

An Investigation Into a Sustainable Transport Option for the UBC Farm: A Triple Bottom Line Assessment

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Abstract:

This report is an investigation into a sustainable transport option for the UBC farm. Specifically, the farm needs a new truck since the old one is failing to meet what is used for. This report investigates a triple bottom line assessment of three major options: diesel, biodiesel, and hybrid. A triple bottom line assessment covers the economical, environmental, and social aspects and impacts of option.

The farm does have constraints and requirements when it comes to this issue. The truck must last for a minimum for three years and be able to haul heavy loads. Furthermore, it is used year round in rough terrain; therefore four-wheel drive is a necessity. In general, the truck is allowed to be manual and only travels short distances each day.

In conclusion, using B20 fuel in the biodiesel option was found to be best. It abides to all the desired requirements and is the most well rounded choice. The following report will give an in-depth analysis of how this recommendation was made.

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Glossary:

No terms to be defined.

List of Abbreviations:

UBC - University of British Columbia

GHG - Greenhouse Gases

GREET - Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation

FMVSS 208 - Federal Motor Vehicle Safety Standard 208

USDA - United States Department of Agriculture

USDE - United States Department of Energy

CHBE - Chemical and Biological Engineering

4WD - Four-wheel drive

Introduction:

As the world makes a shift towards being more sustainable, each local community is contributing. At the University of British Columbia (UBC) farm, they are currently looking for a more green transportation option. In this report, we will perform a triple bottom line assessment of each of the three choices.

At the farm currently, an old 1996 Toyota Tacoma is being used. This truck performs an array of tasks. For example, it hauls heavy equipment and tows a cart full of vegetables. Furthermore, the truck is utilized year-round, but used more routinely during the summer, as this is the peak period for the farm. The background information given will be helpful during the investigation.

A triple bottom line assessment will be conducted comparing the options of a diesel, biodiesel, and hybrid vehicles. This will evaluate economical, environmental, and social aspects that each option has. A recommendation will be made based on this method of assessment.

2.0 DIESEL OPTION:

The use of petroleum diesel fuel is the most common, yet many issues and questions have been raised over the past years. The main concern of the usage of petroleum fuel is the greenhouse gases (GHG) it produces, which include: hydrocarbons, nitrogen oxides and dioxides (NO_x), carbon monoxide (CO), carbon dioxide (CO₂), sulfur dioxide (SO₂) and ozone (O₃). Greenhouse gases are gases in the atmosphere that absorb and emit radiation within the thermal infrared range, causing global warming.

In general case, diesel is assessed based on its life cycle emissions, although in this report, it will be analyzed on three elements of triple bottom line assessment: economical, environmental, and social aspects.

2.1 Economical Factors:

In the table below, the cost and fuel efficiencies of several diesel trucks will be outlined to serve as a set of reference data. This table will also help us balance the environmental impact of fuel consumption and the value of the truck. This table will also illustrate the price discrepancy between new and used vehicles.

New			
Truck Model	Fuel Economy City	Fuel Economy Highway	Price
2012 GMC Canyon	11.4 L/100km	7.8 L/100km	\$25,330
2012 Chevrolet Colorado	11.4 L/100km	7.8 L/100km	\$25,330
2011 GMC Sierra	14.1 L/100km	10.0 L/100km	\$24,455
Second Hand			
Truck Model	Price		
2004 Ford Ranger	\$5,100		
2004 GMC Canyon	\$8,400		

2004 Chevrolet Colorado	\$8,500
2006 GMC Sierra	\$9,900
1996 Ford Explorer	\$2,350

Table 1 - New and Second Hand Truck Prices

Source: Prices obtained from <http://www.autodata.gm.ca> and Craigslist Vancouver

At a glance, this table shows that a new diesel truck will cost roughly \$23,000 - \$27,000 and second-hand trucks may cost up to \$10,000.

Fuel consumption rates are measured by price per unit energy, which is given by a unique energy content for each type of fuel. Values and price are presented below in the following tables, presented is energy density for each type of fuel in the unit of kWh/L and price is \$/L. From the data, we can calculate the price per unit energy, which is what is wanted to compare each fuel economical value. The unit for the price is \$/kWh, which tells one how much it costs exactly per unit kiloWatt-hour.

National Average Price Between July 13 and July 27, 2012	
Fuel	Price
Biodiesel (B20)	\$3.83/gallon
Biodiesel (B99-B100)	\$4.23/gallon
Electricity	\$0.11/kWh*
Ethanol (E85)	\$3.24/gallon
Natural Gas (CNG)	\$2.05/GGE
Propane	\$2.64/gallon
Gasoline	\$3.52/gallon
Diesel	\$3.75/gallon

Figure 1:

Source: retrieved from <http://www.afdc.energy.gov/fuels/prices.html>

	Gross Energy Content ASTM D 240 BTU/lb	Energy Density Calculated Value kWh/l	Energy Content Variation per Unit Mass	Energy Content Variation per Unit Volume	Gross Energy Content ASTM D 4052 kg/m ³
Fuels					
STM Reference Petrodiesel	18,710	10.118			837.1
#1 Petrodiesel	18,554	9.900	-0.8%	-2.1%	826.0
B5 – Animal Fat	18,634	10.101	-0.4%	0.2%	839.1
B5 – Used Cooking Oil	18,632	10.102	-0.4%	-0.2%	839.3
B5 – Vegetable Oil	18,630	10.141	-0.4%	-0.2%	842.6
B20 – Animal Fat	18,406	10.048	-1.6%	-0.7%	845.0
B20 – Used Cooking Oil	18,398	10.055	-1.7%	-0.6%	846.0
B20 – Vegetable Oil	18,392	10.087	-1.7%	-0.3%	849.0
B100 – Animal Fat	17,192	9.740	-8.1%	-3.7%	877.0
B100 – Used Cooking Oil	17,149	9.771	-8.3%	-3.4%	882.0
B100 – Vegetable Oil	17,119	9.831	-8.5%	-2.8%	889.0

Figure 2 - Energy Density Table
Source: Hossate & Lagace, 2003, p.60

Fuel Type	Unit Price	Energy Density	Price
B20	\$1.0118 /L	10.555 kWh/L	\$0.0959 / kWh
B100	\$1.1174 /L	9.771 kWh/L	\$0.1144 / kWh
Petrodiesel	\$0.9906 /L	10.118 kWh/L	\$0.0979 / kWh

Table 2 - Price per unit energy

The data yields that petrodiesel has the lowest cost of price per litre. However, if one carefully studies the energy density, which is the amount of energy stored in a given region of space per unit volume, it is noted that B20 has the lowest cost per unit energy. This result presents the ultimate fact of the economical value of petrodiesel, that the price is greater than B20 biodiesel.

2.2 Environmental Factor:

Argonne National Laboratory's GREET (Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation) model studies the life cycle of petroleum use and greenhouse gas emissions of light-duty vehicles. Based on this model, petrodiesel emits 6%-11% less GHGs than ethanol-based gasoline throughout the entire life cycle. The density is also higher, by approximately 12% more than ethanol petrol (0.832 kg/L compared to 0.745 kg/L). Due to its higher density, petrofuel offers higher volumetric energy density. Comparatively, petrodiesel is more environmental friendly than ethanol based gasoline.

Levelton/NRCan study examines the complete life cycle of each fuel, diesel and B20 from different raw materials. It shows the GHG emissions from each type and here we will focus on the diesel specification alone, while analysis of the others will be presented in biodiesel section.

	Petrodiesel	Biodiesel		
		Canola	Soy Oil	Animal Fat
	G/mile	G/mile	G/mile	G/mile
Total lifecycle	2312.4	2025.1	2028.0	1900.5

Table 3 - LevNRCan B20 GHG Life cycle

Source: Schmidt, 2004 p. 6

	Petrodiesel	Biodiesel		
		Canola	Soy Oil	Animal Fat
	G/mile	G/mile	G/mile	G/mile
Total lifecycle	2312.4	838.4	853.3	194.4

Table 4 - LevNRCan B100 GHG Lifecycle

Source: Schmidt, 2004 p.6

The table below shows carbon intensity of each type of fuel. Carbon intensity is the amount of carbon emitted by weight per unit of energy consumed. The less, the better it is since it will produce a smaller volume of GHG per unit volume consumed. The unit is gram per megaJoule.

Lifecycle Pathway Description	Carbon Intensity (g/MJ)
B.C. Average Diesel	93.33
Biodiesel 2 - Produced in Saskatchewan	11.19

Table 5 - Fuel Carbon Intensity

Source: B.C. Ministry of Energy, Mines and Petroleum Resources, 2011

The comparison presents a result that diesel has higher GHG lifecycle. Fuel carbon intensity above amplifies the fact that diesel has significantly higher carbon concentration in each unit gram. These facts reveal that indeed, B20 and B100 are incomparably more environmental friendly than regular petrofuel.

2.3 Social Factors:

On social aspect of the vehicle, the safety issues are a major concern. The safety, specifically on airbag is the most significant factor since it is going to be used in rough terrain while transporting and hauling heavy equipment and farm products. In addition, by using a specific truck with a chosen fuel option, the UBC Farm can build positive relationships with other departments; it is one of the factors that contribute to social impact.

Table below shows different year of airbag implementation for various truck companies.

Companies	Driver Seat	Passenger Seat
Toyota	1995	1998
Chevrolet	1995	1997
Ford	1994	1997
GMC	1995	1997

Table 6 - Starting year of airbag implementation

Source: Various literature studies and secondary resources

On July 11th, 1984, U.S. Government amended Federal Motor Vehicle Safety Standard 208 (FMVSS 208) to require cars produced after April 1st, 1989 to be equipped with a passive restraint for the driver. Airbags were not mandatory for light trucks until 1995. In 1998, FMVSS 208 was amended to have dual front airbags, and second generation airbags were also mandated.

Taking in consideration of the current UBC Farm truck, which is from the Toyota family, any truck post-1998 will be safer. Thus, if a used truck is purchased, it is greatly advised that its manufacturing date is past 1998. Airbags on driver and passenger sides are a necessity to ensure safeness.

After interviewing the UBC Fleet Operation, they can provide no donation to UBC Farm as of this year, and they also informed that none of their light-duty trucks are diesel powered. This eliminates the possibility of converting the truck from petrodiesel to biodiesel. Therefore, this is no longer a viable option. Furthermore, there is neither connection nor cooperation from the UBC Fleet Operation to the UBC Farm, making this insusceptible to the social impact that is being analyzed.

3.0 Biodiesel Option:

A vehicle running on biodiesel is an attractive option when considering possible service vehicles for the UBC farm. Biodiesel is available as pure biodiesel and blended with conventional diesel. The most common of these blends are B5, B20, and B100, which refer to the percent composition of the fuel. For example, B20 is 20 percent Biodiesel and 80 percent conventional diesel. Biodiesel, or biodiesel-diesel blends, offer both costs and reliability comparable to conventional diesel fuel while reducing the overall emissions (E.E.R.E.) and, in the case of the UBC community, helping to support the CHBE Sustainability Club and the on-campus production of biodiesel.

3.1 Economic Factors:

The price of operating Biodiesel vehicles is almost identical to operating conventional diesel vehicles. Most biodiesel blends require no engine conversion meaning that the initial investment in a biodiesel vehicle and its operation costs are almost identical to that of a conventional diesel vehicle. The few points that the two vehicles differ on are directly related to the fact that biodiesel is slightly more corrosive than conventional diesel. This causes two minor issues that are relatively inexpensive compared to the overall cost of the vehicle to remedy, increased wearing on seals and hoses that come into contact with biodiesel, and shorter fuel filter life.

The increased wear and tear on fuel hoses and seals may provide issues when running on biodiesel blends higher than 20 percent biodiesel. The corrosive nature of biodiesel may hasten the deterioration of already worn seals in the case of previously used vehicles (Butler), or soften and degrade certain types of new seals and hoses causing them to soon leak and disintegrate (N.R.E.L.). While this may cause performance and reliability issues if left unchecked, such as leakage and loss of pressure in parts of the fuel system, this is a minor repair that may be completed for minimal expense.

During the first few months of operating a vehicle with biodiesel that has previously operated on conventional diesel it is common for the life span of fuel filters to noticeably decrease. Like the corrosive effects on the fuel seals and hoses, this does not add considerable expense to the maintenance cost of the vehicle but will cause decreased performance and reliability if left unchecked. The shortening of the fuel filter life span is due to biodiesel's corrosive nature acting as a cleaning agent for the fuel system and dislodging accumulated debris from conventional diesel. It is recommended that the fuel system be cleaned before operating the vehicle on pure or blended biodiesel to avoid this problem entirely (N.R.E.L.). If the fuel system is not cleaned prior to using biodiesel blends, this problem may only persist for the life of one or two filters and is almost negligible in price.

Both the initial and maintenance costs of operating a biodiesel vehicle are almost identical to that of conventional diesel vehicles, especially if kept in proper maintenance.

3.2 Environmental Factors:

Due to the similarities between biodiesel and conventional diesel, and that it is quite common for diesel vehicles to be used for service vehicles in many situations similar to that of the UBC Farm, conventional diesel vehicles can be used as a benchmark against which we can compare biodiesel vehicles. Although a biodiesel vehicle cannot claim zero emissions like an electric vehicle can, it can boast many emission decreases over conventional diesel vehicles. In particular, biodiesel fuels release fewer particulate emissions, which can be linked to environmental effects such as smog and increased health risk for the population of the immediate area.

A joint study by the U.S. Department of Agriculture (U.S.D.A.) and the U.S. Department of Energy (U.S.D.E.) claims that "B100 (100 percent biodiesel) exhibits life cycle total particulate matter emissions that are 32.41 percent less than those of petroleum diesel". The emissions of particulate matter less than ten microns in size is reduced even further than the total particulate matter with B100 producing as much as sixty-eight

percent less than conventional diesel. This decrease in particulate matter is particularly relevant for the UBC Farm which will be operating its vehicle mostly on the UBC campus and the immediate vicinity, and may be considered as both an environmental and social factor as the amount of particulate matter smaller than ten microns in size, can be directly linked to respiratory disease, especially in urban areas (U.S.D.A. and U.S.D.E.).

“Biodiesel’s life cycle produces 35 percent more total hydrocarbons than petroleum diesel’s life cycle, even though tailpipe total hydrocarbons emissions (emissions measured from the only the consumption of the fuel, not its production) are 37 percent lower”. This increase of hydrocarbon emissions over petroleum diesel is due to the production of the biomass required to produce biodiesel (U.S.D.A. and U.S.D.E.). In the case of the biodiesel produced on campus it is arguable that the emission from biomass production may be discounted. The CHBE Sustainability Club produces its biodiesel from waste cooking oil that cannot be sold (Butler), not biomass that was purpose grown for biodiesel. That is to say that the biomass has already been created for another purpose, and will not create any net positive emissions.

Making the argument that the CHBE Sustainability Club’s biodiesel does not create any net emissions to produce, it is clear that while not as clean as an electric or hybrid vehicle, it is less harmful to the immediate environment than conventional diesel vehicles.

3.3 Social Factors:

Biodiesel vehicles demonstrate several social advantages over conventional diesel vehicles. While not being able to boast zero emissions like an electric vehicle, they are more appealing and fit better with the UBC Farm mission statement than conventional diesel vehicles, and they help to support the Chemical and Biological Engineering Sustainability Club.

Particle emissions have the most impact on the surrounding community and environment, increasing the health risk to the population around their source and causing environmental impacts such as smog. By reducing these emissions the harmful effects of a vehicle's operation on the community are directly decreased.

While not as appealing to many as electric vehicles, biodiesel vehicles are much more appealing than petroleum fuel vehicles, especially to individuals looking to support a sustainable organization. Whether or not the environmental advantages are as great as they are perceived, the appeal and perception of a biodiesel vehicle fits into the mission statement of the UBC Farm, specifically "the creation of new patterns for sustainable and healthy communities integrated with their surrounding ecology," (Centre for Sustainable Food Systems at UBC Farm).

While strengthening the UBC Farm image, the consumption of biodiesel on the UBC campus directly supports the Chemical and Biological Engineering Sustainability Club, which is the only producer of biodiesel on campus. Support from the UBC Farm would help the CHBE Sustainability Club to prove their biodiesel production process and increase their production, which is currently limited by a lack of demand (Butler).

4.0 HYBRID OPTION:

A hybrid truck is a satisfactory option when choosing a vehicle for the UBC farm. A hybrid vehicle is an automobile that uses at least two sources of power to put the vehicle in motion. The two most common power sources are an internal combustion engine and an electric motor. It is by far the most beneficial option when assessing the environmental effects, but it comes at a very high price.

4.1 Economic Factors:

The cost of a truck is a strong determining factor when considering purchasing one. By far the most influential factors around the cost of a truck are the base price and the fuel economy.

Hybrid trucks base price is expensive. Currently, the average price to purchase a hybrid truck is around \$40,000. Since the farm will need a model with four-wheel drive (4WD), this adds roughly \$4,000 to the base cost. There are a variety of features that can be added to the vehicle such as Bluetooth, dual-zone climate control, navigation system, et cetera. Most of these luxuries are unnecessary and will only make the truck more costly. In addition, since hybrid trucks are a very new technology, there are scarcely any used ones available. Due to this issue, it is difficult to save money when going to purchase a hybrid truck.

With oil prices constantly increasing, fuel economy is an important aspect to consider when buying any vehicle. With an average price of around 120 cents per litre in the greater Vancouver area, and assuming the hybrid truck is driven 10km per day; the money spent on fuel will be \$515 per year. When compared to a conventional diesel truck with the same analysis, \$689 will be spent each year on fuel. This creates a savings of \$174 each year on fuel (see figure 1). With the hybrid base price being \$44,000 and a

diesel truck being \$20,000, it would take nearly 140 years to offset the cost and for the farm to begin seeing a benefit.

Money spent per year on fuel with hybrid truck:

$$\frac{\$1.20}{L} \cdot \frac{11.76L}{100km} \cdot \frac{10km}{day} \cdot \frac{365 days}{year} = \$515/year$$

Money spent per year on fuel with conventional diesel truck:

$$\frac{\$1.20}{L} \cdot \frac{15.68L}{100km} \cdot \frac{10km}{day} \cdot \frac{365 days}{year} = \$689/year$$

Money saved per year with use of hybrid over conventional:

$$\$689 - \$515 = \$174 \text{ saved per year}$$

Figure 3

Since the truck must run for a minimum of three years, a similar analysis can be performed to find out how far the truck must be driven each day for the saved fuel to be beneficial. See figure 2 for this calculation. Since the hybrid truck must be driven 466km/day, it is completely impractical. Furthermore, the truck would undergo far more maintenance when put under that much duress. Therefore, the maintenance cost would rise. Hybrid trucks have a great impact on fuel economy, but in this situation it is unrealistic for it to be an advantage.

Fuel efficiency difference between hybrid and conventional:

$$\frac{15.68\text{L}}{100\text{km}} - \frac{11.76\text{L}}{100\text{km}} = \frac{3.92\text{L}}{100\text{km}}$$

Distance that must be driven each day for a hybrid to save \$8,000 per year in fuel costs:

$$\frac{\$8000}{\text{year}} \cdot \frac{1 \text{ year}}{365 \text{ days}} \cdot \frac{1\text{L}}{\$1.20} \cdot \frac{100\text{km}}{3.92\text{L}} = 466\text{km/day}$$

Figure 4

4.2 Environmental Factors:

The hybrid option is the top pick if it was solely based on the environment. The fuel efficiency, particle emissions, and battery disposal are all factors that play into this.

Fuel efficiency and power consumption are major factors to consider when looking for a sustainable transport option. Since the UBC farm will only be doing city driving, hybrid trucks will on average achieve 11.76 litres per 100km. When compared to diesel trucks, it is a vast improvement at roughly 8-10%. However, when related to hybrid cars, which can attain up to 4.70 litres per 100km, it is not nearly as efficient. In addition, hybrid trucks do not need to be plugged in to charge their battery. It generates its own power using a brake and acceleration method. Furthermore, the gas motor can charge the battery when it is not in use.

Each year, roughly 1.54 billion metric tonnes of Carbon Dioxide (CO₂) are released into the atmosphere. This can greatly alter the global atmosphere. A hybrid truck is a great contributor in reducing this effect. It approximately emits half the amount of CO₂ of a normal vehicle. Moreover, a used hybrid truck releases up to 97% less toxins.

Hybrid trucks are major step forward in improving the atmosphere and are still improving.

Conventional trucks utilize a series of lead-acid batteries but hybrid trucks utilize a special kind of battery. They use a 300-volt nickel-metal hydride battery. It poses as a hazardous waste, but is difficult to quantify since hybrid trucks are a very new innovation. Most hybrid trucks use a nickel cadmium (NiCad) compound for the battery. Cadmium is a very toxic metal and must have special treatment when the battery is recycled. Nonetheless, the lifetime of the battery lasts around 160,000 kilometres with proper maintenance. Since the truck must only run for three years and is often inactive or dormant most days, this will be sufficient. In the long run though, the Cadmium in the battery may impact the environment negatively.

4.3 Social Factors:

Hybrid trucks have numerous social advantages. The most prevalent benefits are the low particle emissions on the community and the manufacturing location.

Particle emissions have the biggest effect in the immediate surrounding neighbourhood and environment. Since hybrid trucks consume much less fuel, less particles are emitted. This allows the air to be cleaner and overall healthier, and reduces the negative effects on the community.

GMC is currently the only manufacturer of hybrid trucks in the world. The hybrid trucks are made in Oshawa, Ontario where their manufacturing plant is. This gives Canadians jobs and by purchasing a hybrid truck, helps out the country.

These two factors aid in supporting the UBC farm's image. They are able to give back locally and nationally, which is favourable on the social standpoint.

5.0 Conclusion and Recommendations

This report has covered the three possibilities that we found to be the most likely most likely solutions for the UBC Farm. While review these options we had to keep in mind the triple bottom line targets set out for us by the UBC Farm. Most important to the UBC Farm was to find a transport option that fit their mission statement, “the creation of new patterns for sustainable and healthy communities integrated with their surrounding ecology” (UBC Farm). If this were simply the case then our recommendation would be to invest in a new hybrid vehicle, or possibly electric, which would provide everything one would look for in a utility vehicle while adhering to the UBC Farm’s sustainability goals. Unfortunately such a vehicle is a large investment, unreasonably large for what the UBC Farm has available in it’s budget of approximately \$5,000-\$10,000. This limitation kept us from doing any in depth research into the possibility of an electric vehicle as our preliminary research found it to be out of our price range, leading to our decision to examine hybrid, diesel, and biodiesel vehicles. Following our research we found that a biodiesel vehicle would be the best solution for the UBC Farm’s next vehicle. We found that this option has the least environmental impact while remaining within the UBC Farm’s budget and allowing for the possibility of vehicle repair at the UBC Plant Operations garage. The biodiesel required to run a vehicle is available from the CHBE Sustainability Club and made on UBC’s campus, and using this fuel would support the Sustainability Club as they expand their production to supply more utility vehicles around the UBC campus.

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