

An Investigation into sustainable transport options for the University of British Columbia

Farm

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An Investigation into sustainable transport options for the University of British Columbia Farm

Submitted to
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Care of: Dr. Carla Paterson
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Impact of Technology on Society

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ABSTRACT

The truck on the UBC farm is nearing the end of its life. It has reached the point where continued maintenance is more costly than the purchase of a replacement. A replacement vehicle that is either a ten passenger van or a small pickup truck is required. Three options were considered to meet this requirement: joining a car co-op and sharing a vehicle over a longer period of time, purchasing a used vehicle that meets the requirements and purchasing a used diesel vehicle that is converted to run on fuel consisting of 20% biodiesel or more. Economically and environmentally, joining a car co-op is worse than buying a used vehicle and there is little if any social benefit. The overall costs were found to be greater than using an used vehicle and the availability of vehicles was poor. Buying a used gasoline vehicle is much cheaper initially than a diesel vehicle, but does not allow for any future conversion to a more environmentally fuel source. Buying a used diesel vehicle and using it without modification allows for the use of B5 biodiesel from plant ops. Conversion to biodiesel allows for the use of higher blends but the benefit of any blend above 20% is overshadowed by the cost and lack of biodiesel sources around campus. A blend of 20% is only provided by UBC's CHBE Sustainability Club, and is a newly emerging source of biodiesel; however, the biodiesel has not yet reached the market. The recommendation therefore, is to purchase a used diesel vehicle and to use it without modification. If at a future point in time higher blends of biodiesel become economically viable and readily available, the option to modify the vehicle is still open.

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GLOSSARY

Biodiesel - Diesel fuel based on renewable sources such as vegetable oils and animal fats.

Carbon dioxide - A chemical compound of carbon and oxygen. One of the leading contributors to greenhouse gases.

Modo - A Vancouver car sharing co-operative

Nitrogen oxides - A chemical compound of nitrogen and oxygen atoms. One of the major components found in smog.

LIST OF ABBREVIATIONS

B5 - Biodiesel blends of 5% biodiesel and 95% petroleum diesel

B20 - Biodiesel blends of 20% biodiesel and 80% petroleum diesel fuel

B100 - Biodiesel blends of 100% biodiesel

CHBE - Chemical and Biological Engineering

NREL - National Renewable Energy Laboratory

UBC - The University of British Columbia

1.0 INTRODUCTION

Sustainability is at the forefront of any new endeavours at UBC, resulting in UBC's status as one of the most environmentally friendly universities in Canada. Projects large and small are undertaken with not only the economic impact in mind, but the social and environmental effects as well, and the UBC Farm is no exception. The UBC farm currently utilizes an old vehicle to transport goods. However, it is in poor condition, requiring extensive maintenance for continued operation. Thus, the UBC Farm has been investigating sustainable transportation options in order to replace the old vehicle. The replacement vehicle should fulfill the requirements of being a 10 passenger van or pickup with a 2" ball hitch.

The investigation focuses on comparing three plans of action: joining a sustainability conscious car co-op, buying a used vehicle and using it without modification, and buying a used vehicle and converting it to run on UBC's biodiesel supply. This report aims to explore each option by outlining the potential benefits and drawbacks in order to provide a recommendation based upon the research as to which course of action to follow.

2.0 INDICATORS

2.1 Economic Indicators

There are two economic indicators that are used to compare the three possible options. The first economic indicator includes total initial costs. A large sum of investment must be paid at the initial stage to acquire a vehicle or to join a co-op program. This also includes any applicable taxes and other fees that may be incurred. The other indicator is the cost over three years, the minimum amount of time that the transportation replacement should be usable for. This consists of such costs as fuel, maintenance and repairs. The costs are estimates based on averages from aggregators, and as such, may vary based on usage.

2.2 Environmental Indicators

As all three options involve using a vehicle, the primary focus will be on the environmental impact of the fuel choices and resulting emissions as well as any driving habit changes that may occur as a result of a choice. The factors that determine emissions are the amount of gases released into the atmosphere, the fuel economy of the vehicle, and the distance travelled.

2.3 Social Indicators

Raising social awareness of sustainable transportation options is a side-effect of choosing environmentally friendly options. As a largely subjective indicator due to the limited impact on anyone not directly associated with the vehicle, impacts are estimated and some benefits may not be realized as they're hypothetical and will differ based on affected persons' reactions to a choice.

3.0 JOINING MODO CAR CO-OP¹

3.1 Economic Impact

Joining Modo has the lowest initial cost of any option with a \$20 registration fee and \$500 refundable shares purchase per additional driver. Once purchased, the shares must be held for a minimum of 180 days before they can be refunded. Every person that will use the truck must register as a member in order to use the truck. Over time, the cost is \$3 per hour and \$0.42 per kilometer (varies slightly with fuel prices). Any other costs such as insurance, maintenance and fuel are covered by the hourly and per km charges. The nearest truck to the UBC farm is approximately 7 kilometres away with a total fixed travel distance of at least 14 km which is approximately 15 minutes of time. If the nearest truck is unavailable, additional trucks are available further away. Minivans are available closer to the farm, however, they are smaller than desired with only seven and eight passenger vans available. In addition, the need to keep the interior clean as a requirement to use Modo vehicles may be difficult to follow.

The estimated current truck usage is a minimum of two days a week for errands and off-site meetings, going up to three days a week during summer and autumn months with a total use of approximately 130 days per year. The stakeholder has stated that the maximum travel distance in a day is 30 km and is generally shorter. With an estimated five hours of use per session travelling 20 km, every trip costs approximately \$34.70 with a total yearly cost of \$4500. Over three years, the cost of using Modo will be around \$13,500 with an additional investment of \$500 per driver that uses the vehicle.

All trucks that Modo offer have a receiver that can accept a 2" ball hitch but a hitch will need to be purchased, attached and detached every time the truck is used as the truck is available to non-farm users. There will also most likely be additional costs to manpower as additional labour is required to attach/detach the hitch every time it is used and ensure that the truck is reasonably clean before returning it to the assigned location.

¹ All information gathered from Modo website

3.2 Environmental Impact

Sharing a car is innately positive for the environment, as fewer cars need to be manufactured for the same number of people. However, by using Modo, drivers need to travel a greater distance in order to retrieve and return the vehicle, in addition to the transportation of the driver to and from the vehicle location. The trucks that Modo has available for use are similar in fuel efficiency to the used vehicles used in the other options. This means that by using Modo, approximately 60% extra fuel is required to do the same tasks due to the need to always retrieve and return the vehicle from an off-campus location which in turn increases emissions by a similar amount. This may be lower in cases where the only purpose is to get to and from a location using any vehicle as smaller cars are available on campus, some within walking distance of the farm.

3.3 Social Impact

Joining Modo entails changing the habits of everyone that currently uses the truck as it will no longer be readily available on the farm. Some of the changes including booking the truck in advance, modifying transit routes to allow time for retrieval and return of the truck and allocating extra time in order to do so. It is also necessary to attach and detach the hitch as required as the truck is shared. A requirement of the co-op is that the truck should be reasonably clean after every use. This may entail the use of a tarp to cover the truckbed before use or cleaning the truckbed with other means prior to returning it. Joining Modo would serve to raise awareness as to the availability of the co-op to people who interact with the truck, but in the context of use at the farm, it may prove to be detrimental to perception of Modo due to perceived and real inefficiencies associated with joining. It may have additional positive effects if Modo members choose to use Modo outside of their work on the farm as an alternative to purchasing personal vehicles.

4.0 BUYING AN USED VEHICLE

4.1 Economic Impact

Buying an old vehicle that uses diesel is a lucrative option because it allows for the use of diesel or biodiesel. Standard diesel engines can use biodiesel blends B20 or less without modification. To use blends higher than B20, the diesel engine requires slight “modifications to seals, gaskets, and other parts (National Renewable Energy Laboratory [NREL], 2009).” The cost and time to modify the vehicle to use higher is low in comparison to the purchase price of the truck biodiesel blends. The other option is to purchase a gasoline powered vehicle. Choosing to purchase a gasoline powered vehicle nets the benefit of a lower purchase price compared to diesel and a larger variety of vehicles to choose from.

4.1.1 Performance and Availability

According to Adam McCluskey, the UBC Plant Operations fleet manager, their fleet is powered only by B5 biodiesel from Chevron at a price of \$1.19/liter. There is no source of pure diesel on campus. Adam McCluskey stated the UBC Plant Operations would be able to fuel the UBC Farm Truck with B5 biodiesel (personal communication, Nov 2012). The US Department of Energy claims that B5 and biodiesel have no discernable differences, aside from changes in emissions (2005). The pricing of commercial diesel and B5 biodiesel from the UBC Plant Operations are very similar. Therefore, it makes no economic sense to pick diesel, a source that is further away off campus. B5 will be considered for use over diesel if a diesel vehicle is purchased.

The other on-campus source of biodiesel is B20 biodiesel from the CHBE Sustainability Club’s latest biodiesel project. However, their biodiesel project is still in its infancy. September 21st, 2012 was the first time the club has put a significant amount of biodiesel into a vehicle. The ability of the club to produce high quality diesel consistently from batch to batch has not been proven. They are currently not seeking to commercially sell the biodiesel and it is unclear when commercial viability will arrive (Jwbutler, 2012). In the past, the UBC Plant Operations vehicles have tried using B20 biodiesel. McCluskey stated that the B20 biodiesel “wrecked havoc” on their fleet vehicles, hence, the switch to B5 biodiesel (personal communication, Nov 2012). Higher blends of biodiesel are known to be less stable, so it is prudent to assume that biodiesel blends B20 and higher are not reliable fuel sources in the long term until proven otherwise.

Gasoline is the standard and most used fuel source, with gas stations littered across Vancouver. One downside of gasoline engines is that they are weaker than their diesel counterpart. However, for the UBC Farm truck’s tasks a V4 or V6 cylinder engine would suffice (Richer 2012). Most gasoline engines are V4 or V6, so the engine is adequate in terms of power requirements. Another downside is that diesel engines have better gas mileage and engine lifespan. Diesel engines can last up to twice as long as gasoline engines. According to Hino, a

Toyota truck subdivision, diesel can be expected to last up to 480,000 km without major repairs, while gasoline are only expected to last up 200,000 km (Hino Trucks, n.d). Lastly, gasoline prices have a continuing trend of increase over the past years.

4.1.2 Overall Cost Over 3 Years

To calculate some of the annual costs for diesel and biodiesel, the data from the 2001 4-cylinder Ford Ranger is used. The reasons for choosing this vehicle is its popularity and high gas mileage which was determined by the US Department of Energy website's vehicle search engine (2012a). It is also readily available to purchase locally through local classified ad sites such as vancouver.en.craigslist.ca and autotrader.ca. The 2001 model is ideal for gasoline because of the balance between cost and reliability. The average asking price through these sites is approximately \$4000. Other data used to calculate the annual costs are listed below on Table 1. Finding exact information based on vehicle model, year, and fuel source has proven difficult, so data from a assortment of similar vehicles is used. An additional cost for gasoline is the need to go off campus to refuel. Using Google maps, the closest gas station found near UBC is Shell on 4314 W 10th Ave. The gas station is located 4 km from the UBC farm, adding an extra 8 km per refueling trip. Considering the vehicle will travel approximately 2600 km per year, has a tank size of 62L, and a gas mileage of 9.78 km/L (US Department of Energy [USDE], 2012a), the truck should only need to fully refill the tank roughly five times a year.

For diesel, the same method is used to find a suitable vehicle. The 1995 Chevrolet Silverado is used to help calculate the annual purchase cost (vehicle purchase cost / 3 years). Although the Chevrolet is older than the 2001 Ford Ranger, the performance of the Chevrolet should still be adequate as a result of the longevity of diesel engines. The demand for old diesel vehicles is reflected through the price of the 1995 Chevrolet Silverado, which is on average \$5000 on the sites. The mileage of the Ford Ranger is still used to calculate the cost of fuel consumption because the goal is to calculate the cost of each fuel, not the gas mileage of each vehicle. The Chevrolet Silverado has a lower gas mileage (USDE, 2012b), but the vehicle UBC ends up purchasing could be less or more fuel efficient. Due to greater thermal efficiency, diesel engines have a 20-40% lower fuel consumption than gasoline (Isuzu, n.d). In order to compensate for this fact, the average of 30% is taken off from the Ford's mileage to calculate the fuel costs of diesel. Another complication is the cost of maintenance. Diesel engine repairs cost more than gasoline, but as mentioned previously, diesel engines require less maintenance in the long run. Assuming the maintenance costs do not vary significantly, the average cost of maintenance for gasoline vehicles is used to estimate diesel calculations.

According to the average pricing of biodiesel in the USA for July 2012, the price difference between diesel and B20 is negligible with a 1-2 cent difference per litre (USDE, 2012c). The price difference is assumed to be the same in BC. Following the pricing of the closest local B100 supplier, B100 is 40 cents higher at \$1.68 per litre (Vancouver Diesel, 2012). In addition, both B20 and B100 have higher fuel consumption than normal diesel. From a previous UBC study, MECH students Christensen, Hearle, Norrgard, and Schwartz performed a 10 hour test on biodiesel fuels and concluded that B100 has a 25% increase in fuel consumption and B20 has a 6.8% increase (2005).

Table 1: Annual Costs for Gasoline and Diesel

Average Insurance Cost for BC in 2009 ¹	\$1113
2011 Vancouver Average for Gasoline ²	\$1.31 /liter
2012 National Average for Vehicle Maintenance ³	\$0.0255 /km
2012 National Average for Tires and Repairs ³	\$0.0253 /km
Average 2001 Ford Ranger Mileage for Highway and City ⁴ (Gasoline)	9.78 km/liter
2001 Ford Ranger Tank size ⁴	62 litres
Cost of B5 Biodiesel from UBC Plant Operations	\$1.19/liter
Cost of B20	Approximated to be same as B5
Cost of B100	\$1.68/liter
Average Annual Distance (excluding refueling)	2600 km

Sources:

¹The Province (2011). *Study reveals B.C. has second-highest auto insurance rates in the country.* Retrieved from

<http://www.canada.com/business/Study+reveals+second+highest+auto+insurance+rates+country/5493740/story.html#ixzz2CwnIRmIO>

²Natural Resources Canada (2011). Fuel Focus, 2011 Review. Retrieved from

<http://www.nrcan.gc.ca/energy/sources/petroleum-crude-prices/gazoline-reports/2012-01-13/2080>

³Canadian Automobile Association (2012). *Driving Costs.* Retrieved from

http://caa.ca/docs/eng/CAA_Driving_Costs_English.pdf

⁴US Department of Energy (2012a). Retrieved November 21, 2012

from <http://www.fueleconomy.gov/feg/Find.do?action=sbs&id=16963>

Using the data from Table 1, the annual costs are summarized below (see appendix A for calculations).

Table 2: Cost Comparison between Gasoline, B5/B20 and B100

Fuel Source	Annual Cost of Fuel	Annual Overall Cost	Total 3-Year Fuel Costs	Total 3-Year Costs
Gasoline	\$399	\$2980	\$1197	\$8940
B5/B20	\$273	\$3184	\$819	\$9552
B100	\$481	\$3392	\$1443	\$10176

Retrieved from appendix A. Source data calculated into equivalent CAN dollar

The results show gasoline is the most economical in terms of the monetary cost over 3 years. The main factor is the price of a gasoline truck is significantly cheaper than a diesel vehicle using B5. Also, the distance travelled annually is low; therefore the cost of gasoline is less significant in the overall costs. It would take a total of 8 years to recover the \$1000 lost from purchasing a diesel vehicle, using B5 over a gasoline. (See appendix A). The cost of B100 over gasoline is significant at a difference of \$1236, making it an expensive choice.

4.2 Environmental Impact

The effect on the environment from one vehicle is very insignificant, regardless of the fuel type chosen. In order to assess the environmental impact, data on how the different fuel types have affected North America are compared.

Greenhouse gases are accelerating the problems related to global climate change. Emissions from vehicles are one of the major contributors to greenhouse gases. Hence, reducing emissions is vital to a cleaner and better world. The main culprits of greenhouse gases are carbon dioxide, methane, nitrous oxides, and ozone, and water vapor. Next to water vapor, Carbon emissions are the greatest contributor to greenhouse gases. Nitrogen oxides are one of the largest components of smog (Koo, Tham, & Yew, 2012) In our assessment only carbon dioxide and nitrogen oxides are considered. The environmental benefits of diesel and biodiesel are primarily in the reduction of carbon dioxide and nitrous oxide. Each option is assessed to compare their impact on the environment. Gasoline is the standard fuel source used today, so it is considered environmentally neutral in this report. By using gasoline, no changes are being made to emissions.

4.2.1 Carbon Dioxide Emissions

The carbon emissions rates of diesel and gasoline are listed below

Table 3: Carbon Emission Rate of Diesel and Gasoline

Diesel	2.67 kg/L
Gasoline	2.32 kg/L
Percent Difference for Diesel/Gasoline	15%

source: United States Environmental Protection Agency (2005). *Emission Facts*. Retrieved from <http://www.etieco.com/content-files/EPA%20emissions%20calc%20420f05001.pdf>

The results show that each litre of diesel releases more carbon than gasoline, but this does not take into account that diesel is more fuel efficient than gasoline. If the average 30% fuel efficiency of diesel versus gasoline is considered, then diesel has a 19% reduction in carbon emissions compared to gasoline (see appendix B). B5 is also the fuel the vehicle will use, so the emissions will be reduced further. The decrease in emissions is approximately linear in biodiesel blends. The US Department of Energy lists B5 as being 3.8% more efficient than diesel and B100 as 78% (2005). In total, this makes the emission of B5 23% lower than gasoline, B20 32%, and B100 82%. Gasoline requires to go out of campus to refuel, but that only translates to 40 km a year. The additional emission released from this distance travelled is ignored.

4.2.2 Nitrogen Oxides Emissions

The California Environmental Protection Agency's Office of Environmental Health Hazard states 30% of all nitrogen oxide emissions in the US are caused by diesel fuels and only 2% of vehicles are diesel (The California Environmental Protection Agency's Office of Environmental Health Hazard Assessment, n.d.). Gasoline vehicles make up the majority of vehicles, therefore it can be assumed diesel vehicles emit higher amounts of nitrogen oxides when compared with gasoline, making diesel a large contributor to smog problems. However, better fuel additives are being developed to reduce the nitrogen oxide emissions. The increase in nitrogen oxide emissions for B5 from regular diesel is negligible. B20 and B100 have a 2-4% and 10% increase, respectively (USDE 2005). Our research was unable to find exact data on nitrogen oxide emissions for diesel compared to gasoline. Therefore, it is not possible for us to make a direct comparison between the two fuel sources.

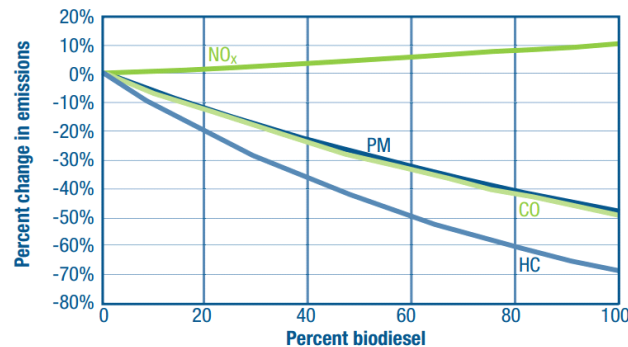


Figure 1 - Effect of Biodiesel on Emissions
[-http://www.nrel.gov/vehiclesandfuels/npcf/pdfs/37136.pdf](http://www.nrel.gov/vehiclesandfuels/npcf/pdfs/37136.pdf)

4.2.3 Concerns over Biodiesel

One of the major critiques of biodiesel is the use of resources to grow the crops necessary for biodiesel. Biodiesel generally comes from oils such as soybean oil, canola oil, and animal fats, meaning the resources normally used to grow food must be diverted to producing biodiesel. In order to compensate for higher demands of biodiesel, either more land must be used or crops normally used for human consumption must be converted into biodiesel. Reducing the food supply would increase the price of food. Using more land requires the clearing of forests. Forests are the greatest sources for reducing greenhouse emissions, hence there may be no benefits in terms of emissions for biodiesel.

The Canadian Renewable Fuels Association counters those claims, arguing there is no conflict between food and crops used for biodiesel. Canadian farms have idle farmland throughout the year. For example, the USA and India, countries with population magnitudes higher than Canada, have approximately $\frac{2}{3}$ of their farmland unused each year. These idle farmlands can be used before it is necessary to clear more land or use crops meant for food. Also, conventional extraction methods for other fuel sources already strip lands, so biodiesel should not be singled out. In addition, supporting current biodiesel increases funding for developing new biodiesel technology independent of crops (Canadian Renewable Fuels Association, 2010).

4.3 Social Impact

Using a gasoline vehicle, there is no social benefit as the truck becomes much the same as any other passenger vehicle. Choosing to purchase a used gasoline vehicle and use it unmodified is neutral socially as it does not change the status quo. Using a diesel vehicle, fueling up at the plant-ops fueling station requires an RFID chip which is unavailable to the general public (McCluskey, personal communication, Nov 2012). Knowledge of the fueling stations only benefits UBC Farm truck, as it limits the distance the truck has to travel to refuel. There may be minor positive social impacts from increasing users' awareness of the availability of biodiesel.

In the short term, it is possible to use B20 with an unmodified vehicle in order to support the CHBE Sustainability Club's biodiesel project however; a modified vehicle is required for long term use of B20 without problems. The biodiesel project is in its infancy and is not actively looking for any partners beyond UBC's Housing and Hospitality Services so it is unclear when it will be possible to purchase B20 from the club. Supporting sustainability initiatives at UBC, a particularly student initiative is important to foster awareness of sustainability issues for the future and moving UBC towards its sustainability goals.

5.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the information gathered, from an economic perspective, purchasing a used vehicle is superior to joining a car co-op over the course of three years. The initial costs of joining a co-op are lower while the long term costs are significantly higher. Using an unmodified vehicle is cheaper than a modified vehicle in the short and long run as the fuel costs are lower. The higher initial price of a diesel vehicle using B5 or B20 compared to a gasoline one is offset after eight years by the difference in fuel costs. From an economic perspective, a gasoline vehicle is better over the minimum timespan of use, however, a diesel vehicle is better over a longer period of time. However, there is no reliable source of B20 yet and B20 has caused problems in the past for the UBC Plant Operations.

From an environmental perspective, joining Modo is worse than the other two options due to a large amount of wasted fuel and excess emissions as a result of unnecessary travel. Gasoline produces more CO₂ but fewer nitrous oxides. Using higher biodiesel content fuel offers minimal benefits compared to low biodiesel content fuels when taken in context of their associated environmental problems and costs. Socially, the option that has the most potential is utilizing B20 fuel, by supporting student sustainability initiatives. The other available options are close to socially neutral or even negative.

Considering all factors, it is beneficial to leave the option open for a high biodiesel content capable vehicle; however, it is not prudent to immediately modify the vehicle to run on biodiesel. Biodiesel could improve in the future and the CHBE Sustainability Club's biodiesel project shows promise. Therefore, the recommended course is to purchase a used diesel vehicle using B5 fuel from the UBC Plant operations. Then re-evaluate the possibility of using higher biodiesel blends at a future date.

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APPENDIX A – VEHICLE COST CALCULATIONS

Annual distance travelled by gasoline vehicle

$$\begin{aligned} &= (\text{Number of days used}) (\text{Distance per trip}) + (\text{Distance travelled per refuel}) (\text{Number of refills per year}) \\ &= (130\text{days})(20\text{km}) + (8\text{km})(5) = 2640\text{km} \end{aligned}$$

$$\begin{aligned} \text{Number of refills per year} &= \frac{\text{Annual distance travelled}}{\text{Distance Travelled per tank}} = \frac{\text{Annual distance travelled}}{(\text{Tank size})(\text{gas mileage})} \\ &= \frac{2600\text{km}}{(62\text{L})(9.78\frac{\text{km}}{\text{L}})} = 4.3 \end{aligned}$$

Number of refills can only be an integer, so the value is rounded up

Annual distance travelled by diesel vehicle

$$\begin{aligned} &= (\text{Number of days used}) * (\text{Distance per trip}) \\ &= (130 \text{ days})(20 \text{ km}) = 2600 \end{aligned}$$

Annual cost of fuel source

$$= \left(\frac{\text{Annual distance travelled}}{\text{Gas mileage of vehicle}} \right) (\text{HST}) (\text{cost of fuel per litre})$$

Annual fuel cost of Gasoline

$$= \frac{2640\text{km}}{9.78\frac{\text{km}}{\text{L}}}(1.12)\left(\frac{\$1.32}{\text{L}}\right) = \$399.07$$

Annual fuel cost of B5 and B20

$$= \frac{2600\text{km}}{(9.78)(1.3)\frac{\text{km}}{\text{L}}}(1.12)\left(\frac{\$1.19}{\text{L}}\right) = \$272.56$$

Note: 1.3 comes from diesel being 30% more fuel efficient

Annual fuel cost of B100

$$= \frac{2600\text{km}}{(9.78)(1.3)\frac{\text{km}}{\text{L}}}(1.12)\left(\frac{\$1.68}{\text{L}}\right)(1.25) = \$480.98$$

1.25 is due to 25% extra fuel consumption

Annual cost of maintenance

= (Distance travelled) (Cost of maintenance per km)

Annual cost of maintenance for gasoline vehicle

$$= (2640km) \left(\frac{\$0.0255}{L} \right) = 67.32$$

Annual cost of maintenance for diesel vehicle

$$= (2640km) \left(\frac{\$0.0255}{L} \right) = 66.0$$

Annual cost for tires and repairs

= (Distance travelled) (Cost of tires and repairs per km)

Annual cost of tires and repairs for gasoline vehicle

$$= (2640km) \left(\frac{\$0.0253}{L} \right) = 66.79$$

Annual cost of tires and repairs for diesel vehicle

$$= (2600km) \left(\frac{\$0.0253}{L} \right) = 65.78$$

Annual purchase cost of vehicle

$$= \frac{\text{Initial Purchase Cost of vehicle}}{3 \text{ years}}$$

Annual purchase cost of gasoline vehicle

$$= \frac{\$4000}{3} = \$1333.33$$

Annual purchase cost of diesel vehicle

$$= \frac{\$5000}{3} = \$1666.67$$

** Annual Total Cost of Vehicle **

= (Annual purchase cost of vehicle) + (Annual Cost of fuel source) + (Annual cost of maintenance) + (Annual cost of repairs and tires) + (Annual Cost of insurance)

For Gasoline = 1333.33 + 399.07 + 67.32 + 66.79 + 1113 = \$2979.51

For B5 and B20 Diesel = 1666.67 + 272.56 + 66.00 + 65.78 + 1113 = \$3184.01

For B100 Diesel = 1666.67 + 480.98 + 66.00 + 65.78 + 1113 = \$3392.43

APPENDIX B - EMISSION CALCULATIONS

Carbon Emission for Diesel vs Gasoline

$$\begin{aligned} &= 1 - \frac{(\text{Carbon released per litre by diesel}) (\text{Fuel efficiency compared to Gasoline})}{\text{Carbon released per litre by Gasoline}} \text{ times } 100\% \\ &= 1 - \frac{(2.67 \frac{\text{kg}}{\text{l}})(0.70)}{(2.32 \frac{\text{kg}}{\text{l}})} \text{ times } 100\% = 19.44\% \end{aligned}$$

Carbon Emission for B5 vs Gasoline

$$\begin{aligned} &= (\text{Percentage of reduced emissions by diesel vs gasoline})(\text{fuel efficiency of B5 vs pure diesel}) \\ &= 1 - (1 - 0.1944)(1 - 0.038)(100\%) = 22.50\% \end{aligned}$$

Carbon Emission for B20 vs Gasoline

$$\begin{aligned} &= (\text{Percentage of reduced emissions by diesel vs gasoline})(\text{fuel efficiency of B20 vs pure diesel}) \\ &= 1 - (1 - 0.1944)(1 - (4 * 0.038))(100\%) = 31.69\% \end{aligned}$$

Note B20 is has 4 times the biodiesel content of B5 and emissions were said to be linear

Carbon Emission for B100 vs Gasoline

$$\begin{aligned} &= (\text{Percentage of reduced emissions by diesel vs gasoline})(\text{fuel efficiency of B100 vs pure diesel}) \\ &= 1 - (1 - 0.1944)(1 - 0.78)(100\%) = 82.27\% \end{aligned}$$

APPENDIX C – REFERENCED E-MAILS

B1 Email With Véronik Campbell (veronik.campbell@ubc.ca)

B1.1 Email Conversation #1

Received Oct 10, 2012

Hello everyone,

See below for the answers to the questions discussed yesterday. Please make sure to distribute to your team members.

Véronik

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Véronik Campbell

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Sustainable Transport Options

1. What is the budget?
 - As low as possible. A donation from Plant Ops would be ideal, especially if they could do it as a sponsorship for a biodiesel vehicle project.
2. What fuel will be used?
 - All options are open: diesel, biodiesel, veggie fuel, normal fuel, electric, etc.
3. What will the vehicle be used for?
 - One day a week from June to October for carrying produces to the on-campus farmer's market. One day a week all year long to run errands, which generally mean carrying equipment which sometimes can be large and heavy. One day a week all year long for off-site meetings
4. How often will the vehicle be used?
 - See question #3.
5. What will be the costs for maintenance and spare parts?
 - Will try to get you an answer as soon as possible, but this is the kind of statistics you could probably find elsewhere (i.e. average maintenance and insurance cost for small truck/10 passenger minivan).
6. Is the main role of this project to perform a triple bottom line assessment of the vehicles (diesel, bio-diesel and car co-op) or are we also trying to find you a vehicle, that performs the best in the triple bottom line assessment?
 - Triple bottom line assessment not finding us a vehicle.
7. What is the expected life cycle of the farm truck?
 - At least three years.

8. How would you define the social aspect of the farm truck (is the interaction with the public of importance)?
 - Yes. The Farm has many community engagement programs and relies on market sales for financial sustainability.
9. What have previous teams come up with?
 - Donations from Plant op.
10. Are there any experts in relevant fields that we could talk to?
 - I don't know them all, but for biodiesel, you can talk to the Biodiesel Club in the engineering department. As for car co-ops, chatting with a representative of the coops, telling them you are doing a research around sustainable transport options, would make you learn lots.
11. Would we be able to arrange any special business deals with Modo?
 - I don't know, but I look forward to you telling me.
12. Has UBC had any experience with Modo?
 - I don't know, but I look forward to you telling me.
13. If we buy a used car, is there any interest or possibility of UBC mechanical engineering students working on it?
 - I don't know, but I look forward to you telling me.
14. What was the old UBC farm vehicle (diesel, gasoline?)? How was its performance?
 - Nissan. Sorry, I said Toyota during the workshop, but it is an old Nissan.
15. Is there any need to get a vehicle with more payload capacity than the current vehicle?
 - No. Smaller truck is ideal.
16. If a larger vehicle was chosen, would that enhance the efficiency of operations on the farm? Conversely, if a smaller vehicle was chosen, would that harm the ability to work efficiently?
 - No. Smaller vehicle is ok.
17. Will UBC have a feasible biodiesel source?
 - Maybe. Look into biodiesel AMS funded projects at UBC.
18. Can the truck be manual? (Can people who will use the truck be able to drive manual?)
 - Yes. But remember, whether the vehicle is manual or automatic doesn't have much impact on its economic, ecological, or social impacts.
19. Is there someone employed by the farm or nearby mechanic that can maintain the truck?
 - No to employed at the Farm and yes to nearby mechanic, but \$.
20. What is the approximate cost to convert the truck to run on biodiesel fuels at UBC?
 - I don't know, but I look forward to you telling me.
21. How far , or what is the distance it needs to travel in daily basis ? What is the terrain like ?
 - I would say within 30k in a Vancouver like terrain.
22. Would convenience or luxury be necessary over durability and cost ?
 - Durability and cost is prime.

B1.2 Email Conversation #2

Sent By Gary Huang Nov 13, 2012

Hello Véronik,

I was wondering if you could answer a few more questions about the UBC Farm truck.

1) Are the days on which the truck used fixed? For example, it is only used on Monday, Wednesday, Thursday every week from 1pm to 5pm.

2) How was the truck refueled? Did it regularly go to a gas station to refuel or was/is there a way to store diesel for the truck to prevent trips to the city?

Thanks for any help.

Received Nov 13, 2012

Hi Gary,

Here you go. I hope these answers will be helpful.

1) Some of the days are fixed, such as the Wednesday when we hold our farmer's market on campus. The other days are at random, depending on meetings, repairs needed, etc.

2) The truck is refueled on campus, at the UBC Plant/Building Operations building. And our current truck is not diesel, but normal fuel. This being said, the diesel at the pump is partly normal diesel, partly biodiesel.

Hope the report is coming along well. I look forward to reading it.

B2 Email With Adam McCluskey (adam.mccluskey@ubc.ca)

B2.1 Email Conversation #1

Sent Nov 13, 2012

Hello Paul,

I am UBC student doing a investigation on transport options for the UBC Farm's Truck. I was informed UBC plant operations vehicles used biodiesel from chevron. I was wondering if you could answer a few questions about that. I apologize in advance if this is your not your area of work.

1) Does UBC plant operations have any plans on moving to local biodiesel sources from UBC facilities rather than chevron?

2) Is the biodiesel source solely for plant operations vehicles, or would the UBC Farm's Truck be able to use the biodiesel source as well? What would the costs be?

3) Have there been any problems with the vehicles using biodiesel?

Thank you for any help.

Received Nov 14, 2012

Gary,

Answers are below in red:

1) Does UBC plant operations have any plans on moving to local biodiesel sources from UBC facilities rather than chevron?

Not at present, though we're not opposed to the idea. Our relationship with Chevron is one of convenience as we need a high volume, consistent supply of Biodiesel that meets ASTM D6751. We're currently using B5 which arrives pre-mixed.

2) Is the biodiesel source solely for plant operations vehicles, or would the UBC Farm's Truck be able to use the biodiesel source as well? What would the costs /be? –

Our fuel dispensing site is used by most vehicles across campus and several external units as well. The UBC Farm truck would be able to use our site, we would need to set you up in our system and install a RFID on the vehicle.

3) Have there been any problems with the vehicles using biodiesel?

Not at the current B5. We did had B20 in the past and it was causing havoc with our older diesel vehicles...specifically in the winter.

Sent by Gary Huang Nov 14, 2012

Thanks for the answers Adam.

For the problems with B20, were there still issues in warmer weather?

Received Nov 15, 2012

Gary,

Yes, but whether they were related to the older diesel engines or the fuel mix, I couldn't accurately say. If we were to up our B5 to a higher mix, we wouldn't shoot up to B20. B10 would probably be a more prudent choice...but no plans at present.

B2.2 Email Conversation #2

Sent by Gary Huang Nov 18, 2012

I apologize for all the questions. How much does UBC building plant operations pay per litre for the biodiesel and diesel? If the costs are confidential, is it possible to state which one costs more? Thank you

Received Nov 19, 2012

Gary,

We're a public institution and as such we have no secrets. The price sheet from Chevron says 1.1899 per unit which is Litre.

I meant to add, that we currently don't look at purchasing conventional Diesel. I believe there is a minimum bio-blend set by the municipality which is currently at B5.