UBC Social Ecological Economic Development Studies (SEEDS) Student Report

Triple Bottom Line Assessment of Sustainable Transport Options

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Stakeholder: UBC Farm – Veronik Campbell

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1.0 A Triple Bottom Line Assessment for Transportation Options for UBC Farm

The UBC farm truck is a 1996 Toyota Tacoma and is nearing the end of its life cycle. There are numerous sustainable options to replace this truck and leave a good impact environmentally, economically and socially for the farm. The UBC farm has a reputation for sustainability through its wide array of organic crops and sustainable practices when harvesting them. The truck they use should reflect these positive change they are trying produce for the planet.

For this project, UBC Farm has asked students enrolled in the APSC 261 course to consider several options with regards to the purchase of a new truck to be used to make deliveries to restaurants which use UBC farm products, carry carts full of vegetables to campus every Wednesday for the Wednesday Market, run the occasional farm errand in town, and hauling heavy farm equipment. Due to the strenuous tasks the truck will undergo for the duration of its life, the farm only expects and budgets for the truck to work for three years.

The farm has recommended three types options to be assessed before they make their final decision for a new truck. A regular used diesel truck, a truck that runs on biodiesel fuel or a car rental or car sharing program. Our team members set out to describe all three options to the farm in order for an informed decision to be made. We looked at the environmental impact of the decision, the feasibility of the decision economically and the convenience and efficiency this kind of option might bring for the farm.

2.0 Car Sharing and Car Rental

Car sharing and car rental share some characteristics, they are both community involvement programs aimed at saving the consumer money but also limiting usage to each individual consumer and sharing the vehicles just as the name implies. This can bring economic benefits because even though these programs are for profit the truck UBC farm uses is not used daily.

The pattern of use is also worth taking note as less of these trucks are being produced as they being shared by the collective community, so even though the truck life will be shorter it will not be shorter proportionally to the number of people using them resulting in a net positive environmental benefit.

2.1 Car rental

Car rental is the practice of going to a car rental agency and renting a vehicle for a predetermined amount of time. This fashion of obtaining a car is primarily used for vacations and to move heavy equipment such as furniture. Normally there are no start up fees associated with this method and for that reason this tends to be the best option in the very short term

This can prove costly even after the first month, even at low cost rentals in the summer time will range from $150-$250 for three days (the amount of time needed) for trucks. These trucks need to picked up and put back at specific rental agency locations. Frequently cars cannot be booked any days in advance and certain vehicles may not always be available. For the farm there may be some issues with reliability as they cannot skip days to the market.

Environmentally car rental is no different than owning a regular gas powered car, as almost all cars provided by rental agencies are gas powered. Though because more people are using a single car this does decrease manufacturing needs to produce more vehicles. Car sharing has this same benefit along with numerous economic benefits that traditional car rental does not have.

2.2 Car sharing

2.2.1 Benefits of Car Sharing

Car sharing programs are companies that own a wide variety of vehicles in many locations around Vancouver that customers can borrow at will. Some of the benefits to this style of transportation are that you don’t own the vehicle, which gets rid of maintenance fees, the

overall cost of buying a vehicle, insurance, and in some cases gas (depends, some companies include gas, others do not). Sharing the cars also means that they are getting the maximum amount of use, thus needed fewer vehicles overall (By this I mean that one vehicle can be used by many people, meaning less are made). Another environmental benefit is that you can change which type of vehicle you drive. When moving produce or heavy farm equipment a truck can be borrowed but when you are doing errands that don't require a large vehicle, a small car can be used.

2.2.2 Downsides of Car Sharing

Some of the downsides to car sharing are the inconvenience of not having the vehicle on hand all the time, and trips will have to be planned ahead for usually (although usually you can get a car easily and on campus, but maybe not a truck). Someone will have to pick up and return the vehicle every time it needs to be used, which could cause problems/be annoying.

2.2.3 Options for Car Sharing Services in Vancouver

Car sharing – book a car, pick it up and return to specified location

MODO: http://www.modo.coop/

Rates

Weekdays 6am – 11pm	Evenings 11pm - 6am	Weekends 6am - 11pm
• $6 per hour, to a maximum charge of $54 per 24 hours • Daytime cap of $36 for not-for-profit orgs, M-F 6am - 6pm	• Free for the portion of bookings that spill over into this time period • $6 for bookings	• $8 per hour to a maximum charge of $72 per 24 hours

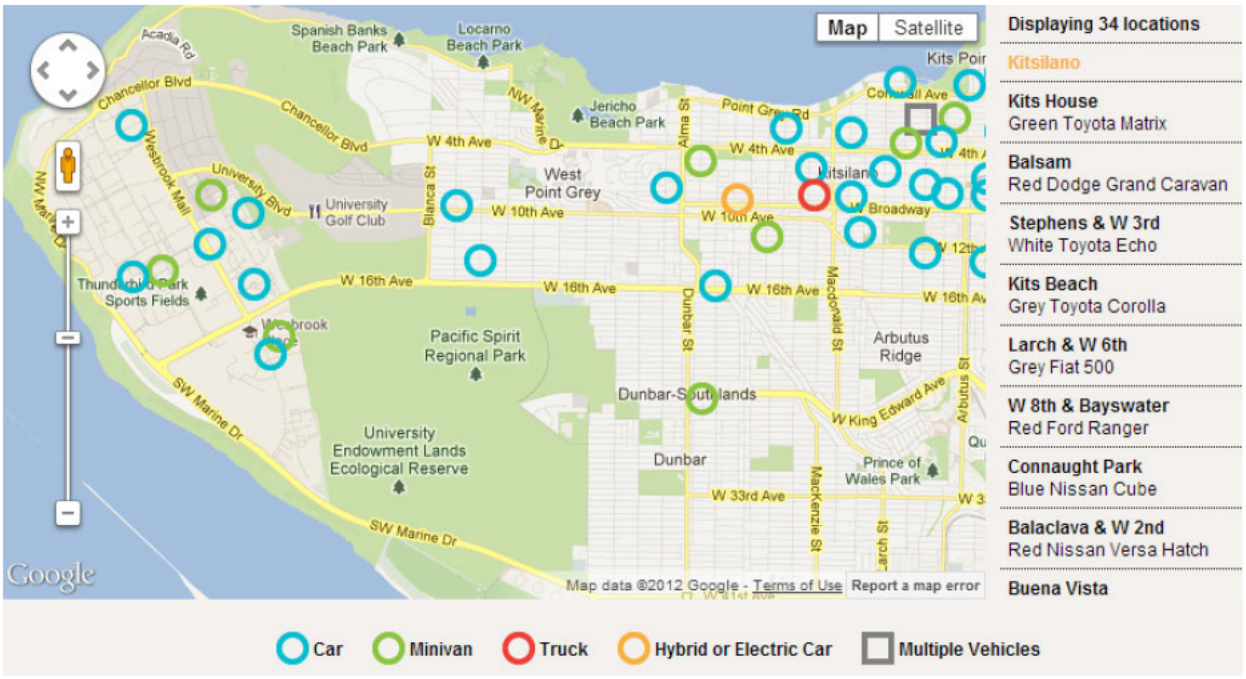
	made entirely within this period	

- 20$ registration fee for each driver
- 28 cents/km after 150 km
- 500$ refundable deposit for first five drivers, additional 500$ for next 20 drivers (returned once you close your account)
- 1$ membership fee on Oct 1 each year
- Have cars on campus that could be used, and when a truck is needed, there is a Ford Ranger at West 8th and Bayswater
- Can switch between car and truck as needed to lessen environmental impact
- A gas card is included in every vehicle, can fill up whenever, should leave the vehicle with at least a quarter tank

Additional info:

- Although you can repeatedly book a certain vehicle in advance, modo prefers that you change up the specific vehicle, or type (ex: change the location you get the truck from, or use a van with stow and go seats every once and awhile instead) to allow the other customers access to the vehicles
- You can book up to a year in advance, or immediately before you need a vehicle
- Can book by phone or online, each user has their own home page, even though they can all share an account
- Setting up an account for a business is easy and takes between 24 and 48 hours
- Depending on who is coming to the farm, different employees can pick up vehicles from a variety of locations

Below is a map of the available vehicles around UBC
(Source http://www.modo.coop/find)



Car2go http://car2govancouver.com/

RENTAL RATES[1]	
Registration fee	$35 plus tax
Per minute	$0.38 plus tax
Per hour maximum	$13.99 plus tax
Per day maximum	$72.99 plus tax
Per mile after 150 mile per rental	$0.45 plus tax

- Can rent per minute
- Don't seem to have business rates
- No return time or return location (must be within home area however)
- Home area boundary is at Blanca between West 16th and NW Marine St. (closest point to UBC)
- Only use Smart cars
- Lifetime membership is 10$

Here is the “Home area” in Vancouver:

Zipcar: http://www.zipcar.com/

- Have cars, trucks, and SUVs
- Cars don’t have fixed locations, so there could be less choice if all trucks are far away
- 75$ one-time fee to join, 30$ annual fee
- Up to 200 km/day free

Joining fees

One-time acct. setup $75

Each driver annual fee $30

Vancouver rates from*
Monday – Friday
Hourly rates from $8

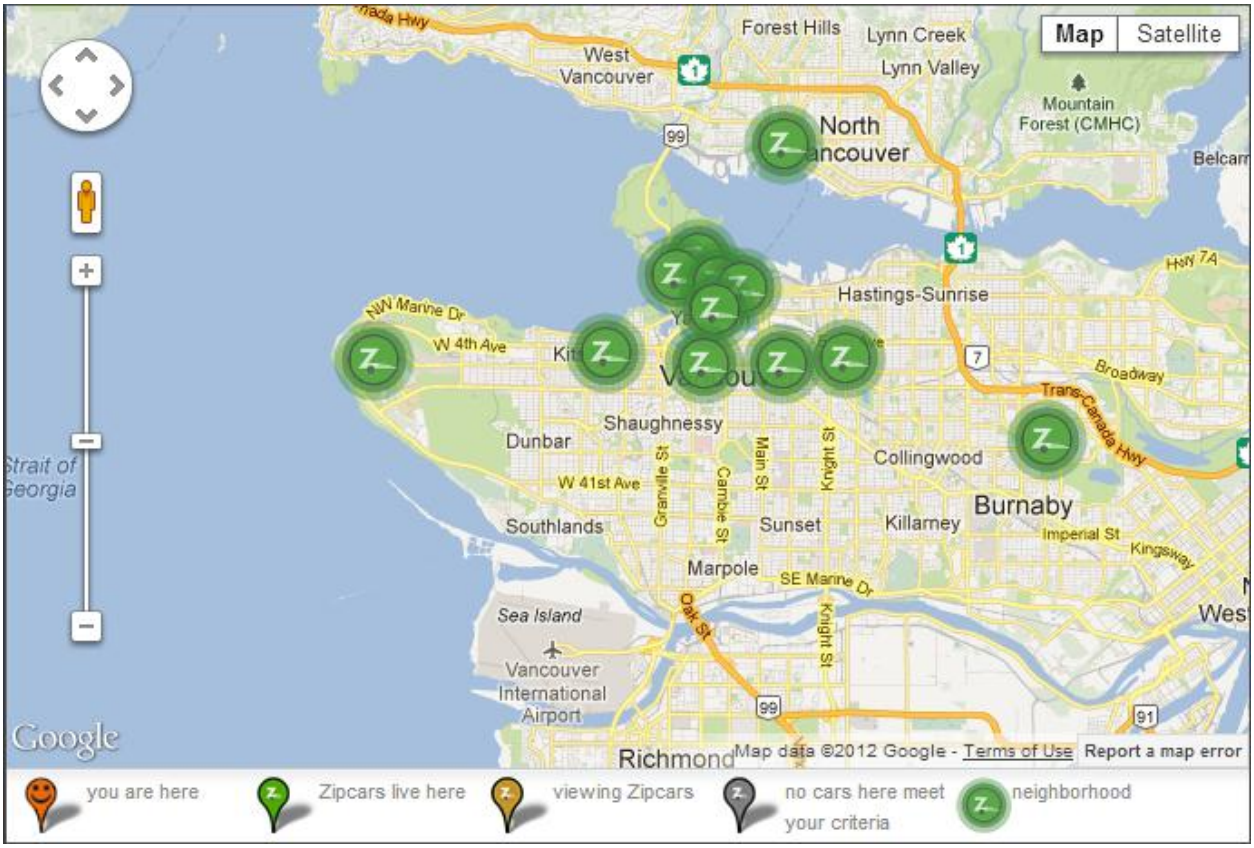
7-to-7 Business $53

Full day$63

What's included
Gas (they give you a card to use to fill it up)
Insurance
Up to 200 kilometers per day

- You can book a vehicle in advance

Here is a Map of the Zipcar Neighbourhoods, however, the cars move around semi freely:



Source: http://www.zipcar.com/vancouver/business/find-cars
This can be used to find where vehicles are at specific times

2.3 Conclusion of Car Rental and Car Sharing

After checking through the different companies I think that MODO is the best option, because they have a variety of vehicles available, you can book in advance, and they have special rates for non-profit or profit businesses. They seem to be the most flexible and user friendly choice as well.

When using a rental service, in this case specifically Modo, these are the steps you would need to take. First, sign up. There is a deposit (which you will get back at the termination of the contract) and a membership fee, and you will need to decide on the number of drivers to register. On the days that a specific vehicle is needed, it would be wise to book in advance. The vehicle can be picked up at its designated location, used for the time needed, and returned later. The main issue with a car sharing program is the inconvenience of picking up and dropping off the vehicle. This could be solved by employees picking them up on the way to work, from wherever they are commuting from. If this is not an option, there is a truck located relatively near campus, and a few vehicles kept right on campus. The other issue with car sharing is that the vehicles need to be available for others, so booking one specific vehicle at the same time every week is not the best for the company; however there are lots of different trucks around, as well as mini vans with Stow and go seating that can be substituted occasionally. Aside from these two convenience issues car sharing is a very good option from an environmental and economic point of view.

3.0 The Diesel Truck Option

There are plentiful options in the open market for used cars. This gives us and more importantly the farm flexibility in choosing a safe, environmentally friendly and reliable option. We also need to consider as any car owner would the cost of maintenance incurred after purchasing the used truck. A secondary investigation has been done to understand the implication of buying a truck in this way. Some of the main positive tenents

3.1 Environmental Factors of a Diesel Truck

According to a new study at CICERO, both gasoline and diesel give a net climate warming effect (Bond 1982). The study shows that diesel causes more warming than gasoline in the first decade after emission into the atmosphere, while gasoline causes most warming after that period. When the emphasis is on more long-term climate changes, diesel clearly comes out best due to lower CO2 emissions per kilometer driven over the entire life cycle of the vehicle.

The reason for the difference between diesel and gasoline is in the composition of their emissions. We know from before that passenger cars with diesel engines emit, depending on their condition, about 20 percent less of the greenhouse gas carbon dioxide (CO2) than its gasoline counterpart. However, other than CO2, the exhaust contains a number of other components such as nitrogen oxide (NO), carbon monoxide (CO), and particles. With the exception of CO, emissions of these components are generally higher from diesel cars, and lead to lower air quality and negative health effects. But the particles CO and NO also have important climate effects. The emission of NO not only contributes to the formation of ozone that has a climate warming effect, but it also reduces the amount of the greenhouse gas methane, which results in a cooling effect. Soot particles from diesel engines absorb solar radiation and cause warming.

According to the U.S. Environmental Protection Agency (EPA), because diesel has a higher carbon content, it also emits more carbon dioxide per gallon of fuel consumed when compared to gasoline. However, the higher fuel economy of diesel reduces the amount of greenhouse gas emissions over the car's lifetime. There are also certain fuel additives, such as smoke suppressants and detergent additives that have been developed to decrease the effect of diesel fuel on the environment. Smoke suppressants are organic compounds that reduce the amount of soot emitted by diesel engines, but conversely also increase the number of ultra-fine particles released into the atmosphere, as well as overall sulfate emissions. Detergent additives are used to keep engines cleaner by removing oil deposits on fuel injectors, which also increases efficiency of the engine.

3.2 Economic Factors of a Diesel Truck

The benefits of using diesel fuel include higher fuel economy and lower costs generally. According to a study recently conducted by Carnegie Mellon's Tepper School of Business, diesel cars are generally a better value than gasoline cars. Cars that use diesel fuel have higher residual value, which is an estimate of an object's future worth. In some cases, the researchers observed residual values up to 30 percent higher for diesel, which indicates much lower depreciation. Diesel cars' higher fuel economy also leads to lower vehicle operating costs. Since diesel fuel is more efficient (due to its higher density), each trip will require less fuel and will reduce money spent on fuel.

They are lots of options for used diesel trucks when searching the market, this ensures that the farm can find almost exactly what they are looking for. Narrowing the results down, we can find based solely on fuel efficiency Toyata trucks tend to perform the best, the Tacoma series in

particular. It is also the main selling point of the Toyota Tacoma, but with the most fuel economy we can infer it also has the least waste attributed to the atmosphere. The weight of the car structure is light and horse power is absolutely enough for delivery the vegetables and haul heavy equipment while we chose this truck for its fuel efficiency on the road.

3.3 Maintenance of a Diesel Truck

The mileage is another important factor that we have to consider during the process of selecting the optimum truck. The farm has budgeted the truck to last 3 years therefore mileage is an issue for them to consider as it correlates with the life cycle of the truck. By Bond's "Lemon's model" we can insinuate that if they are looking for a truck that will last them the amount of time they would like and they are looking in the 2001 models for the price point, they should want no more than 230 000km on the vehicle to leave the greatest possibility of it lasting 3 years.

The transmission of the truck is a worthy point of discussion as well. Doing some primary research we can find that on average trucks that use a standard transmission tend to cost less used or new. A standard transmission may also factor into convenience as starting it in cold weather can be easier and being in low gear generates more torque for when the car has to go through dirt or mud. Finding certified drivers may be a potential downsides but as long as the talent is available a standard transmission is the right decision for a diesel truck.

3.4 Conclusion for the Option of a Diesel Truck

A diesel truck brings familiarity, it is an old mode of transportation and many see its merits thus its continued use. Based on environmental research we can see its releasing more CO2 into the atmosphere but gains ground because of its fuel efficiency over its gasoline counterpart. Maintenance for the truck doesn't need to be a grave concern as it does not give this option a large advantage or disadvantage over other trucks, through mileage and other basic checkups we

can assure that maintenance is kept to a minimum. In total value diesel looks like it comes on top with many sources claiming the entire life cycle can be up to 30% cheaper than a similar gasoline truck. Environmentally and economically we can follow that a diesel truck in the end is a completely viable option for the UBC farm.

4.0 Introduction to a Biodiesel Truck

Currently UBC Farm is using a Toyota Tacoma (1996) to carry out their errands. As the truck is gaining years, UBC Farm is looking into the option of buying an old diesel vehicle and converting it to biodiesel. This option shall be evaluated using triple bottom line assessment.

4.1 Environmental Social and Economic Factors of a Biodiesel Truck

With the rising cost and limited supply of petroleum fossil fuels, the world is looking for a solution to solve for the fuel demands of today's society. Enter biodiesel, which can be used in most diesel engines since 1994. This allows for the use of biodiesel fuel by a regular diesel truck. This reduces extra costs to maintenance and servicing that would be otherwise encountered. However, such blends tend to be low blends of biodiesel such as B5 (Biodiesel Conversion Simplified).

Biodiesel can be blended and used in many different concentrations, including B100 (pure biodiesel), B20 (20% biodiesel, 80% petroleum diesel), B5 (5% biodiesel, 95% petroleum diesel) and B2 (2% biodiesel, 98% petroleum diesel) (Alternative Fuels Data Center).

Brewing of biodiesel, in a biodiesel processor, can be done from one's garage. Organic Mechanic offers biodiesel processors and all the necessary equipment - filters, heaters, testing equipment and pumps – that aid in fuel independency (Biodiesel Conversion Simplified).

4.2 Economically

Biodiesel is a domestically produced, clean-burning, renewable substitute for petroleum diesel. Using biodiesel as a vehicle fuel increases energy security, improves public health and the environment, and provides safety benefits (Alternative Fuels Data Center).

4.2.1 Oil Prices

One of the main concerns in further usage of biodiesel is the economic viability of its production. A few years ago, biodiesel unit price was relatively higher than that of petroleum-derived diesel fuel. One of the major reasons for this difference in prices lies in the social implications that come about from the production of biodiesel. Crops used for human consumption also hold the potential to be used for biodiesel production. However, currently, due to the dramatic increase of crude mineral oil price, cost of biodiesel is not too far from diesel price, as can be seen from Table 1 below (Pinzi, S.).

Fuel	Price (USD/t), Sept 2007	Price (USD/t), Sept 2008
diesel fuel	733	1017

Fuel	Price (USD/t), Sept 2007	Price (USD/t), Sept 2008
RME[1] (B100)	1020−1060	1415
SME[2] (B99)	850−865	1185
PME[3] (B99)	780−850	990

Table 1. Price of Biodiesel from Different Raw Materials and Diesel Fuel (Pinzi, S.)

Currently, regular diesel prices range from $1.22 CAD to $1.80 CAD in the general British Columbia area (n.d.). The price of biodiesel blend B100 in Vancouver is $1.68 CAD and is only available through Vancouver Biodiesel Co-op located on 360 Industrial Ave, Vancouver. (The Little Pump that Could).

4.2.2 Manufacture of Biodiesel (*optional at UBC Farm)

The Alma Mater Society (AMS) at the University of British Columbia (UBC) have already set forth on trying to produce their own biodiesel with the help members of the Chemical and biological Engineering Sustainability Club. The project is still at its early stages however, with the purchase of a biodiesel truck by UBC Farm, this project may well be underway (Butler, J.).

Manufacturing costs and raw feedstock prices are the main economic criteria to consider

[1] RME: rapeseed oil methyl ester
[2] SME: soybean oil methyl ester
[3] PME: palm oil methyl ester

for biodiesel production to compete with diesel fuel. Manufacturing costs of biodiesel include direct costs for oil extraction, reagents, operating supplies, and manpower, as well as indirect costs related to insurance and storage (Pinzi, S.).

Moreover, several studies have identified that the price of feedstock is by far one of the most significant factors affecting the economic viability of biodiesel manufacture. In fact, approximately 70% − 95% of total biodiesel production cost arises from the cost of the raw material. Thus, to produce a competitive biodiesel, the feedstock price is a factor that needs to be taken into consideration (Pinzi, S.).

4.2.3 Maintenance Costs

As most regular diesel trucks, manufactured after 1994, are able to use lower blends of biodiesel fuel (B5 and B10), maintenance and service costs do not differ much between the use of either type of fueled vehicle. This price changes from service point to service point and also on the damage to the vehicle, if any.

4.3 Socially

The major obstacle for large-scale adoption of biodiesel from vegetable oils is the production of sufficient amounts of oilseed crops without significantly affecting food supply and cost. To reach

this goal, researchers, industries and some governments have put a lot of effort proposing and developing alternative sources to produce biofuels. A large proportion of these efforts are focused on conversion of lignocellulosic[4] feedstocks to ethanol (second-generation fuels) (Pinzi, S.).

Moreover, there is currently a social controversy over biofuels produced from energy crops[5] that are primarily used for feeding purposes. In case the that scientific community eventually finds an efficient technology to produce alcohol from agricultural pruning and forest residues that definitely will not compete with human food consumption, this will provide us with an insufficient quantity of biofuels. Plantations of trees to process biomass into alcohol may be needed, leading to the same social alarm caused by the use of energy crops (first-generation fuels) instead of crops for food (Pinzi, S.).

However, having a biodiesel fueled truck on UBC Farm encourages the surrounding community to also take note of their carbon foot print. This is an important step towards catering for a better future and healthy generations to come.

4.4 Environmentally

The biggest advantage that biodiesel has over petroleum diesel is its environmental friendliness

[4] Lignocellulosic biomass refers to plant biomass that is composed of cellulose, hemicellulose, and lignin. The carbohydrate polymers (cellulose and hemicelluloses) are tightly bound to the lignin. Lignocellulosic biomass can be grouped into four main categories: agricultural residues (including corn stover and sugarcane bagasse), dedicated energy crops, wood residues (including sawmill and paper mill discards), and municipal paper waste (Lignocellulosic biomass).

[5] An agricultural or tree crop grown for the specific purpose of being converted into heat, power, or transportation fuels (Glossary)

(Demirbas, Ayhan.).

4.4.1 Carbon Dioxide (CO_2) Emissions

Table 2 and Figure 1 summarize CO_2 flows from the total life cycles of biodiesel and petroleum diesel and the total CO_2 released at the tailpipe for each fuel. The dominant source of CO_2 for both the petroleum diesel and the biodiesel life cycles is the combustion of fuel in the vehicle (Sheehan, J.).

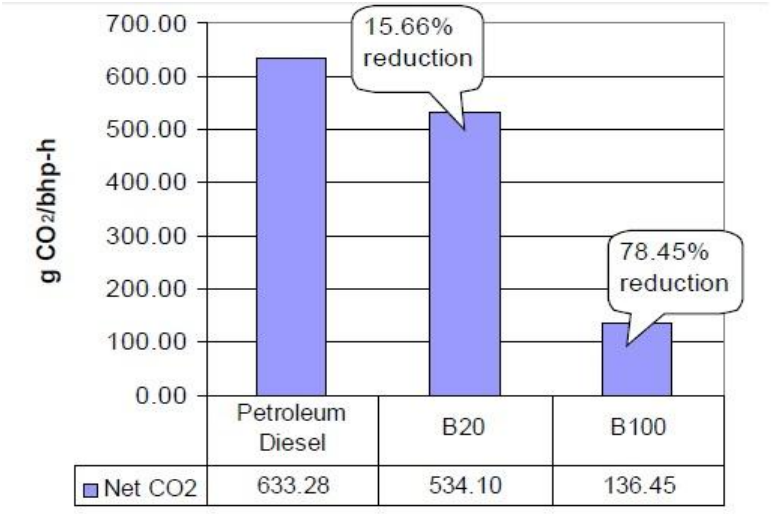


Figure 1. Comparison of Net CO_2 Life Cycle Emissions for Petroleum Diesel and Biodiesel Blends (Sheehan, J.)

Fuel	Total Life Cycle Fossil CO_2	Total Life Cycle Biomass CO_2	Total Life Cycle CO_2	Tailpipe Fossil CO_2	Tailpipe Biomass CO_2	Total Tailpipe CO_2	% of Total CO_2 from Tailpipe
Petroleum Diesel	633.28	0.00	633.28	548.02	0.00	548.02	86.54%
B100	136.45	543.34	679.78	30.62	543.34	573.96	84.43%

Table 2. Tailpipe Contribution to Total Life Cycle CO_2 for Petroleum Diesel and Biodiesel (g CO_2/bhp-h) (Sheehan, J.)

For petroleum diesel, CO_2 emitted from the tailpipe represents 86.54% of the total CO_2 emitted across the entire life cycle of the fuel. Most remaining CO_2 comes from emissions at the oil refinery, which contribute 9.6% of the total CO_2 emissions (Sheehan, J.).

For biodiesel, 84.43% of the CO_2 emissions occur at the tailpipe. The remaining CO_2 comes almost equally from soybean agriculture, soybean crushing, and soy oil conversion to biodiesel. Figure 2 shows the effect of biodiesel blend levels on CO_2 emissions (Sheehan, J.).

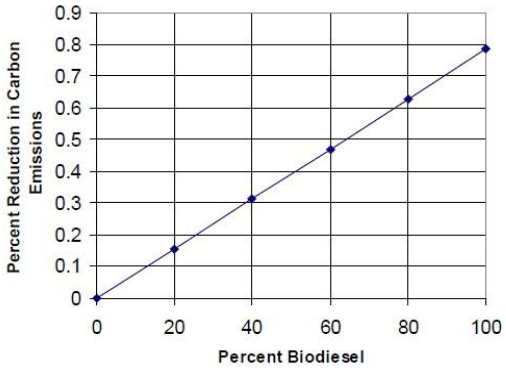
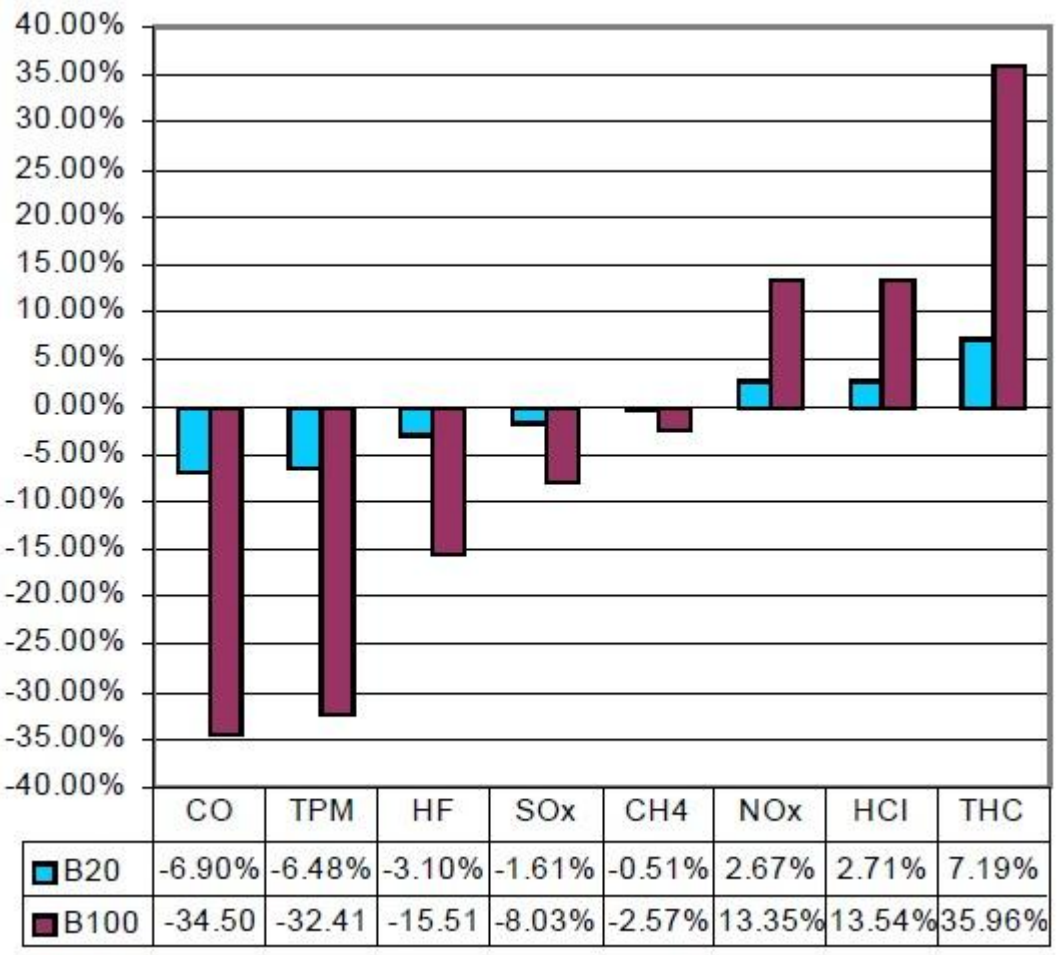


Figure 2. Effect of Biodiesel Blend level on CO_2 Emisions (Sheehan, J.)

4.4.2 Life Cycle Air Emissions



	CO	TPM	HF	SOx	CH4	NOx	HCI	THC
B20	-6.90%	-6.48%	-3.10%	-1.61%	-0.51%	2.67%	2.71%	7.19%
B100	-34.50	-32.41	-15.51	-8.03%	-2.57%	13.35%	13.54%	35.96%

Figure 3. Life Cycle Air Emissions for B100 and B20 Compared to Petroleum Diesel Life Cycle Air Emissions (Sheehan, J.)

The Figure above summarizes the differences in life cycle air emissions for B100 and B20 versus petroleum diesel fuel (Sheehan, J.). From these results it is observed that Biodiesel Blends B20 and B100 produce less of Carbon Monoxide (CO), Total Particulate Matter (TPM), Hydrofluoric acid (HF), Sulfur Oxides (SO_x) and Methane (CH_4) than petroleum diesel. However, Nitrogen Oxides (NO_x), Hydrochloric acid (HCl) and Total

Hydrocarbons (THC) are produced more by vehicles operating on biodiesel as opposed to petroleum diesel.

4.4.3 Cold Weather

The cold performance characteristics of biodiesel blends (B5, B10 and B20) of six different types of biodiesel and diesel were investigated. The startability and driveability were tested with the passenger car and the light duty truck at -16°C and -20°C. The results of the cold performance of the biodiesel fuel blends are shown in Table 3 (Kim, J. K.).

Biodiesel	Blend	Passenger car		Light duty truck	
		-16 ℃	-20 ℃	-16 ℃	-20 ℃
Soybean	B5	○[a]	○	○	○
	B10			○	○
	B20			○	○
Waste cooking	B5	○	○	○	○
	B10			○	○
	B20			○	○
Rapeseed	B5	○	○	○	○
	B10			○	○
	B20			○	○
Cotton-seed	B5	○	○	○	○
	B10			○	○
	B20			○	△[b]
Palm	B5	○	○	○	○
	B10			X[c]	X[c]
	B20			X[c]	X[c]
Jatropha	B5	○	○	○	○
	B10			○	○
	B20			○	○

[a]○: succeed engine operation, △[b],: stop engine operation after 8 minutes, [c]X: no engine operation.

Table 3. Results of Cold Weather performance of three difference biodiesel blends (Kim, J. K.)

From the table above, we are presented with a setback to biodiesel. This setback is more so present in smaller vehicles but may still occur in bigger vehicles. The empty spaces also denote a failed engine start attempt.

4.4 Concluding Remarks for the Biodiesel Truck Option

The advantages of biodiesel as diesel fuel are its portability, ready availability, renewability, lower sulfur and aromatic content, and higher biodegradability. The main disadvantages of biodiesel as diesel fuel are its higher viscosity, lower energy content, higher nitrogen oxide emission, lower engine speed and power, injector coking, engine compatibility with higher blends of biodiesel, high price, and higher engine wear (Balat, M.). There is also the issue surrounding the potential for biodiesel to compete with our current food supplies.

The above review focuses on three main criteria that may influence UBC Farm's decision in the choice of truck they make. Based on this review, a more modern diesel truck would suffice as that would allow for a more environmentally friendly fuel as well as guarantee engine start during cold weather climate.

5.0 Conclusion

The UBC farm system is an extraordinary landmark in sustainability and an example to be followed. In order for future growth and expansion the right decisions need to be made for them to still claim to be leaders in farming sustainability. Our team has outlined potential decisions and factors that will play into each of them. They will need to look at economic feasibility, environmental impact and other factors outlined in this report. Before UBC can make a decision they need to understand their own needs and categorize them by importance in order to take the benefits and faults of their own options and successfully choose their preferred transportation method.

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