UBC Social Ecological Economic Development Studies (SEEDS) Student Report

An Investigation into Biodiesel as Fuel for UBC Plant Operations Vehicle Fleet

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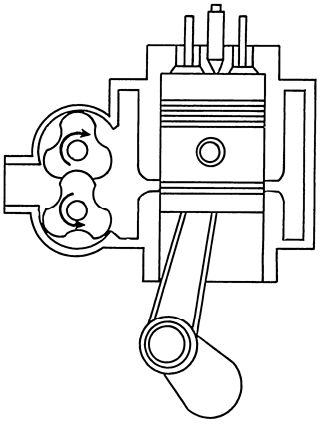

Abstract

The purpose of this report was to investigate the feasibility of fueling the small utility vehicles used by UBC Plant Operations with biodiesel made from waste vegetable oil produced from on campus food outlets. The report discusses the social, economic and environmental benefits and impacts of such a plan, as well as the analysis methodology, with conclusions and further recommendations.

Key economic issues were found relating to the current university fuel supply contracts. The current 5% biodiesel blend being supplied from Chevron must be used or else the warrantee will be voided. There are high costs associated with creating a production facility, and the costs are greater than the expected benefits are worth.

The environmental benefits from switching to locally refined biodiesel include reducing the overall carbon footprint of plant operations by reducing the amount of fuel being delivered and the amount of waste being driven away from campus, and a small reduction in some harmful tailpipe emissions over conventional diesel vehicles.

Socially, making the switch to UBC produced biodiesel can bring benefits by showing that UBC is striving to be at the forefront of green technology, while not making any drastic changes to the way UBC operates.

In conclusion, it is recommended that UBC should not pursue the implementation of a waste biodiesel program for the plant operations vehicles fleet, as the high costs and current arrangements with fuel and vehicle suppliers make it impossible to implement such a program economically, despite the possible environmental benefits. Currently, these conditions make it difficult to implement the proposed fuel program, but it is recommended that UBC continue to research biodiesel on a small scale so that it can eventually be reliably produced to the standards that are required for fuel commercial vehicles.

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List of Abbreviations

UBC	University of British Columbia
SEEDS	Social Ecological Economic Development Studies
AMS	Alma Mater Society
GHG	Greenhouse Gases
B5	5% Biodiesel Blend

1.0 Introduction

Technology surrounds our daily lives and continues to be a driving economic factor for the world. Smartphones, alternative energies, and other large scale applications of new technological innovations thrive at capturing imaginative thinking in engineering marvels. Business is, and always will be, primarily about making money. As emerging technologies drive the modern business world, increased emphasis on the effects of technology on people and the planet has influenced the societal view of assessing a corporate entity to change. The concept of sustainability has many definitions and various applications that remain to be discussed and argued among top scholars. Regardless, a widely accepted definition for sustainability considers people, planet, and prosperity. Sustainability can be defined as meeting present needs without endangering the ability to meet the needs of future generations.

Key performance indicators of a product performance towards meeting the goal of sustainability include economic, social, and environmental considerations. By assessing a product or idea on these three considerations, sustainability achievement can be discussed holistically.

1.1 UBC SEEDS

The University of British Columbia's (UBC) Social Ecological Economic Development Studies (SEEDS) initiative aims to provide the opportunity for staff, students, and faculty to address approaches for campus operations to be more sustainable. Topics ranging from energy, food, water, and more can be researched and implemented. Projects must involve operational sustainability issues at UBC and can be worth academic credit. All project reports are archived through the main UBC SEEDS website and are available to the public.

1.2 Project Description

As a SEEDS project, the Alma Mater Society (AMS) of UBC suggested the idea of investigating using waste grease from AMS Foods and UBC Food Services operations in campus vehicles as fuel. The economic, social, and environmental considerations were of concern. Our team decided to focus on the triple bottom line assessment of replacing fuel with biodiesel in the two-stroke engines of the very small pick-up cargo trucks of the UBC Operations vehicle fleet

found around campus. After initial research, it was clear that UBC only operated four-stroke engines in their vehicles.

Therefore, the project focus was to investigate the economic, social, and environmental impacts of replacing the four-stroke engine fuel of the UBC Operations vehicle fleet with biodiesel.

1.3 Problem Significance

The project description has significant objectives. Firstly, biodiesel can be created from waste grease already created on campus and used to fuel vehicles theoretically. Successful applications of such systems have been proven at various sites around the world. By reusing waste grease, there is potential for a greenhouse gas (GHG) emissions decrease towards UBC's environmental footprint. The project objectives are also in agreement with the objectives of the UBC Climate Action Plan. The goal is to provide an initial investigation on the use of biodiesel from waste grease for significant GHG emissions reductions.

2.0 Background

The assessment of biodiesel as a replacement fuel for vehicles commands a review of basic background information regarding important technical factors.

2.1 What is Biodiesel?

When a triglyceride reacts with alcohol and applied heat, fatty acid esters and glycerol are formed (Meher et al, 2004). This transesterification reaction process is used to create biodiesel. Figure 1 displays the chemical reaction equation.

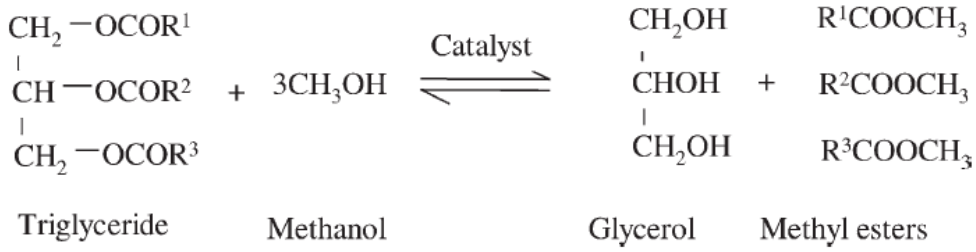

Figure 1: An example chemical reaction transesterification.

Animal and plant fats constitute of triglycerides. Triglycerides are simply esters that have three attached fatty acids. The produced fatty acid esters are the desired product, biodiesel. By reacting waste grease that is full of animal and plant fats with ethanol or methanol, biodiesel and glycerol are produced. The fatty acids are incredibly diverse because they are combinations of complex molecules. Major considerations for biodiesel production include storage stability, glycerol separation, and moisture content. Biodiesel must be processed in a plant to create industrially useful fuel.

2.2 UBC GHG Emissions

UBC's Climate Action Plan website presents a particularly interesting figure displaying the breakdown of UBC GHG emissions. Figure 2 displays the GHG emission details.

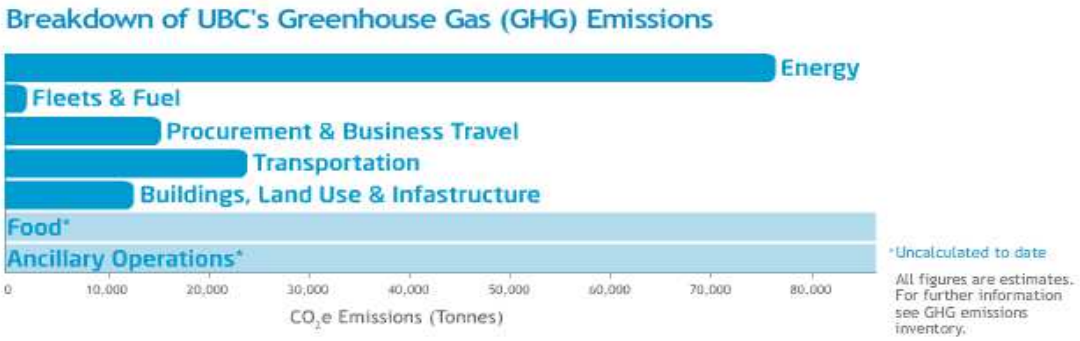

Figure 2: Breakdown of UBC GHG emissions.

It is clear that the UBC operations vehicle fleet emits a very low amount of greenhouse gases to the environment compared to other major contributors such as energy, business travel, and transportation. In fact, it is the lowest contributor among all the factors reported. With only about 2000 carbon dioxide equivalent tonnes emitted to the atmosphere due to fleets and fuel, any percentage reduction would be practically negligible. Regardless of the low contribution potential of biodiesel decreasing UBC GHG emissions, a fair triple bottom line assessment must be conducted to prove a favorable or unfavorable case.

2.3 Previous UBC SEEDS Biodiesel Results

The UBC SEEDS library contained many project reports relating to energy topics with six specifically regarding biodiesel at the writing time of this report. An analysis report on UBC waste oil biodiesel quality (Ngan, 2006) concluded that improvements must be made to the lab scale biodiesel production to meet the American Society for Testing and Materials (ASTM) standards. Production viscosity, a key indicator of reaction completion, also showed production viability concerns. Other reports focused on engine performance and not biodiesel production. A UBC climate change report was found in the SEEDS library (Zirnhelt, 2008) discussing UBC GHG emissions contributors. Natural gas combustion was the largest emission contributor found. Biodiesel was mentioned to burn cleaner but was not necessarily carbon neutral or sustainable. No reports focused specifically on replacing UBC fleet vehicle fuel with biodiesel.

2.4 The Investigative Approach

The investigative approach taken for this project report was simple. The team first contacted the UBC Operations Fleet Manager, professors with biodiesel expertise, and UBC Food Services to focus the project scope. Soon after, academic journals, informative websites, and previous SEEDS projects were consulted in order to determine the key performance indicators for switching to waste biodiesel fuels. Finally, a group assessment on the information found was conducted so useful recommendations could be made.

3.0 Economic Considerations

3.1 Investigation

Economic advantages are usually the strongest driving force for the implementation of any technology. Biodiesel production is no exception. For the project, the economic impacts of biodiesel at UBC were evaluated by assessing the UBC fleet status. Government subsidies and research impacts were also considered.

3.2 Results

Currently, the UBC vehicle fleet operates using conventional diesel trucks, which use 5% biodiesel (B5) blends from certified companies such as Chevron. According to Darren Major, manager of the UBC fleet, the maximum biodiesel blend percentage permitted by the manufacturer's warrantee is 5%. The warrantee also does not hold if the vehicles use biodiesel made from UBC because UBC is not a certified producer. In addition, research has shown potential gelling affects caused by excessive biodiesel usage results in additional fees for repairs and downtime. Therefore, the UBC vehicle fleet has no plans to use higher biodiesel blends due to their overwhelming economic and performance disadvantages.

However, the usage of B5 blends does offer significant advantages over conventional diesel. In Canada, biodiesel and ethanol added fuels are eligible for tax exemptions regardless of environmental impacts. In addition, UBC receives carbon credits for using B5 fuels. Although the exact amounts of savings were not determined due to confidentiality concerns, using B5 biodiesel blends offers significant economic advantages over conventional diesel which do not rely upon government subsidies.

Tax incentives are provided on both the federal level and the provincial level (Global Subsidies Initiative, 2009). Table 1 shows the current tax exemptions for biodiesel in Canada. As illustrated, total subsidies account for almost 20% of the current fuel prices.

Table 1: Canadian Biodiesel Tax Exemptions

Jurisdiction	Value of exemption (C$per litre biodiesel)	Duration of exemption
Federal	0.04	2003 to 2008
Alberta	0.09	2006 to 2007
BC	0.15	2006 onwards
Manitoba	0.115	2006 (to be reviewed after five years)
Nova Scotia	0.154	2006 onwards
Ontario	0.143	2006 onwards
Quebec	0.162	2006 onwards

Sources: U.S. Department of Agriculture (2008); provincial tax and biofuel legislation; press releases.

The current actual cost of biodiesel production depends a lot on the raw material. For large scale productions, the subsidies for each litre of biodiesel are almost as much as the cost to purchase one litre of conventional diesel. In addition, the cost of subsidizing biodiesel is far higher than subsidies for other green initiatives on a per carbon dioxide tonne basis. Table 2 shows the cost comparison between subsidies for different biodiesel feeds and other programs.

Table 2: Comparison of Cost per Tonne of CO_2 Reduced

Indicator	Unit	Ethanol		Biodiesel	
		Corn	Cellulosic	Recycled oil	Canola
Support per tonne of CO_2-equivalent avoided	C$/tonne of CO_2 equiv.	200–430	90–160	205–330	265–580
for a CO_2-equivalent offset, Chicago and European Climate Exchanges	C$/tonne of CO_2 equiv.	4.25–33.85			
Offset multiple foregone by subsidies		6x–100x	3x–38x	6x–77x	8x–137x

In addition to direct subsidies, significant amounts of funding have been invested to promote biodiesel. One example is the ecoENERGY for Biofuel Program, a 500 million dollar fund providing interest-free loans for the construction of biodiesel production plants (NRCan,

2012). Another similar program, the Next-generation Biofuels Fund, provides 500 million dollars for the private sector to establish large scale demonstration facilities to showcase biodiesel production using the newest possible technologies (NRCan, 2012). These research subsidies do promote the advancement of biodiesel technology. For example, the Next-Generation Biofuel Fund is limited to biodiesel productions from unconventional feed stocks, which could lead to the discovery of an ultimate environmental solution.

However, as history has shown, governments are not experts when it comes to deciding which technology to promote. In the current case, it is especially critical because biodiesel is still not confirmed to be good for the environment. Numerous reports are published every year, each with different and often contradicting conclusions on the effects of biodiesel. In addition, the life cycle analysis of biodiesel is often done without considering the origin of the land. For example, world-wide usage of biodiesel can inevitably lead to massive land use for biodiesel feed stocks only. This will very likely result in third world countries cutting down rainforests and harvesting their lands for biodiesel use which can cause devastating environmental impacts.

Fortunately, research done at UBC does not have this issue. As an advanced and knowledgeable institute, the focus is on using waste grease and oil from restaurants as feed stock. Currently a small biodiesel plant is operational, and professors such as Dr. Naoko Ellis from the Department of Chemical Engineering are actively doing research on improving the efficiency and productivity of biodiesel production plants.

Procuring waste grease is very economical for UBC because feed stocks can be obtained for free. Currently, grease taken from restaurants on the UBC campus is more than enough to keep a plant active. The total amounts of grease taken are outlined in the Table 3.

Table 3: Amount of Waste Grease Obtained for Biodiesel

Pacific Spirits / AMS	LTK University Center	TOTEM Dining Room	Triple O's
13200 lbs	2100 lbs	9450 lbs	5700 lbs

The environmental benefits also go beyond simple CO2 reduction, as it will also contribute to domestic waste reductions, while raising public awareness for renewable energy. It also provides restaurants with an economic solution for their waste oil.

Overall, respectable incentives are provided by the government to promote both the research and the consumption of biodiesel, and UBC will continue to benefit from these programs by using B5 biodiesel blends from certified providers. Beyond that, issues with manufacturer warrantees prohibit any additional biodiesel usage. Simply, political and legal issues have prevented UBC from using anything other than B5 biodiesel fuel blends from certified providers regardless of researched environmental impacts.

4.0 Social Considerations

4.1 Investigation

A sociological investigation is always important with any new technology, as there will be concerns about whether or not the technology is ethical and safe. Furthermore, a sociological lens can be used to examine how new technologies effect society and people. UBC's plan to replace fuel for the fleet operations with biodiesel has its sociological benefits and concerns. There are the promotional benefits of switching to biodiesel, as it would decrease the GHG emissions for UBC. However, there are safety concerns in the production of biodiesel as well many ethical implications. The positive and negative impacts of switching to biodiesel fuel are discussed more in depth below. The sociological impact of using biodiesel for UBC plant operation vehicles was analyzed by contacting the manager of the UBC fleet operations in addition with research of other academic papers.

4.2 Results

UBC has become a leader in adopting environmentally friendly practices. Evidence can be found from the recently constructed Centre for Interactive Research on Sustainability building, which is considered one of the most sustainable buildings in North America. It shows that sustainable innovations can be put into effect with a successful result. If UBC was to replace fuel for the plant operation vehicles with biodiesel it will continue in promoting an environmentally conscious culture on campus. Replacing the fuel with biodiesel would allow UBC to decrease its GHG emissions, which in turn will create several sociological benefits. UBC has the potential to be a positive influence on other campuses and communities, hopefully by creating a domino effect with the result of being a more sustainable global community. The UBC fleet operations vehicles are using B5 fuel, as that is the highest blend that is currently certified. The manager of the UBC fleet operations stated as of now there are no major sociological concerns with using B5 for the vehicles. It should be noted that remaining at B5 or switching to a higher blend would continue to aid in the awareness of a sustainable campus. UBC's plan for the production of this biodiesel is to produce it on campus from waste grease obtained from restaurants around campus. This would create a sociological accepted cycle, as restaurants would

no longer have waste grease to discard of because it would now be used to produce biodiesel, which would be used on campus as fuel feed stock. The cycle would be using all local byproducts which would cause a decrease in the consumption of outside sources for fuel and at the same time promote sustainability (Chou et al, 2003). Although the change from B5 fuel to complete biodiesel may seem small, however, looking at the bigger picture, UBC is taking the first step to becoming a more sustainable community and a positive emissions reduction influence.

Producing biodiesel in a plant located on campus brings up health concerns, as there will be people working in the plant who are being exposed to potential toxins. A question of concern is: is it safe for the health of workers to be put into jeopardy over biodiesel production? A positive aspect of biodiesel is that in its purest form, it is considered to be a non-toxic substance. With this being said, workers are not putting their health at risk. With no major health concerning the storage of biodiesel it is considered to be more socially acceptable; therefore, beneficial towards social impacts of replacing UBC fuel with biodiesel (Zhang et al, 2003).

The plan to use grease waste from campus restaurants and cafeterias to produce biodiesel seems to be sustainable, however, it also raises another ethical sociological concern. While trying to promote an environmentally friendly message to the community, the process of producing biodiesel may be doing the exact opposite. The more waste produced will lead to more biodiesel for the UBC fleet. In this particular case being wasteful can have positive impacts on the environment. From a sociological aspect, the production of biodiesel from waste products may not be as environmentally ethical as it seems because a negative message is being delivered to students and workers on campus, as well as nearby communities, in regards to producing more waste for more fuel.

In conclusion, replacing the UBC plant operations fuel with biodiesel has its social concerns. However, the positives outweigh the negatives. Even though it might promote a more wasteful culture, UBC switching over to biodiesel fuel decreases our carbon footprint and shows that turning waste into energy is something that is possible in today's modern age and promotes an environmentally friendly culture without drastically changing our way of life.

5.0 Environmental Considerations

One of the main drivers for introducing biodiesel into the fuel stream for UBC's maintenance vehicles is reducing the impact of the university's operations on the environment.

5.1 Investigation

The proposal to use waste cooking oil from the university restaurants and kitchens has the potential to make a positive environmental impact by converting a waste product that must be trucked away to a disposal facility into a fuel that can be both produced and used on campus. This reduces the carbon footprint by reducing both the amount of waste that must be transported off campus, as well as consumption of diesel that must be refined from crude oil and transported to campus. The usage of biodiesel also changes the amount of harmful engine emissions, and the positives and negatives of that will be discussed in depth. As well, in its pure form, biodiesel is non-toxic, unlike petroleum diesel, and as such, is less of a storage hazard (Dufour and Iribarren, 2012). Running a mixture of 20% biodiesel has the potential to realize most of these beneficial effects and at the same time keep the engine covered by the manufacturer's warranty.

5.2 Results

Oil based diesel fuel must be transported great distances over its lifespan. It starts in a well, anywhere from the Gulf of Mexico to the Middle East. From there it must be transported by tanker to a refinery, and then by truck to numerous stages in the distribution network before arriving at UBC to be used by plant operations vehicles. This is a very long distance, and fuel is used at every stage, causing each drop of diesel on campus to have produced a significant amount of emissions attributed to it before it is even burned. The waste vegetable oil produced by the restaurants on campus have a similar effect, as they are required to be transported away to a suitable processing facility. A 20% biodiesel blend, using biodiesel refined at an on campus plant reduces the consumption of petroleum diesel by 20%, and all associated life cycle emissions (Lardon et al, 2009). This reduction in the use of petroleum diesel is the real reason for promoting biodiesel usage. Any other advantages of using biodiesel should be considered secondary to the benefits that stem from reduced usage of petroleum, as many of these, which are mentioned in the following section, vary greatly depending on the quality of the fuel feedstock

and process quality control. The reduced usage of petroleum is important, as it yields an overall reduction in GHG emission production by UBC, and is a positive step in reducing UBC's environmental footprint.

Biodiesel exhaust emissions are different from the emissions of petroleum diesel, and there are some benefits and a few drawbacks from using one over the other. Biodiesel, at the maximum 20% blend and made to applicable standards, yields a 10-12% reduction in particulate matter and carbon monoxide emissions compared to straight diesel, which are both known to cause health problems (Kubota, n.d.,a). Additionally, there is a 20% reduction in hydrocarbon emissions, which contribute to ground level smog. However, biodiesel causes an increase in nitrogen oxide emissions of around 1 to 2% (Haas et al, 2006). Nitrogen oxides contribute to both smog and acid rain, but like most undesired tailpipe gasses, they can be dealt with by using an appropriate catalytic converter. The final undesirable effect of biodiesel is a slight 2% decrease in fuel economy, with negligible differences in carbon dioxide emissions. These numbers were found in an EPA technical report, but were specifically for biodiesel made from virgin soybean oil feedstock. As such, these numbers are not perfectly accurate, and waste oil containing animal fats do not produce consistent results. They do, however, show that biodiesel engine emissions have the potential to be less harmful than petroleum diesel emissions, especially with respect to smog and health issues, and real figures should be comparable as long as the biodiesel that is produced is held to applicable standards (Kubota, n.d.,b).

In addition to having the potential to reduce the amount of harmful tailpipe emissions, biodiesel, by itself, is non-toxic, and as such poses less of an environmental risk in the event of a spill. This only applies to the biodiesel in its unblended form, as when in an 80% petroleum diesel mixture, the benefits will not have any effect in the event of a spill, as the spill will be comprised mostly of petroleum, which is toxic. Unfortunately, this benefit is unlikely to be of much value unless UBC is able to switch to a 100% biodiesel blend in its fleet, which is currently not possible.

Implementing biodiesel as a fuel source for UBC has the potential to reduce the overall GHG emissions of UBC's daily operations. Additionally, it has the potential to reduce the harm of the tailpipe emissions of the vehicles that use biodiesel.

6.0 Conclusion

A successful investigation on the economic, social, and environmental impacts of replacing the four-stroke engine fuel of the UBC Operations vehicle fleet with biodiesel was completed. The economic cost of biodiesel production on about 30 thousand pounds of waste oil from various campus sources easily proved very high. A production facility construction with the required expert staff needed to operate is easily priced in the millions of dollars range. The environmental benefits also proved modest in GHG emission reduction percentage compared to conventional fuels, but the carbon dioxide equivalent tonne per dollar savings potential was extremely low. Socially, the political resistance to an unreliable technology such as biodiesel production from waste fuels seems to be the major factor for any significant advances in implementation. In conclusion, it is not advised that the fleet run on complete biodiesel from waste oil.

A lot was learned about biodiesel production, UBC operations, and assessing a sustainability project. We would like to acknowledge the help of Dr. Dawn Mills for helping provide the focus of this report, the time and expertise of Mr. Daren Major, and enthusiastic willingness to help find information from Dr. Naoko Ellis.

6.1 Recommendations

After using the triple bottom line technique for assessing the net benefits of switching the UBC vehicle fleet from regular fuel to campus produced biodiesel, a few key recommendations must be mentioned. The economic details were not calculated due to the immediate identification of the expected scale of costs and expertise needed. Future work on the details is not advised until the environmental savings are quantified. The logistics of collection, refinement, and distribution for biodiesel derived from waste oil would be very interesting to investigate. The complete political and social hurdles to implementation can also be further investigated to qualitatively assess the mechanism for gaining support. Nonetheless, academic research on biodiesel production is still encouraged because production advancements might easily make it a favorable alternative energy form.

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