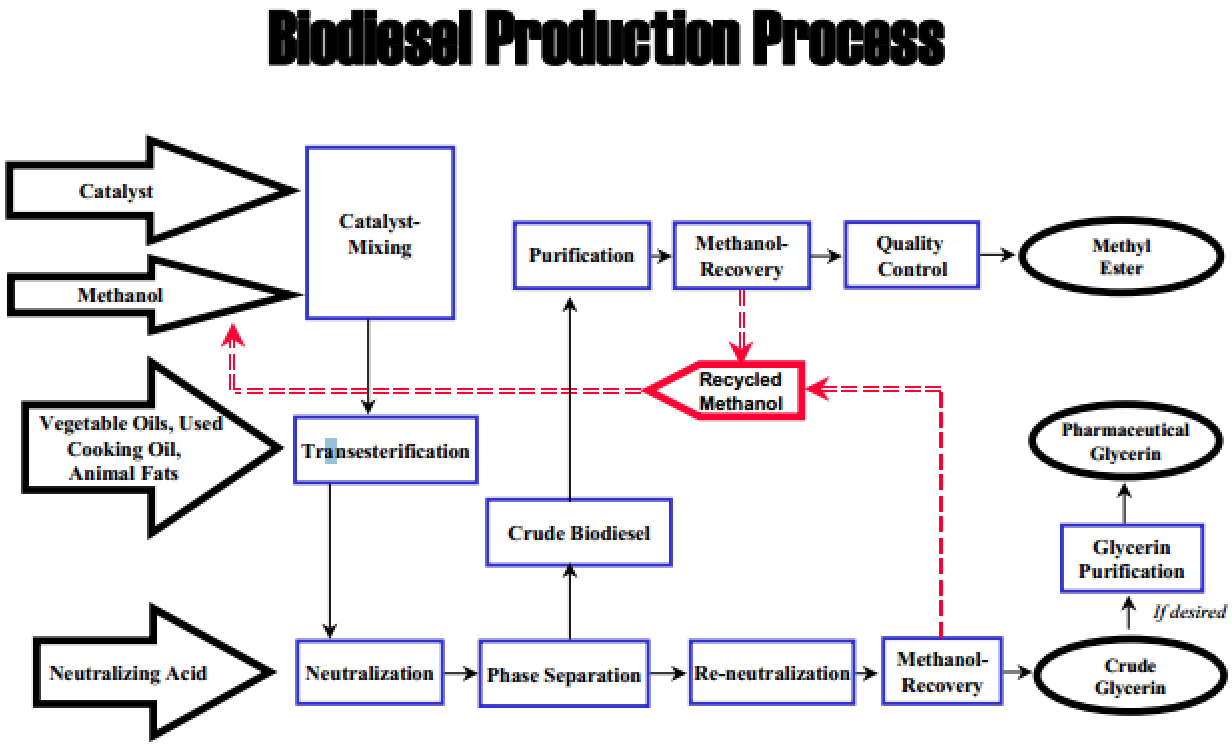

Figure 2 - Process of Biodiesel Production

Firstly, we must mix the catalysts and the alcohol. For the catalyst we typically use sodium hydroxide or potassium and for the alcohol we typically use methanol. We then mix the two compounds together with a standard agitator or mixer.

After the catalysts and the alcohol are mixed, we move on to the main reaction. Here, we add the vegetable oils, used cooking oils or animal fats with the catalyst and the alcohol. For a complete reaction to occur we must completely close the system to the atmosphere or there is the potential that the alcohol can be lost. While, this reaction is being performed the temperature must be kept above boiling point at around one hundred and sixty degrees Celsius. The mix is kept in there from anywhere between one to eight hours before the reaction is complete. To further ensure that a complete reaction will occur, the excess alcohol must be removed during this process. Also, the amount of water present in the reaction must be tightly monitored because excess water leads to the problems with the formation of soap. This will eventually lead to the separation of glycerin by-products downstream.

Now that the reaction is complete, there should be three main products that exist, the biodiesel, the glycerin and a large amount of methanol. It is time that we separate these two elements. There are two main approaches to doing this. One is letting the gravity separate it, since glycerin is substantially denser it is destined to sink. The other method is to use a centrifuge to separate the two materials. A centrifuge is a rotating unit that keeps the encompassed specimen at an angle and then spun at high speeds so that the two chemical elements of varying densities separate from each other; this is a much faster process.

Once the biodiesel and the glycerin are separated, it is time to separate the extra alcohol from each compound. We do this by either a flash evaporation process or by distillation. While this process is being completed the alcohol is collected and will be re-used in future reactions. When collecting the alcohol, water must be filtered from the recovered alcohol.

Next, the glycerin by-product should be further neutralized which certain acids, because before this process it will contain some of the unused catalysts and soaps. After this process is complete it finally becomes crude glycerin. Furthermore, we refine the crude glycerin by further removing alcohol and water this will allow one to obtain 80-88% glycerin.

Finally, the only product left is the methyl ester. This product needs to be purified and we do this by washing it with warm water. This removes the residual catalysts and soaps. Once washed we dry the biodiesel and it should be tested. Now that the biodiesel is done it must be analyzed and evaluated to ensure that it is of commercial grade and meets the standards and qualifications of the American Society for Testing Materials (ASTM). After it is approved it is ready for use as a commercial fuel.

2.2 Biodiesel Economics

The economics of biodiesel depends highly on how you acquire it. If one were to buy biodiesel in the marketplace, the price is generally a little higher than the price of petroleum even with the subsidies that governments currently provide to the public (McMillen et al , 2005). Currently the Canadian government subsidizes around 10-20 cents per gallon of biodiesel made; this helps to make it more feasible, but does not provide an advantage over petroleum.

An option that UBC can consider is, taking the waste cooking oil that it currently has from its food services system and convert this into biodiesel. The system for basic premade equipment, that comes ready for operation, typically costs a few thousand dollars for a small scaled version. If a larger scaled system is desired the price can scale up to 20 000 $. The life expectancy of these machines is expected to last from a few years up to ten years. According to Justin Richie, UBC would have 14 000 liters of waste

oil every month. This would amount to 3500 gallons per month or 42000 gallons per year. This suggests that UBC would require a large scale pre made machine for it to be able to convert its own waste cooking oil. If we say that the machine runs for six hours a day and that the labour cost of the person running it is 10$ per hour then the monthly cost of their salary would be around 1800$ and around 21 600$ per year. Also, let's assume that the machine will have a lifespan of eight years. That means that the machine would cost around 25 000$ per year. So if you add the total costs divided by total volume one should get the average cost per gallon:
(21600$+25000$)/42000gallons=1.10 dollars/ gallons. This shows that it would be cheaper for UBC to make its own bio diesel and use it as heating oil as the oil price and diesel prices currently oscillates in the ranges of 3.7-4 $/gallon and 4.0-4.4$/gallon. So from this it makes sense for UBC to use a B20 blend(20% biodiesel blend mixed with 80% petroleum) , if they were using a 100% petroleum based heating oil system. Also, in the process of making biodiesel, by products such as glycerin, would form. This product can be sold on the open market at around 0.3-0.9 dollars per gallon. This money can be used to offset the cost of methanol that is used to start this process.

However, in UBC's heating systems, they use natural gas to provide heating oil for the systems. From a cost point of view natural gas is priced at 0.3 $/ gallon. This is dramatically lower than any blend or any petroleum based heating oil that anyone can buy. It would be totally unfeasible for UBC to consider a switch from natural gas to anything else. It is optimum for UBC to continue running natural gas from a heating oil point of view.

2.3 Environmental impact

Biodiesel is being promoted as an alternative energy because of the potential that it can be a clean alternative to petroleum. It emits 100% less sulfur dioxide, 37% less unburned hydro carbons, 46% less carbon monoxide, and 84% less particulate matter (Environment Canada, 2009). One of its key advantages in this area is that it doesn't tilt the carbon tilt the carbon balance of the world. It is just processing the carbons that are already out in the world, petro fuels on the other hand releases ancient carbon into the atmosphere. Furthermore, in research it has been shown that if all factors of production are accounted for (production, transportation, manufacturing and distribution) bio diesel is four times more efficient in amount of fossil fuels used.

Biodiesel is not only good for the environments in the reduced emissions that it will inevitably create. It is also much safer for the environment. This is because it is made from bio materials. This allows it to be biodegradable. Also, biodiesel is a non-toxic compound, which means that the danger in transporting of this material is very low. Another key advantage bio diesel holds is in its flash point. Compared to petroleum its flash point is significantly higher (at around 130 degrees Celsius), which means it is much less flammable, hence it is much safer. Note petroleum flash point is around 64 degrees Celsius.

However, the boilers in UBC currently use natural gas and like biodiesel it is considered a much cleaner option to petroleum. Natural gas emits 21% more carbon monoxide, which is its main disadvantage. In other areas though like in nitrogen oxides it emits

80% less, sulphur dioxide 100% less, 92% less in particulates and 100% less mercury (Natural Gas Organization, 2010). These numbers show that natural gas also has a distinct advantage in being a cleaner fuel for the environment. Their emissions numbers are comparable to biodiesel. From an environmental standpoint switching neither fuel really has much of an advantage over the other.

2.4 Biodiesel social impact.

Biodiesel's social impact starts from its ability to help us clean our environment. If bio fuels and petro fuels are both able to complete the same task, the biofuel would be able to do it in a way that helps us to clean our environment and keep people healthy. It will help us clean our environment because biofuel naturally emit less than petro fuels. This leads to less pollution being emitted into the atmosphere, which in turn results in less air pollution. Less air pollution would allow the general population to be able to live healthier lives with less risk of contracting respiratory diseases caused by air pollution.

For our specific project, biodiesel usage in heating oil applications in UBC, this project as shown would be economically unfeasible, but the social benefits of having it is that it opens up potential for research for this at UBC. Since, UBC should be a centre for innovation, this further enables us to continue to try and experiment with using biodiesel in unconventional ways, that could lead to biodiesel being able to be implemented in the masses to replace petro based fuels in many other applications.

Employment in this field could also be a social impact. If biodiesel continues to develop, it may open up many employment opportunities locally and decrease our dependence on external sources of fuel. This is great because it would provide a more stable industry locally for many citizens to be employed long term.

A potentially negative impact of biodiesel however, is that if this becomes a more prevalently used technology, there could be a dramatic rise in food prices, since biodiesel and food would be competing for fertile landing. If food prices rise, the welfare of all citizens in that nation or region will be severely affected and this may lead to political instability within the region.

3.0 BIODIESEL USE IN HEATING OIL

The rapid growth of green house gases in earth has been a major environmental concern over the past few years because of global warming. Many industrialized countries already made the move to try and reduce the amount of carbon emission to the atmosphere by using more sustainable and renewable resources while using less fossil fuel; this approach should help diminish the effects of global warming. One of the major alternatives for renewable resource is biodiesel and it can potentially be used as heating oil blend which is used in residential heating systems. Initial experimental investigation of biodiesel as heating oil blend demonstrates that there is a strong reduction in carbon monoxide (CO) and particular matter (PM) emission in a residential heating system(Macor, 2007).

3.1 Investigation of Biodiesel Impact in the Environment

Biodiesel has showed fascinating results when used in residential boilers for space heating; studies show that boiler efficiency has negligible change when biodiesel blend is used (Macor, 2007). It can be used in its pure form to replace home heating oil, although a blend of 5-20% is usually used because it is the most efficient blend. In an experiment, B20 show significant decrease in CO, HC and SO2 emissions with respect to regular heating oil. The combustion of B20 in a residential-scale hot water boiler reportedly reduces SO2 by 20% while PM is reduced by 13% (Macor, 2007). The emissions of CO, NO, NO2, NOx, and SO2 are recorded and listed below on table 1.

Table 1 - Average Values of Emissions in Parts Per Million (PPM)

	Biodiesel	Heating
CO	3.3 ± 0.2	38 ± 2
NO	106 ± 5	101 ± 5
NO_2	7.4 ± 5	6.8 ± 5
NO_x	113.4 ± 7	108 ± 7
SO_2	2.5 ± 2	0.29 ± 2

In the experiment, the data is gathered all day for twenty four consecutive days but only takes into account one day for both biodiesel and heating oil. From this table, it can be concluded that the carbon emission of biodiesel is at least ten times less than heating oil while every other emissions are negligible. Biodiesel is less harmful to the environment and it will reduce oil consumption by a few million gallons a year if all heating oil customers switched to B5, a 5% blend of biodiesel (Macor, 2007); the use of biodiesel has a large implication in driving down air pollution. Furthermore, biodiesel is biodegradable and non-toxic; biodiesel is as biodegradable as sugar and less toxic than table salt. With this information, we can deduce that using biodiesel in heating oil can help a lot in reducing green house gases and solve global warming.

3.2 Investigation of the Economic Impact of Biodiesel

Normal heating oil and commercial biodiesel B100 have been experimented with to determine the efficiency of burning biodiesel compared to regular heating oil. The performance of the boiler using biodiesel has been measured with the following components: fuel flow rate meter, energy meter and thermometer. In table xx below, it can be seen that using biodiesel has little effect on the performance of the boiler. The instrumentation equipment was connected to a computer to gather data and, based on table 2 below, we can see that there is a slight increase in fuel consumption but the overall performance is comparable.

Table 2 - Average Values During Continuous Operation Period of 24 days

Characteristics	Heating Oil	Biodiesel
Ambient Temperature – C°	**9.4 ± 0.5**	**14 ± 0.5**
Fuel Flow Rate – l/h	**40.6 ± 0.4**	**44.5 ± 0.4**
Water Flow Rate – kg/s	**8 ± 0.2**	**7.95 ± 0.2**
Hot Water Temp - C°	**58 ± 0.5**	**54.7 ± 0.5**
Cold Water Temp - C°	**46 ± 0.5**	**44.5 ± 0.5**
Fire-place Power – kW	**429 ± 4**	**362 ± 4**
Thermal Power –kW	**401.8 ± 18**	**339 ± 17**
Boiler Efficiency	**0.93 ± 0.04**	**0.93 ± 0.05**
Specific consumption – gr/kWh	**83.9 ± 4**	**115.5 ± 6**

Using biodiesel in heating system will not have a major impact on people's jobs because standard heating oil use will not completely end since a B20 blend will be used, not B100. Consequently, jobs that involved disposing waste cooking oil will instead shift to transporting them to biodiesel production site.

3.3 Social Impact of Biodiesel in Heating Oil

Using biodiesel as fuel to heat up buildings can improve the well-being of people because we are using fuel that is 100% biodegradable. The potential leakage of heating oil from a household can damage ground water, which can be dangerous to, not only the household with heating oil, but also to its neighbors. On the other hand, if biodiesel leaks at all, it will decompose like sugar, as previously mentioned. In addition, less energy for transportation will be consumed with biodiesel because it is manufactured locally, meaning the fuel only needs to travel a small distance to reach the consumers. Overall, air pollution will shrink as more biodiesel is used in heating oil. Using a renewable fuel such as biodiesel also raises sustainability awareness in the community which in turn encourages environment friendly living.

4.0 PROPOSING BIODIESEL IN HEATING OIL IN UBC

We propose that UBC looks into a plan where they take their waste cooking oil from UBC food services and convert that to biodiesel. In doing this it will be necessary for UBC to buy equipment for this process to be done efficiently. Using the biodiesel that the school make we suggest that the school consider blending it with its heating oil and formulate a blend up to 20% diesel with 80% petroleum. We believe doing this UBC will be able to cut costs, be more environmentally friendly, as well as help further the progress in biodiesel.

4.1 Investigating Environmental Impact of Biodiesel

Using biodiesel to heat up buildings in UBC can help render waste cooking oil from UBC kitchens useful again instead of disposing them. Generating biodiesel within UBC premises means waste cooking oil does not need to be transported out of UBC so cars do not have to travel in and out of UBC and generate air pollution from the process. Furthermore, UBC is one of the leading institutions that promote sustainable development. Encouraging renewable resources will also stimulate other organizations to follow suit and research on sustainability. As a result, carbon emission will decrease and global warming will be minimized.

4.2 Investigating Economic Impact of Biodiesel

Every month UBC generates 14 tons of waste cooking oil that can be converted to biodiesel. To fully convert all of the waste cooking oil, UBC must invest in large scaled equipment that is able to handle 80 gallons every three hours. This type of machine generally lasts 20 000$ and lasts around 8 years. We will assume that the labor costs would be around 10 dollars per hour and is needed around 6 hours per day for 7 days a week. This yearly wage would come to a total of around 21 600$ per year. Now if we expect that the machine will last for eight years we believe the average cost of the machine per year will be at around 2500 dollars per year. Ever year, UBC is capable of producing up to 42 000 gallons of biodiesel. The average cost per gallon of diesel would then be calculated by the total cost/the number of gallons of biodiesel produced which would give you a dollar/gallon ratio of 0.57. This shows that making biodiesel locally is a good investment and cheaper than the open market. It is significantly lower than the price of petroleum (3.7-4.0$) and diesel (4.0-4.4$). So according to this it makes sense for UBC to pursue this option. Also in the process of making biodiesel, it also makes another product called glycerin. On the open market raw glycerin can be sold for 0.3-0.9 dollars per gallon. This money would be used to offset the cost of methanol that is used to start the biodiesel production process.

However, we later discovered that this was not a very viable option. This is because UBC actually uses natural gas to power its heating systems and natural gas is tremendously lower in price around 0.3$ per gallon which is tremendously lower in price no matter how much of diesel you decide to incorporate.

4.3 Investigating Social Impact of Biodiesel Use in the UBC boiler

Using biodegradable fuel in the UBC boiler has major implications in sustainability living. Using biodiesel in the UBC boiler raises social awareness while helping UBC move into a more eco-friendly building that operates with zero carbon emission. The general impact on UBC employees will also be minimized since the process of producing biodiesel requires very little labor. The only requirement for UBC employees would be to collect waste cooking oil, which is already performed in the first place. Burning biodiesel blend is proven to be cleaner than burning regular heating oil alone. The amount of particles released by burning 20% percent blend of biodiesel in heating oil generates up to 13% less PM.

5.0 CURRENT HEATING SYSTEM IN UBC

The UBC boiler currently uses natural gas as its fuel to produce heat for UBC buildings. In table 3 below, it can be seen that biodiesel and natural gas generate almost the same amount of energy, assuming that equal amount of fuel is used.

Table 3 - Biodiesel Energy vs Natural Gas

Fuel Type	Specific Energy (MJ/kg)	CO_2 Gas made from Fuel Used (kg/kg)	Energy per CO_2 (MJ/kg
Biodiesel	37.8	~2.85	~13.26
Natural Gas	38 – 50	(Ethane, Propane & Butane N/C:CO,NOx & Sulfates) ~3.00	~12.67-16.67

(Bioenergy Feedstock Information Network, 2012)

Currently, biodiesel in Vancouver cost three times the cost of natural gas and the heating system has been established in UBC for a few years (Ahouissoussi, 1998). Changing the system to utilize biodiesel instead of natural gas would need new equipments that are designed for biodiesel, in addition, the whole infrastructure need to be overhauled. To justify the cost of switching from natural gas to biodiesel, the price of natural gas has to significantly rise up.

6.0 CONCLUSION

Initially, we thought that UBC should incorporate a higher percentage blend of biodiesel in their heating oils. We thought that this would not affect performance, be able to save the school money and also be a much more environmentally friendly alternative to burning more petroleum. However, we were incorrect to assume this as UBC's heating system uses natural gas and not petroleum. Natural gas is a commodity that is dramatically cheaper in price compared to that of petro, diesel or even biodiesel. It also, is good for the environment emitting at a much lower rate than what normal petroleum would. We believe that the current plan that the UBC boiler has in place is a sound plan and there is no reason why they should convert to a system that burns a high percentage biodiesel blend.

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