An Investigation Into The AMS Sustainable Food Truck

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Abstract

It is a goal of the Alma Mater Society to lower their environmental footprint and be pioneers in pushing forth sustainability. One of the steps they are taking is to build a sustainable food truck that uses technologies considerate of the environment as well as society. However, for this project to succeed, the option taken in building the food truck must also be economically viable. This report aims to analyze, using the Triple Bottom Line, the impacts of the current powertrains as well as proposed alternatives. Based on these findings, the reports seeks to build a recommendation as to whether or not a sustainable food truck is viable at this point in time, as well which method to best make this food truck.

The report first looks at the contemporary methods of powering food trucks--through gasoline and diesel. Afterwards, different alternatives are proposed. The first of which is a solar panel and hydrogen fuel cell hybrid. The second alternative is a biofuel option, which uses vegetable oil as fuel to burn for the engine. Within each of these four options, the report looks at the energy requirements of the food truck, and seeks to calculate whether or not such an option can physically power the food truck. Afterwards, the environmental and social impacts of each option is described, and finally an economic analysis is done.

What the report has found is that the solar panel and hydrogen fuel cell hybrid not only fails to meet energy requirements on cloudy days, but is far too economically taxing to pursue at this point in time. The biofuel option, on the other hand, is less environmentally friendly but more economically so. The reasoning is twofold--first, the fuel needed, vegetable oil, is much more readily available than hydrogen fuel, and second, the acquisition costs of equipment to utilize biofuel is next to none, requiring only filters be bought. Whilst using biofuel is not as environmentally friendly as using solar panels and hydrogen fuel cells, the report finds that it is still better than the gasoline and diesel powered food trucks today. What this report recommends is that the sustainable food truck aim to use biofuels to power the truck, as it is not only more environmentally friendly than current options, but is economically sound as well.

1.0 Introduction

The Alma Mater Society (AMS) is actively pursuing an innovating environmental policy to minimize their overall impact. In 2008, the AMS Lighter Footprint strategy was rolled out, composing of the targets, action plans, and indicators for establishing and measuring performance towards a minimized impact. [1] In the lighter footprint strategy, a target of reducing Green House Gas(GHG) emissions by 33 percent until 2020 was set.

Currently there is a push towards "greener" technologies, which produce less long term environmental impacts. The transition from fossil based fuel technologies which are finite and depleting rapidly to energy sources which are renewable is a thriving industry.

Furthermore in Vancouver, there is the "Greenest City 2020" initiative that will address Vancouver's environmental challenges through a set of measurable and attainable targets. [2] The presence of food trucks in Vancouver creates a market with room to minimize impacts, increase social awareness, and contribute towards both the goals of the city and the AMS.

This project will be looking at the current common powertrains and auxiliary power generation units required for equipment. The auxiliary power generation is utilized for cooking equipment such as grills, refrigeration and deep frying units. The current majority of food trucks utilizing either gasoline or diesel for the powertrain and commonly diesel generators for auxiliary power. This configuration will be taken as a baseline to compare other models against.

2.0 Current Truck Configurations

Currently in the food truck industry, the gasoline engine plays a prominent role for providing the trucks mobility. The alternative to gasoline commonly used is the diesel combustion engine. This has benefits such as increased fuel economy, however generally produces larger emissions and has a larger acquisition cost.

To power accessory equipment such as cooking elements and refrigeration units, a separate diesel generator is most commonly utilized.

2.1 Gasoline Powertrain

The gasoline internal combustion engine has been a common engine used in virtually all industries for decades. The research and development throughout the years has allowed it to become more efficient and maintain economic feasibility. However with the depletion of fossil fuels and large environmental impact it is gradually being phased out.

2.1.1 Gasoline Energy Consumption

From researching common powertrains used for food trucks and similar sized vehicles, the following list had been generated to look at the vehicle weight, engine size, and fuel economy of the platforms.

Table 1: Fuel Consumption of possible food truck vehicles

Vehicle	Engine	Consumption (L/100km)
Ford E350/450 GVWR: 14,500lbs	5.4L Triton V8	19.6
	6.8L Triton V10	23.5
Ford F59 GVWR: 19,500lbs	6.8L Triton V10	33.6
Freightliner MT45/55 GVWR: 19,500lbs(MT45) 23,000lbs(MT55)	6.0L GM V8	29.4

2.1.2 Environmental and Social Impact

Globally each year highway vehicles release approximately 1.7 billion tons of GHGs into the atmosphere [3]. Each gallon of gasoline consumed creates approximately 20 pounds of GHG. From the above fuel economy, food trucks produce approximately 2 pounds of GHG per mile at 10 miles per gallon. The low fuel economy leads to large emissions from food trucks.

The truck will be in public exposure through the majority of its lifespan. Through advertising and visual representation, the vehicle can showcase its powertrain. Utilizing a gasoline powertrain has a minimal social impact as it already has predominant market share.

2.1.3 Economics

Economically, the purchase price of the vehicle plays a large role in the determination of which platform to run. With a gasoline powered unit, the purchase price is relatively low and there is a large used market if the user is inclined.

Table 2: Vehicle accusation cost

Chassis	Year	Engine	Acquisition Cost (USD)
Ford E350 StepVan	2015	5.4L Triton V8	$46,000
Ford F59	2015	6.8L Triton V10	$27,000***

***Price is only for stripped chassis, full vehicle price not included.

For maintaining the vehicle, approximately $300/month is a common budget to keep the unit reliable and running smoothly.[5]

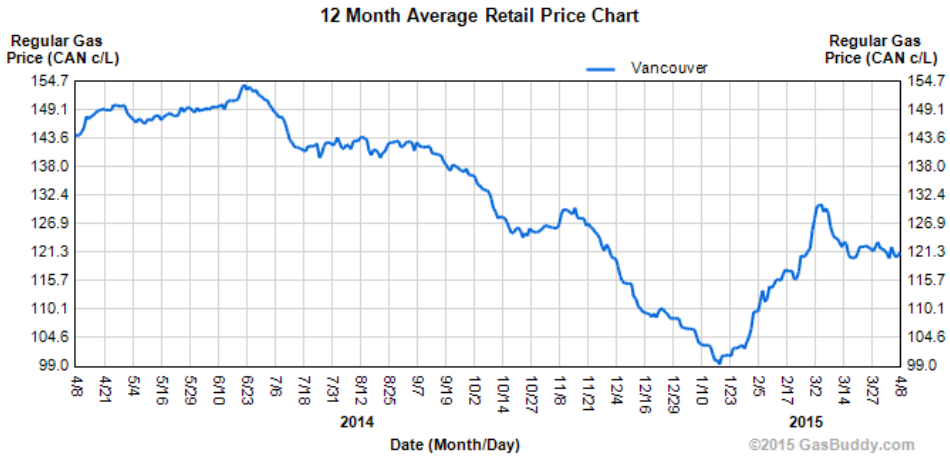

Figure 1: Fuel cost fluctuations

A large operation cost for the unit is fuel costs, as seen in the figure 1 above rising fuel prices can change the cost by approximately 50%. Depending on the location and desired operating range of the vehicle the fuel costs can be more deterministic in the decision making process. [6] For each gallon of gasoline, approximately 6 kilo-Watt hours (kWhr) is available for use. This works out to approximately $1.55 per kWhr for gasoline at an average gas price of $1.20 per liter. [7]

In addition to purely financial costs, innovative and improved technology can help with differentiating the food truck. The market is currently highly competitive due to low barriers to entry. There is no more than one operator commanding 5% of industry revenue in Canada. [4] The increased exposure and awareness that the sustainable truck can help incur is difficult to quantify but likely contributes to branding and product differentiation within the industry.

2.2 Diesel Powertrain

A common diesel powertrain available on the market is the Freightliner MT45/55 Shown in table 3 below.

Table 3: Diesel Power Train Fuel Consumption

Vehicle	Engine	Consumption (L/100km)
Freightliner MT45/55 GVWR:19,500lbs(MT45) 23,000lbs (MT55)	6.7L Cummins I6	19.6

2.2.1 Diesel Generator For Accessories

An alternative to gas powered generators for accessories is using diesel. Diesel generators are generally more powerful than their gas counterparts, so they can power more accessories with less fuel than a gas powered generator.

A comparison of two such generators is shown in table 4 below [8][9]:

Table 4: Diesel Generator Comparison

Generator	Output (Watts)	Tank Size (Liters)	Continuous Runtime (Hrs)
Aurora 6500 Watt	5000	12.5	10-12
Honda EB5000	4500	23.5	11.2

Although most food trucks use a gas generator around 2000 Watts [7] for their accessory power generation, the more powerful diesel generators can be used at a lower capacity for longer, leading to better efficiency. The two tables above show that although the Honda gas generator and the Aurora diesel generator produce roughly the same continuous power for the same length of time on one tank, the Honda gasoline tank size is almost twice as large. This shows that the diesel generator is twice as efficient as the gas equivalent.

2.2.2 Environmental and Social Impact

Figures 2 and 3 shown below, illustrate how diesel releases more CO2 into the atmosphere than gasoline, but less NOx emissions.[7]

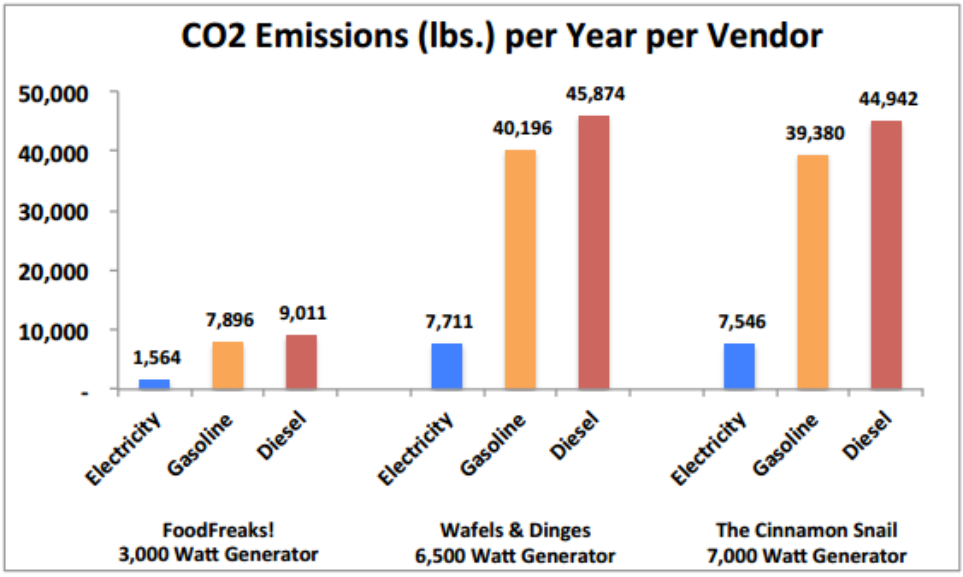

Figure 2: CO2 Emissions of Different Energy Sources

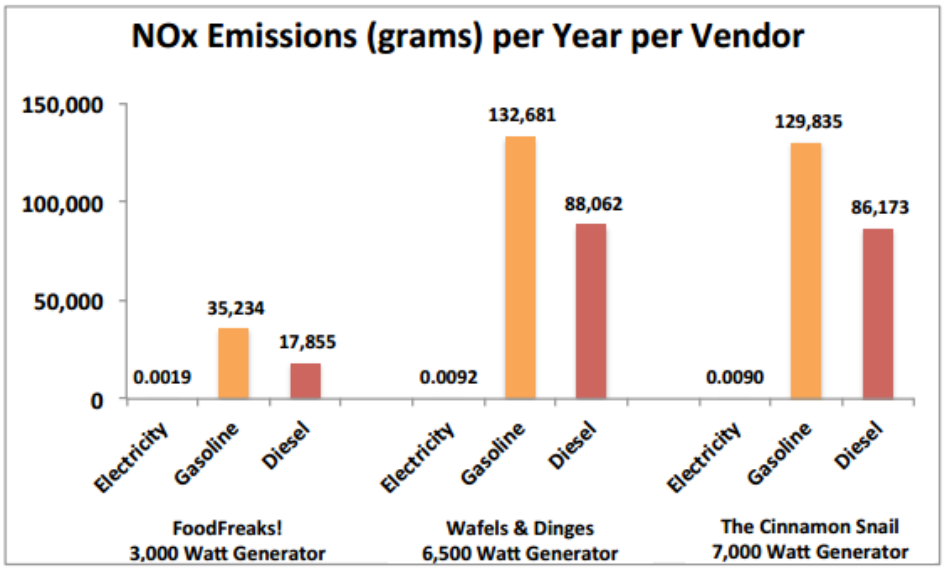

Figure 3: NOx Emissions of Different Energy Sources

The social impact of using diesel trucks and generators will be largely similar to that of its gasoline counterpart, however, diesel engines tend to be louder, which may cause a larger hindrance to nearby businesses, residents, and bystanders.

2.2.3 Economics

Table 5 shown below show the acquisition cost breakdown of an all diesel food truck.

Table 5: Acquisition Cost for an all Diesel Food Truck

Chassis	Year	Engine	Acquisition Cost (USD)
Freightliner MT45	2015	6.7L Cummins Diesel	$75,000
Aurora 6500W Gen.	2015	N/A	$1,200

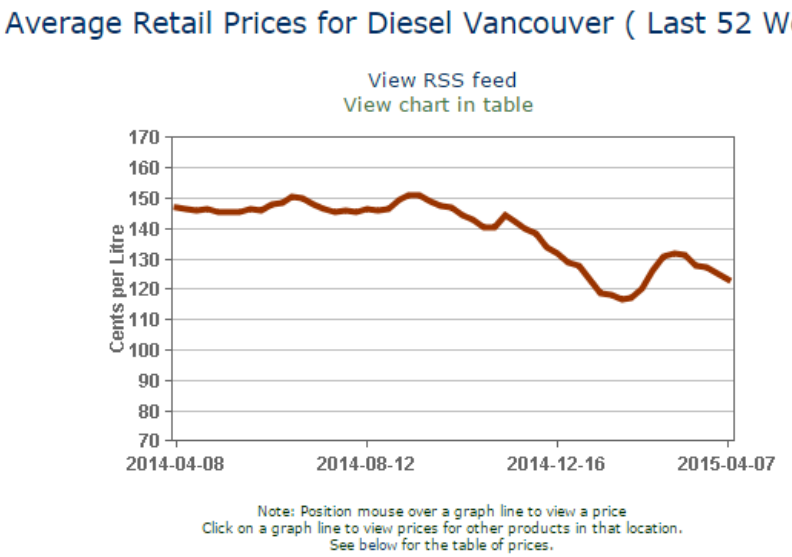

Figure 4: Average Retail Prices for Diesel

Figure 4 shows the trend of diesel prices in Vancouver over the last 12 months. [10] Compared to the graph showing the price of regular gasoline in Vancouver over the last 12 months, the price of diesel is almost the same. However, when the higher efficiency is taken into account, the economics of running a diesel truck and generator is much better. The Freightliner gets 29.4L/100km for the gasoline engine, and 19.6L/100km for the diesel engine. If we use the current price of diesel and gas at 122 cents/L, the difference is about $12 saved for every 100 km driven when choosing the diesel option.

3.0 Proposed Alternatives

3.1 Solar Cells and Hydrogen Cells

Solar Cells or photovoltaic cells are an electrical device that converts the energy of light, such as sunlight into electric energy. The operation of the photovoltaic cell starts with the absorption of the light, then separation of charge carriers and separate extraction of those carriers to an external circuit that in turn becomes electrical current and electric energy. These solar cells are known to be the building blocks of photovoltaic modules known as solar panels that are widely available in the market for the purpose of electric generation.

Hydrogen Cells are a device that converts the chemical energy from the combination of hydrogen and oxygen to produce electricity [14]. Hydrogen is high in energy and yet hydrogen engines produce almost no pollution. However, fuel cell will only produce electricity as long as hydrogen is supplied.

3.1.1 Energy Consumption

Using solar panels just to power up the vehicle is not a very sustainable way because it only generates its full capacity of electricity during sunny days. It will still generate electricity on cloudy days but will not be to its full capacity. A possible solution to this is the combination of solar panels and fuel cell. During sunny days, solar panels will be the main source of generation and during cloudy or rainy days, the hydrogen fuel cell will take charge of generating electricity.

An example of the viability of solar and fuel cells are illustrated as parts of UBC Social Ecological Economic Development Studies (SEEDS) project titled "AMS Sustainable Food Truck: Technology Assessment & Energy Management" [12]. In this project, simulations are conducted with 10 solar panels that have maximum output capacity of 240 Wh total and fuel cells that have maximum rate of 5kWh. The simulated environments are hot and sunny days from 6AM until 9PM. Simulated loads such as stove, deep fryers, microwave oven, fridge and ventilation are turned on and off along the operating hours. It was discovered that in order to have balanced power used by the load and power generated, 14 solar panels are needed with 30 kWh of hydrogen fuel cells [11]. Each of the solar panels used in the simulation are $0.5m^2$ in area bringing total of $7m^2$ of solar panel space. This result shows that solar panels might not be a viable option since most food trucks have less than the required roof area needed to lay down the solar panels.

3.1.2 Environmental and Social Impact

Since do not solar cells produce energy through combustion of fuel, it did not have any direct emission to the environment. To support that, studies conducted by a professor in Utrecht

University argue that the usage of solar panel on a large scale usage reduce air pollutants and greenhouse gases by about 90 percent in comparison to conventional fossil fuels technologies[13]. Hydrogen Fuel Cells on the other hand produce water vapour, warm air and some hydrogen which is not a concern for air quality. However, the fuel cells are not as environmentally friendly as they might seem. A recent $90 million project by BC transit to produce and use hydrogen fuel cell powered buses failed, with the chief reason being that it was not economically feasible [11]. The reason the hydrogen fuel was so expensive was that it was trucked in from Quebec—which not only means higher costs, but greater emissions from the trucks. In an interview with Eric Denhoff, president of the Canadian Hydrogen and Fuel Cell Association, Denhoff revealed that the overall reduction in greenhouse gas emissions were 65 percent less compared to the diesel alternative, when considering the production and transportation of the hydrogen fuel [11]. It is reasonable to assume that acquiring hydrogen fuel for the food truck would be through a similar manner, at least as of now, and that we can see similar environmental impacts.

Zero emission technology will definitely improve the environment that we live in. This will in turn bring a healthier environment which will leads to positive social impact. There will be lesser people getting sick from air pollution and allow the humans to enjoy their lives in the best possible manner.

3.1.3 Economics

The biggest problem with considering this alternative lies in the costs. Not only are acquisition costs much greater, since hydrogen fuel cells are not readily available on the market, but the running and maintenance costs are much greater. A lot of the cost comparisons will be between the hydrogen buses and diesel trucks, mainly because hydrogen trucks simply are not in circulation in the economy as of yet. One method of acquiring a hydrogen fuel cell would be to buy the hydrogen buses, which our stakeholder has mentioned to cost $90,000. Compared to a diesel alternative mentioned in this report, it is more than double in price. Furthermore, additional costs would be accrued from refitting the bus into a food truck. The running costs of

the fuel cell in the buses are $2.28/km, about three times the cost of diesel [15]. Finally, maintenance costs are $1/km, compared to $0.65/km for diesel trucks [15]. The acquisition and the operation of the fuel cell alone would put the cost of the truck far above that of a diesel one. By the current market standards, the solar panels would cost around $4500 for acquisition. One thing to note is that the energy generation of the panels degrade over time, and will be at around 80% efficiency after 25 years. As such, we would need to replace 300Wh panels after 25 years, or if we choose to buy 260Wh panels (since they are smaller in size), we would need replacement in 9 years. The report also mentions that the batteries must supply a maximum output of 10kWh. Most batteries for solar panels supply around 2kWh, and are priced anywhere between $300-$500 (before tax) . Thus the batteries themselves are around $2000. Economically speaking, the solar panel/fuel cell/battery hybrid is not feasible.

3.2 Biofuel

Biofuels are fuels from living matter or the waste of living matter. The living matter can include animal fats, plants like corn, sugarcane, wheat it can also include non-food sources such as trees and grass. It is a renewable energy source created by the conversion biomass. There are many different kinds of biofuel suitable many applications. Some of the available fuels include ethanol, biodiesel, green diesel, biofuel gasoline, and vegetable oil. The client expressed strong interest in straight vegetable oil and therefore will be the biofuel examined.

3.2.2 Straight Vegetable Oil

The straight vegetable oil (SVO) class of the biofuels has many advantages over other biofuels. It can be used directly without major processing or refining. With the addition of a SVO kit any existing diesel engine or generator can be used without further modification. The use of SVO as a source of fuel will take advantage of the large amounts of spent oil produced by the AMS Food Services. This would translate to saving because it will eliminate the recycling costs of spent oil also since the oil would be collected from campus outlets there will be no need to seek

external sources of oil off campus. Furthermore, SVO will greatly reduce hydrocarbon diesel used to power the truck and therefore reduce the associated costs.

2.2.1 Energy Considerations

Since the use of SVO does not require a special power plants for generating energy or moving the truck, an existing diesel truck with a diesel generator would satisfy the energy requirements for normal food truck operation. Refer to section 2.2 for diesel energy generation capabilities.

2.2.2 Environmental and Social Impact

Research published in the Biomass and Bioenergy journal conducted a life cycle assessment of Biodiesel and SVO. It compared the production and the rate of consumption of the two biofuels and assessed the environmental impact of each. When comparing Non-toxicological and toxicological categories, the results show that SVO is more environmentally friendly then Biodiesel. Also the study showed that SVO has a better energy conversion factor. The preferable results were attributed to the fact that SVO does not require large scale processing, and is not competing with food sources to obtain biomass, and is not linked to deforestation[16].

An AMS food truck using SVO can be a tool to raise awareness about SVO as an alternative biofuel. After a period of operation an analysis of the performance and the saving incurred by using SVO can be conducted and used as a real world example of its benefits.

2.2.3 Economics

As mentioned before the use SVO would not add hardware cost other than the cost of SVO kit. The kit is necessary because oil would need to be filtered and heated to reduce its viscosity before being injected into the engines. A typical kit includes a tank for holding the oil, an

electric heating element, coolant heating connections, oil filter, a switch (for changing from diesel to oil), and various hoses and wires.

Figure 5: The 2-Tank SVO kit

Figure 5 shows the various components of a SVO kit and is the one specified in this report.

Acquisition cost of the system:

The specified kit is the 2-Tank kit from PlantDrive shown in figure 5. The kit costs $999.00 and is suitable for many applications [17]. It comes with the filter so there is no initial filter acquisition cost. The kit comes with a setup guide and is reportedly easy to install eliminating the need and the cost of professional installation.

Operating cost:

since the vegetable oil being collected from on campus there will be no cost associated with driving to different restaurants to collect the oil. The only cost would be the labour wage for time spent collecting the oil by truck operator. Another operating cost would be the $229.00 cost for replacing the filter which is to be done every 6000-10000 km.

Conclusion & Recommendation

An investigation of the current methods of power generation showed the impact that the gas and diesel powered food trucks were having on the environment, on society, and economically. After determining that current methods are not viable options for a sustainable food truck, the report looked at 3 alternative methods: solar cells, hydrogen cells, and bio-fuel.

The solar cells by themselves were not shown to be a viable option, due to the fact they cannot generate at full power on cloudy days, which is an issue for a food truck operating in the lower mainland. It was determined that the best option was to use a combination of solar panels and hydrogen fuel cells for the food truck to be able to operate in all types of conditions. Although the solar panel/fuel cell combination was found to be very environmentally friendly, the cost of the panels required, the added weight of the panels (700lbs total), and the 28 sq. meters of solar panels needed, made this configuration unfeasible for a mobile truck.

The third alternative considered was the use of Straight Vegetable Oil bio-fuel to power a diesel engine truck and diesel generator. The use of diesel fuel systems was investigated in section 2.2, and it was found to be a more economical alternative to gasoline. With the addition of a SVO system, this configuration would yield the best results in regards to environmental and social impact. As well, the cost of converting a diesel truck and generator to a SVO compatible system is very cheap when compared to the solar panel/fuel cell combination.

The team recommends that AMS seriously consider the use of a SVO bio-diesel system to power their trucks and generators for maximum environmental sustainability. AMS could also educate the customers and public about the benefits of bio-fuel and potentially spread the use of this technology, thereby having a positive social impact as well.

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