UBC Social Ecological Economic Development Studies (SEEDS) Student Report

Triple bottom line assessment of transport options for the UBC farm

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Abstract

This report investigates and analyzes viable vehicle options to be used at the UBC Farm using Triple bottom line assessment. These options include powering the vehicle with the traditional fossil fuels, natural gas, biodiesel, or use a hybrid or battery powered electric vehicle. After collaborative research on these methods, this report recommends the use of Biodiesel blended with petroleum diesel with a ratio of 1:4 as the fuel source, which is the most economical, social and sustainable choice with optimal performance.

In order to make a decision, a few assumptions were made which were the main contributing factors in the final decision of the report. The assumptions were that the truck will be used on a rough terrain which suggests that a four wheel drive system is high recommended, and that the vehicle must have a descent amount of power so it can tow trailers and such. Another assumption made was that the financing for this vehicle is limited. These assumptions along with few specified requirements for the vehicle were the deciding factors in the conclusion.

The problem states that the truck must at least be operational for next three years thus the economical decision was made based on the average cost of the different options for the vehicle over the span of three years. This eliminates the electric and natural gas vehicles due to their high initial over head cost in comparison to a regular fuel vehicle. Diesel and gas vehicles lack the social and environmental aspect of the assessment thus leaving biodiesel as the top choice. After some research it was found that using 100% biodiesel can have a small initial over head charge as well and also few issues with maintenance. In order to overcome these issues, it was decided to use a 20% blend of biodiesel and petroleum diesel (also called B20) since it eliminates any over head charge for modifying most of the vehicles manufactured after 1993 and it also eliminates few issues B100 (100% biodiesel) might have. The B20 blend provides a cleaner and more sustainable fuel source while keeping the performance of the vehicle intact. Using biodiesel also provides the farm with an opportunity to work with the UBC's CHBE Sustainability Club.

In conclusion, biodiesel is the most optimal choice when considering all three aspects of a triple bottom line assessment: environmental, economical and social.

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Glossary

Smog	- A fog or haze that is intensified by atmospheric pollutants
Greenhouse gas	- Gasses that contributes to the global warming by absorbing radiation.
ASTM D-6751	- American society for Testing and Materials (ASTM). ASTM D6751 is standard specification for using blended or pure biodiesel.
Base catalyzed process	- It is a chemical term meaning that the reaction itself is base catalyzed. Any strong base capable of deprotonating the alcohol will do, but sodium and potassium hydroxide are used because of their low cost. The reaction must be kept dry as water will cause undesirable base hydrolysis. One of the processes used to create biodiesel.
Biocide	- A biocide is a chemical substance capable of killing living organisms, usually in a selective way.
Block Heater	- A block heater is an electric heater that heats the engine of a car to ease starting in cold weather.
Feed Stock	- In this context feed stock refers to any raw material which can be used to make biodiesel.
Flashpoint	- The lowest temperature at which the vapor of a combustible liquid can be ignited in air or simply a point where something is ready to blow up.
Fuel Filter Heater	- Fuel heaters are used to avoid the forming of wax (in case of low temperatures) inside the filtrating element which can stop the fuel flow to the engine.
Glycerin	- a sweet syrupy trihydroxy alcohol obtained by saponification of fats and oils. It is used in many different areas like cosmetic and medical industries.
Hydrocarbons (HC)	- It is an organic compound consisting entirely of hydrogen and carbon.
Particulate Matter (PM)	- particulate: a small discrete mass of solid or liquid matter that remains individually dispersed in gas or liquid emissions (usually considered to be an atmospheric pollutant)
Viscosity	- The state of being thick, sticky, and semi fluid in consistency, due to internal friction.

List of Abbreviations

CNG	- Compressed Natural Gas
UBC	- University of British Columbia
B20	- Fuel consisting of 20% biodiesel
B100	- Fuel consisting of 100% biodiesel
GHG	- Greenhouse gases
HEV	- Hybrid electric vehicle
PHEV	- Plug-in Hybrid electric vehicle
BEV	- Battery electric vehicle

INTRODUCTION

The objective of this report is to perform a triple bottom line assessment of possible replacement vehicles for the UBC farm; analyzing the options based on social, economic, and environmental factors. The options presented by the UBC farm sponsor Veronik Campbell were: biodiesel, renting from a coop, or a regular gasoline combustion engine. Additional options added by our group were: compressed natural gas, and converting to a hybrid or electric. Through our analysis of the social, economic, environmental factors of these options, we determined the best replacement vehicle option for

1 BIODIESEL

1.1 What is Biodiesel and how can we use it?

Biodiesel is a renewable alternative fuel source for diesel compression engines. It can be made from a number of different resources, for example animal fats and new or used vegetable oils can be used to produce biodiesel (Green Truck Association, 2012). This is a huge advantage towards campus sustainability since a huge amount of oil used around the campus could be used for this purpose.

There are number of different processes used to make biodiesel but the most common and economic choice is to use the base catalyzed process. Basically the process uses 10 gallons of alcohol for every 100 gallons of feed stock processed and the result yields in 100 gallons of biodiesel and 10 gallons of glycerin (Green Truck Association, 2012).

Biodiesel is typically blended with petroleum based diesel for optimal performance and reliability. The most common blend is 20 percent or B20. This blend typically allows the vehicle to still run with same power output as using the petroleum diesel thus making it ideal for reducing green house emissions while keeping your engines performance intact (Green Truck Association, 2012). For most vehicles B20 blend can be used without voiding the warranty or modifying your engine in any way. For more information on which vehicles can use what blend with their original engines you can refer to ASTM D-6751 compatible chart – Appendix A. Blend higher than B20 requires special modifications to the vehicle and regular maintenance. Cost of this procedure depends on which vehicle is being modified and what blend is being used.

1.2 What are the advantages?

The use of biodiesel has numerous benefits and advantages. Few of the advantages are:

- Air Quality
- Engine operations
- Safety

Figure 1: Unburned particles.
Source <agtheory.blogpost.ca>

In comparison with petroleum diesel, using biodiesel reduces tailpipe emissions of unburned hydrocarbons (HC), particulate matter (PM) and few other toxins (refer to figure 2.1). The reduction in toxins and greenhouse gases increases as the level of biodiesel blend gets higher. A 100% biodiesel or B100 provides the best emission reduction but a lower blend, for example B20, can also make a difference. B20 has shown to reduce PM emission by 10% and unburned HC by 21% (refer to graph 2.2) (Eric Doherty - BC Sustainable Energy Association, 2008).

When it is mentioned that biodiesel blend can reduce the CO2 or any other gas emission, it is often misconceived into believing that it's because less CO2 is produced when biodiesel is burned when in fact burning of petroleum diesel and biodiesel produces almost same amount of CO2. The reason why biodiesel is considered a clean fuel source is because whatever amount of carbon was used by the plants is the carbon we are releasing back into the environment so basically the net value of CO2 is not affected by use of biodiesel. The carbon cycle of biodiesel is neutral thus biodiesel is a carbon neutral fuel (refer to figure 2.3). UBC's Climate Action Plan aims to substantially reduce the greenhouse gas emissions throughout the campus (CHBE Sustainability Club, 2012). Biodiesel can be carbon-neutral over its life cycle, it burns cleaner, is nontoxic, has low sulfur quantity and is classified as biodegradable. These qualities among others mean that biodiesel can contribute meaningfully towards UBC's Climate Action Plan.

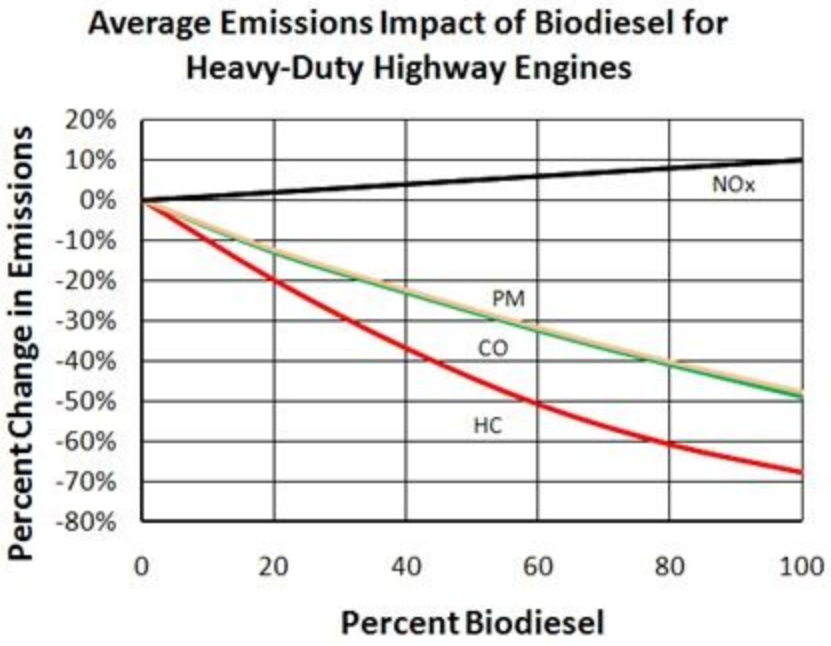

Figure 2: Average emissions impact of Biodiesel.
Source: Alternate fuels data center<www.afdc.energy.gov>

One unintended benefit of biodiesel is that it improves fuel lubricity which results in longer life of the engine since the engine depends on the lubricity of the fuel to keep the moving parts from wearing prematurely. Under regulations the use of sulfur has been reduced over time which also reduces the lubricity of petroleum diesel. Using even 1% of biodiesel blend can add adequate lubricity to the engine (Eric Doherty - BC Sustainable Energy Association, 2008).
Another concern with using petroleum diesel is safety. Biodiesel is nontoxic and it eliminates this concern since it causes far less damage if spilled or released into the environment. Biodiesel is also less combustible. Its flashpoint is 150 C as compare to 52 C for petroleum diesel. Biodiesel is safe to handle, store, and transport (Eric Doherty - BC Sustainable Energy Association, 2008).

1.3 What are the disadvantages?

There are few issues which, depending on the blend, arise from the use of biodiesel. These issues are related to maintenance, storage and use in cold weather.

All fuels, including fossil and biodiesel, are prone to oxidation. In the case of biodiesel oxidation leads to high acid concentration, high viscosity and the formation of gums and

sediments that can clog filters (Green Truck Association, 2012). This brings up the issue of storage and maintenance of the vehicle. It's suggested that the fuel must be used within 6 months to avoid complications in the engine. Depending on the blend, either B20 or higher, frequent cleaning of filters must be done at least every 6 months. Growth of algae or other biological contamination can be a problem thus use of biocides is recommended. Standard biocides used in regular diesel works equally well with biodiesel (Green Truck Association, 2012). In most cases such contamination is the result of water contaminating the fuel. This could be a major issue since it rains constantly in Vancouver.

Cold weather and biodiesel don't go well together; this is a problem especially due to our climate. B100 blend is much more prone to cold weather issues than petroleum diesel or even a B20 blend. One major issue arises from cold weather is starting and running the engine. This issue could be solved by a block heater or a fuel filter heater (Green Truck Association, 2012).

It is also important to note that in regards to emissions, B100 blend can increase nitrogen oxides emissions (refer to figure 2.2) (Alternative Fuels Data Center, 2012).

1.4 Availability and cost

Availability of biodiesel is not an issue in BC. There are number of different provider's right here in lower mainland such as:

- UBC Biodiesel Project
- Vancouver Biodiesel Coop
- Whole Energy Canada

In the past biodiesel was sold at almost double the price of petroleum diesel but today biodiesel is sold at the same price as diesel and in some regions it's even cheaper. This is because of the recent rise in price of petroleum diesel and, tax and production incentive for biodiesel by the government. In 2007 federal budget, Canada committed to a 2% renewable fuel standard for diesel fuel which created market for 650 million liters of biodiesel per year and they also announced $2 billion for renewable fuel production incentives (Eric Doherty - BC Sustainable Energy Association, 2008).

In 2004, The BC government amended the Alternative Motor Fuel Act, allowing the biodiesel portion of the blend to be exempt from the provincial motor fuel tax. With all these incentives

and the recent growth in renewable fuel market, BC has one of the largest markets for biodiesel in Canada (Eric Doherty - BC Sustainable Energy Association, 2008).

1.5 Bottom line

Environmentally biodiesel is much more eco-friendly then petroleum diesel. Biodiesel leaves the environment less polluted. Economically and socially biodiesel is a superb choice. It costs same or even less than petroleum diesel. By using a biodiesel truck at the farm you get the campus involved by utilizing the UBC biodiesel club services and you also work towards UBC's goal of sustainability and reducing green house gases. When producing biodiesel its bi-product glycerin is useful in many application especially in cosmetic and medical industries.

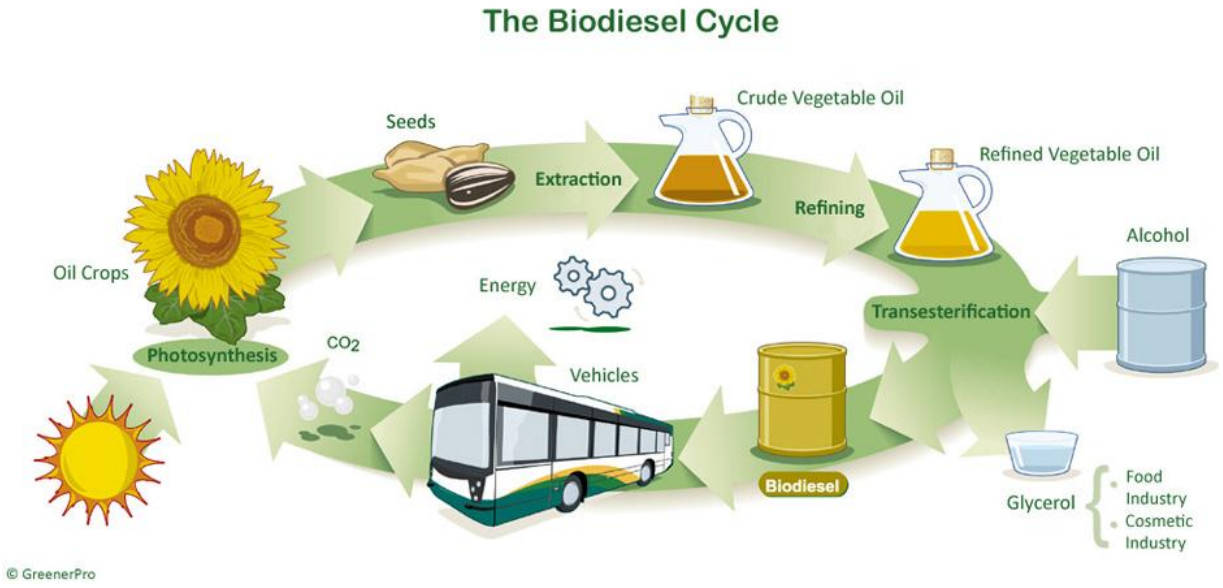

Figure 3: Life cycle of Biodiesel.
Source: Greenerpro <www.greenerpro.com>

In regards to which blend should be used at the farm really depends on the budget and a number of other different issues. Using B100 blend needs more care, regular maintenance and it could be a problem in wet and cold weather. Thus it's safe to assume that the truck shouldn't be left out in rain and snow all the time like the current truck to avoid complications. You also need to modify the truck so that it can use B100 blend which increases the initial cost. On the other hand by using the B20 blend you can have a high level of power output needed in towing and also easily enjoy all the advantages offered by biodiesel but at a smaller scale. That being said you also save

the modification cost by B20 blend in most vehicles and it is a good option if you want a good mix between power output and eco-friendliness.

2 NATURAL GAS

2.1 Natural gas and its availability

Natural gas is a naturally occurring hydrocarbon gas which is usually found in underground reservoirs as a fossil fuel. It is extensively used throughout the lower mainland for the generation of electricity, heating of homes and cooking. This gas can be compressed to create Compressed Natural gas (CNG) which is used in automobiles as a cleaner alternative to gasoline. It is also created as a by-product from waste and biomass in landfills.

CNG is a good source of energy for the farm truck because it is a fairly abundant resource and Canada has the second largest reserves of natural gas in the world. The transmission system for natural gas is also well established in Canada because it is widely used to heat homes and in cooking. This gas can be directly compressed and used to power cars and thus a home fuelling system can be installed. There are also a number of commercial fuel stations which offer natural gas in Vancouver (Canadian natural gas vehicle alliance[CNGVA],2012a) making it a convenient fuel for the UBC farm truck.

2.2 Economic impact

The price of CNG itself is consistently around 25 to 50% cheaper than diesel (FortisBC, 2012), making natural gas powered trucks economically beneficial in the long run. The maintenance costs of natural gas vehicles are also close to that of regular diesel powered ones. Two options for a natural gas powered truck are to either buy a new natural gas powered truck or to buy a used truck and convert it to take natural gas. Brand new natural gas trucks are about 10% more expensive than an equivalent gasoline truck. The BC ministry of environment also offers incentives for purchasing new natural gas powered vehicles (see Appendix A) which can help offset some of the higher cost. Another option is to convert an older conventional truck to natural gas but the cost of the conversion is around $6000-$11000 (Kreindler, 2012). So CNG is only a better option economically if the truck will be used for a few years so that the lower fuelling costs can make up for the higher initial cost compared to a conventional truck. This time period is expected to shorten as the price of gas is expected to rise faster than the price of natural gas.

2.3 Environmental impact

Cars that are powered by natural gas create around 20 to 30% less greenhouse gases than cars powered by gasoline. Although natural gas is a fossil fuel, the major component of it, methane, is produced naturally in landfills due to anaerobic decomposition. Methane is a greenhouse gas whose effect is 20 times worse than that of carbon dioxide. It is usually just burned at landfills to convert it into carbon dioxide. This Methane could instead be used in making renewable natural gas like in figure 4. This would result in being able to recycle energy from our waste(Koch, 2010) and according to the Natural Resources Canada's GHGenius model, a 85-90% carbon reduction is expected overall if only renewable natural gas is used(CNGVA,2012b). Renewable natural gas is currently only planned for Toronto and Quebec but is expected to be expanded to Vancouver as well. Natural gas therefore can provide a good improvement in terms of environmental impact compared to gasoline with a potential for vast improvement with renewable natural gas.

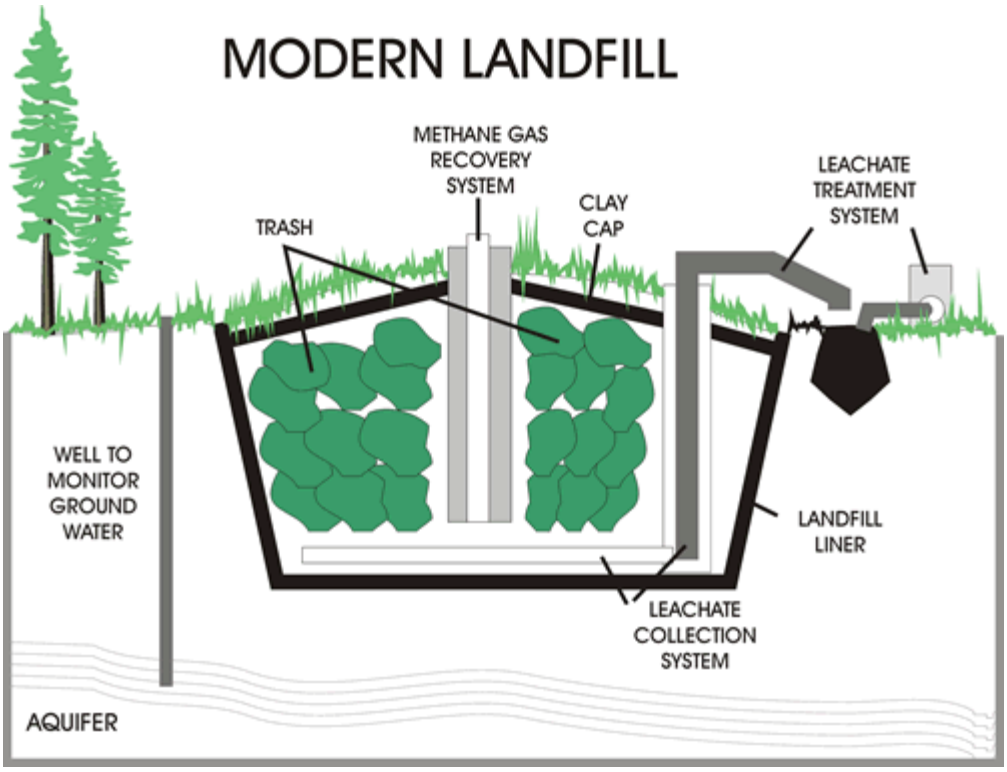

Figure 4: Renewable natural gas.
Source: Cowpatty patty<http://www.cowpattypatty.com/?cat=5>

2.4 Social impact

The social benefits of using natural gas include a better image for the farm because natural gas has less of an impact on the environment than gasoline. UBC has also done a lot of research into natural gas technology for cars especially professor Philip Hill (WestPort, 2012). A natural gas truck at the UBC farm would help sustain future interest in this field and more research at UBC. The community can also be involved in lobbying for bringing renewable natural gas technology to the landfills of Vancouver. Small scale anaerobic digesters can also be set up locally for the production of natural gas (Discover Magazine, 2012). A natural gas powered vehicle is also a little quieter than a gasoline vehicle. This combined with the lower production of air pollutants will provide an immediate positive impact to the people using the truck and the community at large (OWMA Waste Sector Symposium, 2012).

2.5 Conclusion

Compressed natural gas is therefore a good alternative from a conventional gasoline powered truck for the UBC farm. There is a good distribution and large local reserves for natural gas. It also emits less greenhouse gases and air pollutants with the potential of eliminating most of its carbon footprint when renewable natural gas comes to Vancouver. This also provides social benefits to the society along with quieter trucks and better community involvement. The only downside is that with the higher initial cost of switching to natural gas, it would take a few years of operation for the lower fuelling costs to make it more economical than a conventional truck.

3 OIL

3.1 Why we still use Oil?

With all the new advances and different kinds of renewable energy it is a wonder why we continue to use non-renewable resources, chiefly oil in the form of diesel and gasoline, when it is such a harm to the environment. In The United States, 84% of its total energy comes from fossil fuel (National Academies, 2012) because of the amount of money needed to convert the current infrastructure to one that supports alternative energy sources is not supported by the government (Homocon, 2006). With the huge levels of infrastructure already in place for the continued usage of gasoline and diesel, it makes internal combustion engine vehicles a popular choice in the consumer market.. However, there are many issues related to oil that we must also address.

3.2 Advantages

The advantages of fossil fuels are: the low vehicle cost, the convenience of purchasing gasoline or diesel, the high energy density and the reliability of fossil fuel (Distegen, 2005). If we compare the cost between fossil fuel and alternative energy, we find that fossil fuel is the cheapest on a short term basis. In addition, it is very convenient because the infrastructure supporting it is already well established. Fossil fuel vehicles tend to be quite reliable, as most of the research into better vehicles has been put into making internal combustion engines more efficient and powerful.

3.3 Disadvantages

However, there are downsides that come with the usage fossil fuel; the main problem with fossil fuel are the greenhouse gas emissions created by combusting ethanol. Fossil fuel pollutants are known to cause smog and contain many particles that are harmful to biological organisms lungs and other tissues (Wilson, 1973). Looking back at the past 150 years, we can see that we can see a close correlation between increased usage of fossil fuels, and the temperature of our atmosphere due to GHG. (Figure 5). Also, fossil fuel is not a sustainable source of energy, as we are depleting our reserves faster than they are naturally created. The rising cost of fuel and the fact that fossil fuel is a non-renewable source of energy are also factors that we must consider.

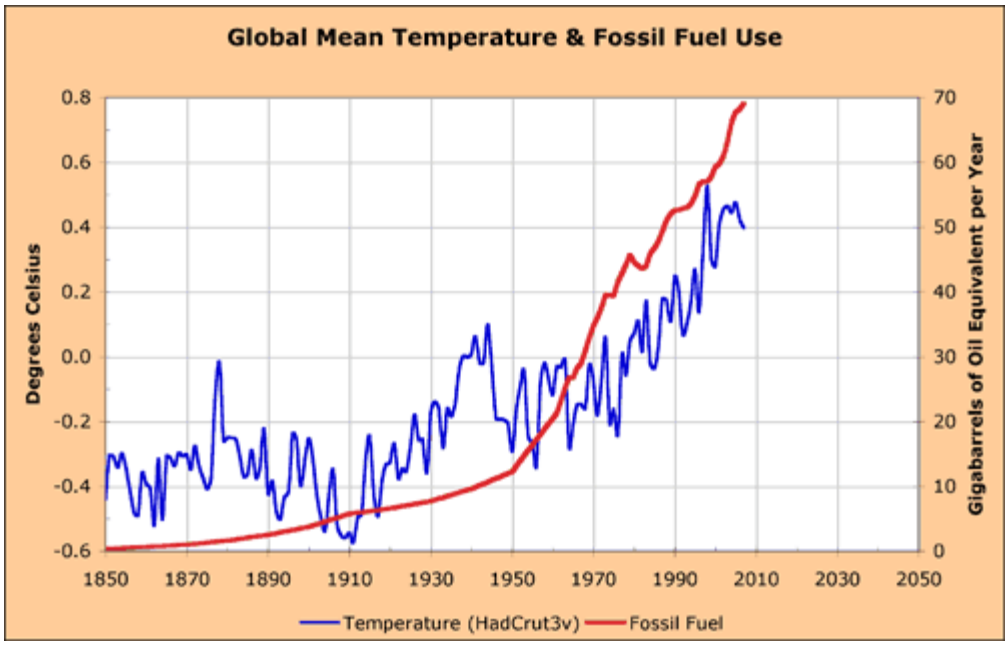

Figure 5: Usage of Fossil Fuel and Global Warming.
Source: The Quaker Economist<http://tqe.quaker.org/2007/TQE158-EN-GlobalWarming.html>

3.4 Image of the farm

Another aspect that we must consider is choosing a right vehicle is the image that the UBC Farm represents. We should choose a vehicle that can portray the positive image of sustainability that the UBC Farm promotes. The vehicle should be able be a green vehicle that doesn't create lots of pollution and is a car that is seen by society that is a clean renewable source of energy. In choosing a gasoline car, the image isn't as pronounced because of the fact that oil creates plenty of pollution and the overall view of society on gasoline vehicles.

3.5 Conclusion

In conclusion, we have decided that a fossil fuel vehicle is not the proper vehicle for the UBC Farm. While a gasoline vehicle will be cheap and convenient, it is the quick and dirty solution. The environmental impact of a internal combustion vehicle using gasoline is too great, and the UBC farm supports sustainable resource use over fossil fuel use. With fuel prices rising, it is likely that within a vehicle's lifetime, it will be cheaper to opt out of fossil fuel usage.

4 HYBRID ELECTRIC

4.1 Introduction to hybrid technology

Hybrid Electric Vehicles (HEV) are more energy efficient than conventional vehicles due to "the optimization of the engine operation and recovery of kinetic energy during braking"(Chan 2007) and when the engine "output is greater than that required to drive the wheels (in parallel Hybrid electric vehicles only)." (Chan 5) With fuel prices rising, HEV and Plug-in Hybrid Electric Vehicles (PHEV) are becoming more popular with consumers. With three main variants on the market of HEV: series, parallel, series-parallel; different types of vehicles can be created using each. A vehicle of the size required for the UBC farm would be of the series-parallel PHEV variant due to the power requirement and the possibility to run solely on electric power for trips within the UBC campus; conclusions will be drawn from this assumption. A breakdown of general advantages and disadvantages to a HEV is shown in figure 6.

4.2 Economic

Costs for a PHEV are broken down into maintenance, energy and fuel pricing, and initial purchase including: overall vehicle cost, drivetrain costs, and battery cell costs. With a HEV, "due to the optimized operation of the [internal combustion engine], the maintenance of the vehicle can be significantly reduced."(Chan 2007) Fuel costs will be on par with every other vehicle burning gasoline, but due to the fact gasoline will rarely be used when driving around UBC energy costs play a larger factor. This means that the majority of the consumption costs past initial purchasing will be very low, with BC's abundance of hydro electric power. Even when running on gasoline, a HEV obtains a higher level of efficiency from its electric motor running with the engine as a generator resulting in better fuel economy.(Chan 2007) While running costs may be low, the initial purchase is where the problem currently lays in hybrid vehicles. As of 2010, powertrain costs for a vehicle the size of a truck would cost approximately five times more for a hybrid powertrain than its internal combustion engine counterpart.(van Vliet 2010). This cost is expected to drop to near 70% by the year 2030 (Offer 2009). The cost of battery cell costs is also very high currently but is expected to drop, along with the size of the battery cells. Due to the light usage of the truck by the UBC farm a

replacement fuel cell does not need to be factored in, as current cells last approximately 250k kilometers (van Vliet 2010). Overall, the initial purchasing cost of a HEV is too high to be considered as a replacement for the UBC farm currently. But as hybrid technologies become cheaper the payback time becomes under a ten year period.

4.3 Social

The social benefit to a PHEV for the UBC farm is: their image of a sustainable farming solution is promoted, and they can promote the electric charging stations across the UBC campus, and GVRD. By using a PHEV, it is possible for the UBC farm to never have to use gasoline, also emitting much less noise pollution; enhancing the feeling that it is co-operating with the environment as long as travel is restricted to campus. Promoting the use of the electric charging stations at UBC is encouraging more Universities and municipalities to adopt a greener transportation system, which re-enforces UBC's stance on leading the way to sustainability (UBC 2012).

4.4 Environmental

The goal for a new vehicle from an environmental standpoint would be to have zero carbon emissions. A PHEV is capable of achieving near zero CO2 emissions within campus due to our clean hydro electric power system. For trips in which the battery would be drained below 20%, gasoline will be burned, and a HEV will use 15% less fuel when driving than a conventional internal combustion vehicle.(van Vliet 2010) Having zero emissions within the campus radius is actually a pessimistic view, as it is possible to have zero CO2 emissions at all with a PHEV as long as total trip lengths are below 80km approx, (Offer 2009) which reaches well beyond campus. An average diesel truck emits 156 g/km of CO2 whereas a PHEV emits 0g/km under 80km, and 129 g/km of CO2 after that (van Vliet 2010)

4.5 Overall

For the purpose of a vehicle for the UBC farm, a HEV is not an appropriate option due to the initial cost of the vehicle. Although it is only one of the three factors in a triple bottom line assessment, it was found to outweigh the beneficial factors by a large margin. In the future however, once drivetrain and fuel cell costs drop, a HEV would be a perfect solution to the UBC farm's needs.

5 BATTERY ELECTRIC

5.1 Introduction to battery technology

Battery Electric Vehicles (BEV) have actually been around since 1834, but have faded in and out in response to global oil pricing. A BEV is "capable of delivering peak power, and average power at an excellent efficiency but has a relatively low energy density."(Offer 2009) With BC's electric grid being stemmed mainly from hydroelectric sources, and energy being so cheap and charging stations around UBC BEV are a possible replacement vehicle for the UBC farm. A breakdown of general advantages and disadvantages to a BEV is shown in figure 6.

5.2 Social

By choosing a BEV for the UBC farm, a zero CO2 emissions will be produced through usage, which fits perfectly with the sustainable goals of the UBC farm. Interaction with the existing network of charging stations, at with 10 being installed at UBC and additional 150 within the GVRD, will help to promote usage of BEV's.(Ubyssey 2012) As electric vehicles are so expensive, it is also possible to team up with UBC's own Electric Car Club, and have a standard vehicle converted to electric as a club project. This would involve more of the UBC campus as a result, and would showcase UBC farm relations.

5.3 Economic

With energy and maintenance costs for BEV's so low, the only real cost is the initial purchase. The capital cost input for a battery pack to drive a larger vehicle will cost nearly 10 times as much as a for a conventional vehicle, due mainly to the cost of the battery. The reason this cost is much higher than in a HEV is due to the fact that much more power is required from the batteries. With energy density of the fuel cells in a near 1:1 ratio between size and power. "In order to double the range, the power, weight and cost must also be doubled."(Offer 2009) With electricity costs as low as 10.35$/GJ in BC running costs however, will be extremely cheap for a BEV compared to other places around the world.(BC hydro) If a range of only 80 km is required, then the lifetime costs of a BEV become much more competitive; as battery costs (figure 6.0) are the largest factor and the battery size can be kept to a minimum. (Offer 2009)

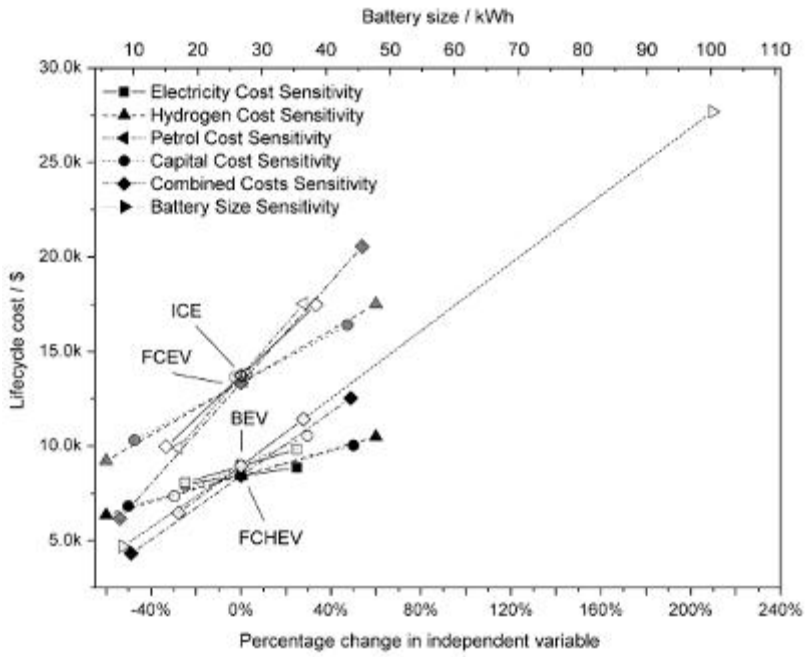

Fig. 2. Sensitivity of analysis to the battery size of the BEV overlaid on the results from Fig. 1, using a battery cost of \$250 kWh^{-1}. ICE (white), BEV (light grey), FCEV (dark grey), FCHEV (black).

Figure 6: Sensitivity of analysis to the battery size.
Source: (Van Vliet, 2010)

5.4 Environmental

A BEV will have zero CO2 emissions during operations, which is by far the most environmentally friendly option of any vehicle type on the market (with the exception of hydrogen fuel cells). After the creation of the batteries, a BEV becomes entirely independent from crude oil sources running solely off the energy grid resulting in the furthering of a goal to become fossil fuel free. By having zero, or near zero CO2 emissions due to BC's extensive hydroelectric power grid, CO2 reductions can reach 163g/km over a standard petroleum vehicle.(van Vliet 2010) Electric vehicles help to greatly improve air quality, and reduce noise pollution in urban areas resulting in a healthier population.

5.5 Overall

With the zero carbon emissions during use, the BEV seems like a great alternative to fossil fuel reliant vehicles. However with the current technology, batteries have such a low energy density "which means that, for a reasonable range, they have to be large, heavy and expensive."(Offer 2009) BEV is a possible future vehicle replacement option for the UBC farm, but currently the capital cost is simply too high

CONCLUSIONS AND RECOMMENDATIONS

After analyzing various options of transportation for the UBC farm viatriple bottom line assessment, this report recommends using a truck with a B20 biodiesel blend as its fuel source.

Currently, the gasoline truck being used in the UBC farm is neither efficient, nor does it support the sustainable methodology the farm is trying to propagate. So using a vehicle with a gas or pure diesel as its fuel source does not meet the minimum requirement of having an environmentally conscious vehicle.

Natural Gas, while also a type of fossil fuel, on average produces 10-30 % less carbon emissions when compared to other fossil fuel powered vehicles and is 25-50% cheaper which makes it both economically and environmentally a better choice. The only issue with using natural gas is the initial overhead charge of converting a regular truck into a natural gas truck. The cost is usually between $6000 and $10000. Even though the natural gas is cheaper, recouping this capital investment will take time since the truck will not be used with high frequency, rendering the cheaper cost to fuel it obsolete and.

The option of using an battery electric vehicle (BEV) or a plug-in hybrid electric vehicle (PHEV) is a viable alternative to fossil fuel. An electric or a hybrid car is excellent for the environment, reducing CO2 emissions by 30-100% depending on usage, promoting a sustainable image for the farm. The reason BEV and PHEV are not suitable is because these cars have high capital cost that cannot be offset by the extremely cheap electricity costs.

The B20 biodiesel blend option was recommended due to its combined benefits economically, socially and environmentally. Most of the diesel vehicles manufactured after 1993 are able to support up to B20 blend without any overhead charge thus eliminating the extra cost related to some other fuel sources and also opening a wide variety of option of vehicles to choose from. Biodiesel, on average, creates 78% less CO2 as it is considered an almost carbon neutral fuel. Among this and other environmental benefits, the infrastructure to support biodiesel fueling is already in place on campus and within the GVRD. Working alongside CHBE Sustainability Club and supporting their Biodiesel Project by utilizing it for the intended purpose, UBC Farm will mark its position as a supporter of UBC’s Climate Action Plan and lead the way to a more sustainable campus.

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APPENDIX

Appendix A: Incentives offered on new cars

CEV Vehicles Eligibility

Model Year	Vehicle Make	Vehicle Model	Fuel Type / Battery Size	12 Month Lease Incentive (33.3%of Maximum)	24 Month Lease Incentive (66.7%of Maximum)	Purchase or 36 Month Lease Incentive (Maximum)
2012	Chrysler	Ram	Compressed Natural Gas (CNG)	$833	$1,668	$2,500
2012	Fisker	Karma	Extended Range Electric Vehicle Vehicle (BEV) / Battery Size: 20.1kWh	$1,665	$3,335	$5,000
2013	Ford Motor Company	C-Max Energi	Plug-In Hybrid Electric Vehicle (PHEV) Batter Size: 7.5kWh	$833	$1,668	$2,500
2012 & 2013	Ford Motor Company	Focus Electric	Battery Electric Vehicle (BEV) / Battery Size: 23kWh	$1,665	$3,335	$5,000
2011 & 2012	Ford Motor Company / Azure	Transit Connect	Battery Electric Vehicle (BEV) / Battery Size: 28kWh	$1,665	$3,335	$5,000
2011 & 2012	General Motors	Chevrolet Express Van	Compressed Natural Gas (CNG)	$833	$1,668	$2,500
2012 & 2013	General Motors	Chevrolet Volt	Extended Range Electric Vehicle (E-REV) / Battery Size: 16kWh	$1,665	$3,335	$5,000
2011 & 2012	General Motors	GMC Savana	Compressed Natural Gas (CNG)	$833	$1,668	$2,500
2011 & 2012	Honda	Clarity	Fuel Cell Vehicle (FCV)	$1,665	$3,335	$5,000
2011 & 2012	Honda	GX	Compressed Natural Gas (CNG)	$833	$1,668	$2,500
2011 & 2012	Mercedes Benz	B-Class F-cell	Fuel Cell Vehicle (FCV)	$1,665	$3,335	$5,000
2011 & 2012	Mitsubishi	iMiEV	Battery Electric Vehicle (BEV) / Battery Size: 16kWh	$1,665	$3,335	$5,000
2011 & 2012	Nissan	LEAF	Battery Electric Vehicle (BEV) / Battery Size: 24kWh	$1,665	$3,335	$5,000
2011	Smart Canada / Mercedes	smart fortwo electric drive	Battery Electric Vehicle (BEV) / Battery Size: 16.5kWh	$1,665	$3,335	$5,000
2013	Smart Canada / Mercedes	smart fortwo electric drive cabriolet (eligible as of Dec 8/11)	Battery Electric Vehicle (BEV) / Battery Size: 17.6kWh	$1,665	$3,335	$5,000
2013	Smart Canada / Mercedes	smart fortwo electric drive coupé (eligible as of Dec 8/11)	Battery Electric Vehicle (BEV) / Battery Size: 17.6kWh	$1,665	$3,335	$5,000
2010 & 2011	Tesla	Roadster	Battery Electric Vehicle (BEV) / Battery Size: 53kWh	$1,665	$3,335	$5,000
2012	Toyota	Plug In Hybrid Electric Prius	Plug In Hybrid Electric Vehicle (PHEV) / Battery Size: 4.4kWh	$833	$1,668	$2,500

NOTE: Fleet vehicles are not eligible for 12 month or 24 month lease incentives and are limited to 10 incentives per organization per calendar year.

NOTE: This list was last updated October 17th, 2012. Please visit www.CEVforBC.ca for more information on the Clean Energy Vehicle (CEV) Program.

Appendix B: Chart on global temperature and fossil fuel use