ALTERNATIVE VEHICLE FLEET

AT DALHOUSIE UNIVERSITY

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This study evaluates the feasibility of alternative fuel vehicles being used at Dalhousie University. Taking into account the social, economic and environmental costs and benefits of various alternative fuel technologies, it was found that hybrid, neighborhood electric and electric vehicles are the most suitable for replacing Dalhousie's current vehicle fleet.

ALTERNATIVE VEHICLE FLEET

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EXECUTIVE SUMMARY

This study aims to evaluate the feasibility of using alternative fuel vehicles, as Dalhousie University fleet vehicles. Through a wide range of academic and grey literature sources and studies the various environmental, social and economic cost benefits were assessed for alternative fuel technologies that Dalhousie, in theory could implement. To supplement this research, a survey and interviews were conducted with Dalhousie employees, who use these vehicles on a regular basis, to find out what their thoughts, concerns and reservations were on the potential switch to alternative fuel vehicles. After having taken this information into account three alternative fuel options were deemed feasible for implementation. These options were as follows: Hybrid, neighborhood electric vehicles (NEV) and electric vehicles. In addition to our findings, it is recommended that a pilot program be executed to assess the benefits and drawbacks associated with alternative fuel vehicles being used in the place of conventional gasoline fueled vehicles. Furthermore the use of a fleet vehicle management system would be beneficial to record and analyze how the current fleet is performing to better understand what vehicles produce the most emissions and which vehicles require replacement before others.

INTRODUCTION

PROJECT DEFINITION & RESEARCH QUESTION

The purpose of our research is to evaluate the feasibility of using Alternative Fuel Vehicles (AFV), as Dalhousie University (DAL) fleet vehicles. In order to narrow the scope of this study, it will be conducted within a clearly defined research question.

What are the environmental, economic, and social costs and benefits of adopting Alternative Fuel Vehicles at Dalhousie University?

In order to specify the parameters of this study, the following terms have been defined within the boundaries of our research question, in order to set clear limitations on the scope of the study.

Environmental:

Defined as the amount of green house gas (GHGs) emissions created by the Alternative Fuel.

Economic:

Defined as the purchase price, operating costs, and maintenance cost of the vehicle. With further analysis we may include Net Present Value, or resale value into this criteria.

Social:

Defined as the cost/benefit to all Dalhousie student, employees, and surrounding communities for choosing a specific fuel type. This will be measured in qualitative terms of leadership, reputation and innovation.

Alternative Fuel Vehicles:

Vehicles, and fuels must meet the following criteria to be analyzed. They must be readily available for purchase and legal to drive on Nova Scotia's roads. The following vehicle and fuel type will be reviewed initially to see if they meet the above stated criteria:

Biodiesel (B100)	Electricity
Plug-In Hybrids	Ethanol (includes only blends of 85% or more with gasoline)
Hydrogen	Fuel Cells
Fuel Efficient Vehicles	Natural Gas (Compressed and Liquefied)
Propane	P-Series
Low Emission Vehicle	Electric Hybrids

BACKGROUND INFORMATION & RATIONAL

The Intergovernmental Panel on Climate Change (IPCC), in its fourth assessment report, predicts dire consequences as a result of inaction on climate change (AR4, 2007). The IPCC argues that, given current mitigation strategies and development policies, global greenhouse gas emissions are *very likely* to increase substantially--meaning global carbon dioxide equivalent emissions will grow between 25 and 90 percent between 2000 and 2030. Over this period, fossil fuels are expected to remain dominant in the energy mix (AR4, 2007).

As a result, the IPCC states that changes to global climate patterns are *very likely* to be larger than changes observed in the 20th century. Significant consequences are projected across the globe: in Africa, between 75 and 250 million people will likely be exposed to increased water stress even as crop yields on the continent fall by up to 50 percent--all by the year 2020 (AR4, 2007). In North America, decreased snow pack coupled with increased winter flooding and reduced summer water flow are expected to put strain on water sources for which there is already excess demand (AR4, 2007). As well, coastal communities may be negatively impacted by sea level rise.

It is worth noting that the IPCC excludes glacial melting from the analysis contained in the fourth assessment report. Hansen et al. contend that this omission may constitute a drastic underestimate of the extent of sea level rise, and that a failure on the part of the IPCC to account sufficiently for the positive feedback effect of surface albedo (reflectivity) results in predictions that are far too conservative (Hansen et al., 2007). Furthermore, sea ice in the arctic is melting a rate much higher than the IPCC has projected--some researchers are predicting an ice-free Arctic summer within 30 years (Wang, M., Overland, J.E., 2009).

In the midst of it all, the Government of Canada has done little to address the concerns of the scientific community: the Harper government has committed to an absolute reduction is emissions of only 17% relative to 2005 levels. This is a far cry from the 6% reduction from 1990 levels by 2012 mandated under the Kyoto protocol: according to Greenpeace (2010) this translates into a 2.5% *increase* relative to 1990 levels, the base year adopted in the Kyoto agreement.

Clearly, our government has not produced a response commensurate to the scale of this problem. Canadian universities, on the other hand, have been much more progressive: in 2009, engineering students at the University of British Columbia completed the conversion of a 1972 Volkswagen Beetle to run entirely on electricity (UBC Electric Car Club, 2011). The UBC Electric Car Club, founded in the same year, aims to "break the fossil fuel dependency for transportation and commuting purposes" and "establish the University of British Columbia as a global leader in implementing green and sustainable technology" (UBC Electric Car Club, 2011).

Dalhousie, for its part, is a signatory to the Talloires Declaration, which states that the university must "set an example of environmental responsibility by establishing programs of resource conservation, recycling, and waste reduction" (ISD-b 1996). The Dalhousie Office of Sustainability has initiated a number of programs in pursuit of the goals outlined in the Talloires Declaration, including the ReThink Sustainability on Campus program, the 2008-2009 Greenhouse Gas Inventory Report, and the natural environment inventory currently underway (Dalhousie Office of Sustainability, 2011). The adoption of an alternative fuel program for the Dalhousie vehicle fleet would be consistent with the university's responsibilities as delineated in the Declaration.

While there has been no systematic investigation of fuel alternatives for the university fleet, the Biofuel Feasibility Report, commissioned by the Dalhousie Office of Sustainability in 2009, explored options related to the conversion of Dalhousie's stream of waste oil, generated as a by-product of day-to-day operations in the five on-campus cafeterias and assorted retail operations operated by Aramark Inc. The alternatives to disposal of the waste oil outlined in the report included use as fuel in the diesel engines of Dalhousie fleet vehicles. Recommendations of the report include preliminary testing of waste vegetable oil (WVO) generated on campus and the conversion of a number of diesel fleet vehicles to a dual-tank system for the combustion of pre-filtered waste vegetable oil.

Evidently, the full range of alternatives to fossil hydrocarbons has not been explored--because of the conspicuous lack of research into fuel alternatives other than waste vegetable oil and biodiesel, the research proposed here is both timely and highly relevant to the future of sustainability initiatives at Dalhousie.

METHODS

DESIGN

This feasibility study has used both descriptive and exploratory research methods. The exploratory research was conducted by gathering information on sustainable vehicle technology from various academic and grey literature sources and studies. This provided the familiarity and background information needed to achieve a solid understanding of alternative vehicle options in order to draw conclusions as to which options are better than others. As for descriptive research, both a survey and interviews were conducted to better understand the work and use of each department's vehicles in order to find a sustainable option that works for all fleet vehicle users at the University.

SAMPLING

University departments and their staff, which operate and work with Dalhousie's vehicle fleet (see Appendix 3 for fleet inventory and contacts), are the target population for the survey and interviews that were conducted (see Appendix 1 and 2). Therefore a non-probabilistic purposive sampling method was used, as Parties that are not involved with the operation of Dalhousie fleet vehicles as well as those who are neutral or uninterested in the topic were excluded from the surveys and interviews. Interviewees were intentionally chosen from a list of individuals who are the primary users of each Dalhousie vehicle, this list was provided by the Dalhousie Insurance Department. Individuals selected for the interview and survey process were chosen because they meet certain criteria for inclusion in the study, as they understand and know best about the use and performance of their respective Dalhousie vehicles. This aided the depth of the study by providing useful and significant information that was needed to make conclusions about the possibility of a more sustainable vehicle fleet at Dalhousie.

RESEARCH METHODS & ANALYSIS

The research methods used in this study consist of a literature review, interviews and a survey. A literature review has been used to solidify an understanding of what technology is currently available and whether or not that technology can be used to create a more sustainable vehicle fleet. The literature review covers a wide range of alternative vehicle options, providing information on the environmental, social and economic cost/benefit of each option, as well as purchase cost, operational cost and resale value. Supplementing the literature review, interviews and a survey were conducted in person and via email. The results of these interviews and survey were used to provide a deeper understanding of what the universities vehicles are used for and how alternative vehicles might aid or inhibit the staff's ability to continue to do their jobs efficiently and safely. Furthermore we used open-ended questions in our surveys and interviews, which allowed for as much insight into the topic as possible, thus allowing for clear and concise conclusions to be made about our findings. Our analysis of the information collected was conducted by finding common themes, demands and concerns of the various interviewees. By cross-referencing our findings with the various sustainable options explored in our literature review, we were able to identify the most feasible options for Dalhousie's vehicle fleet.

RELIABILITY AND VALIDITY

The reliability of the results in this study are uncertain as the interviewees come from different departments that may have opposing views on the topic of alternative fuel vehicles being used at Dalhousie. The study's validity on the other hand relies on its ability to display that it has accomplished the purpose for which we intend to use it (Palys, 2008, p. 62). In this study the methods we chose allowed for high validity to be achieved, by defining what the environmental, economic, and social costs and benefits are of each alternative fuel option we can determine exactly which options are the most feasible.

LIMITATIONS AND DELIMITATIONS

The limitations of this study were mainly to do with availability and time restraints, as they were both restrictions, which there was no control over. Some of the interviewees we attempted to approach were away or unreachable via e-mail or telephone. Accordingly this placed some constraint on what information we were able to gather from our vehicle contacts. Meanwhile, delimitations such as limiting those who were interviewed to people who use or are involved with the operation of Dalhousie fleet vehicles were used. Another delimitation deliberately imposed would be the elimination of any technology from the report, which is not readily available to consumers.

RESULTS

LITERATURE AND JOURNAL REVIEWS

Through gathering information on sustainable vehicle technology from various academic and grey literature sources, a compressive list of alternative fuel vehicle options were complied. In the analysis of each, the environmental, social and economic cost/benefit, purchase cost, operational cost and resale values were taken into consideration. The following options have been explored and evaluated for their feasibility:

Biodiesel Vehicles

"Biodiesel is an alternative fuel that can be produced from any fat or vegetable oil. Biodiesel fuels are methyl or ethyl esters derived from a broad variety of renewable sources such as vegetable oil (soy, canola, rape seed), animal fat and cooking oil. Esters are oxygenated organic compounds that can be used in compression ignition engines because key properties are comparable to those of diesel fuel" (Schmidt, 2004).

The most pure form of biodiesel fuel is called B100, and as the name implies it is 100% pure biodiesel. There are other blends of biodiesel but for the purpose of this report, B100 will be the only type of biodiesel discussed.

The Commonwealth Scientific and Industrial Research Organization (CSIRO) study is an extensive study that looks at the lifecycle emissions from many different alternative fuels. Their report on biodiesel focused mainly on the greenhouse gas carbon dioxide because it makes up "94-98% of the total GHG emitted on a lifecycle basis for biodiesel" (Schmidt, 2004). The CSIRO study found that if cooking oil biodiesel was used you would see a 93% change in the amount of $C0_2$ emitted in the lifecycle versus regular diesel.

Biodiesel can currently be used in any diesel engine with little or no engine modifications. Many major engine manufacturers have stated they accept the use of biodiesel in their engines. These companies include Cummings, Caterpillar, Detroit Diesel, and International. However, at first the auto manufacturers did not agree but that is changing over time. As biodiesel gains popularity the auto manufacturers will start to recognize the benefits of this fuel source. "This trend has already been established in Europe with the following examples of large European (division) engine / vehicle manufacturers that have established specific, favorable warranty policy toward biodiesel: BMW, Renault, Peugeot, Volkswagen, Mercedes Benz, Volvo, Ford, John Deere, etc" (Schmidt, 2004).

Historically, Nova Scotia in the winter months can be very cold. This raises an issue for biodiesel because pure biodiesel (B100) needs to be stored at a temperature of at least 10 degree Celsius. However B100 can be stored under ground but if you wish to store it above ground you need to protect it with heating, insulation, agitation, and other methods of protection (Schmidt, 2004).

Electric Vehicles

An electric vehicle is a plug in vehicle with an electrically charged engine instead of an internal combustion engine. Electric vehicles pollute no emissions while they are operational however they do create some greenhouse gas pollution during the production of the vehicles. "The Department of Transport has recently acknowledged that Electric vehicles are more environ mentally friendly than petrol/diesel cars, even taking into account the CO_2 emissions from producing the electricity" (EV Canada, 2008).

There are many different types of electric vehicles but all the companies that currently produce electric vehicles are not large enough to mass-produce them to meet up with the potential for high demand. However the largest company currently producing electric vehicles is Phoenix Motorcars. They are located in Ontario, California and they produce electric trucks and SUVs (EV Canada, 2008). These vehicles are not currently available in Nova Scotia or anywhere in Canada. This is the main issue with electric vehicles in Canada. There are a number of different small companies producing electric vehicles but the majority of them are in California because the legislation in that state allow for the production of this vehicle type.

Another option would be a smaller truck such as the Eagle electric van; this is a smaller vehicle that could drive around transporting salt for the salting of the walkways in the winter or soil for landscaping. With a maximum loading weight of 800 kilograms, the Eagle electric van is a perfect option for Dalhousie if they were to start a pilot project they could potentially start with these smaller vehicles then eventually move up to bigger SUVs or trucks.

Neighborhood Electric Vehicles (NEV)

Neighborhood Electric Vehicles (NEV) are fully electric battery powered vehicles (charged through by plugging into a standard wall socket) that are capable of traveling at a maximum speed of 25mph (GEM, n.d.). Usually equipped with energy monitoring systems users are able to tell exactly how much energy in kilo-watt-hours (kWh) that their vehicle has removed from the grid (GEM, n.d.). In most States and in some Canadian provinces they can be operated on the roads where the posted speed limit is 35mph or less and can cross streets posted at 45mph or less (GEM, n.d.). However current Nova Scotia transportation legislation prevents them from being able to be on the road in the province. A company called GEM (now owned by Chrysler) offers a lightweight pickup NEV that is priced at USD $10,395, however the price is significantly lower when purchasing a small fleet of these vehicles (GEM, n.d.). Therefore the economic cost is relatively reasonable, while the social impact is high due to the potential for Dalhousie to be the first institution in Nova Scotia to integrate this technology into their vehicle fleet. Furthermore the environmental benefits are high with no emissions being produced other than the CO_2 produced by electricity production at the power source. There is also potential to completely eliminate CO_2 if the power source, which the vehicle charges through, is a renewable source such as solar or wind power.

Hybrids

A true full hybrid operates in the following ways to help save gasoline. When the car stops, whether it is at a light or the driveway, the engine shuts off and the batteries and electric motor run the vehicles systems (Fishetti, 2005). When the car starts moving again the motor will propel the vehicle until efficient engine operation is possible, this speed is usually somewhere between 10 to 40 miles per hour (Fishetti, 2005). Furthermore when hard acceleration takes place the electric engine and the motor work together so the transmission can work at maximum efficiency in order to save fuel (Fishetti, 2005). Together these features significantly reduce the amount of gasoline used and create a very positive environmental effect as a result. From the economic side however hybrid vehicles tend to cost USD $2,500 to $3,500 more than comparable non-hybrid models. A solid example of a readily available, proven hybrid vehicle would be the Toyota Prius, which retails for about USD $21,650 for the base model (Halvorson, 2010). This vehicle in particular gets 51 miles to the gallon in the city even, thus would operate with a extremely high efficiency on campus and within the city of Halifax. Meanwhile the economic and environmental benefits do not hinder the social ones, as this vehicle remains on of the safest on the market with seven standard airbags, anti-lock breaks, traction and stability control and tire pressure monitors (Halvorson, 2010).. Newer models such as the 2011 are even equipped with a rearview camera and intelligent parking assist (Halvorson, 2010).

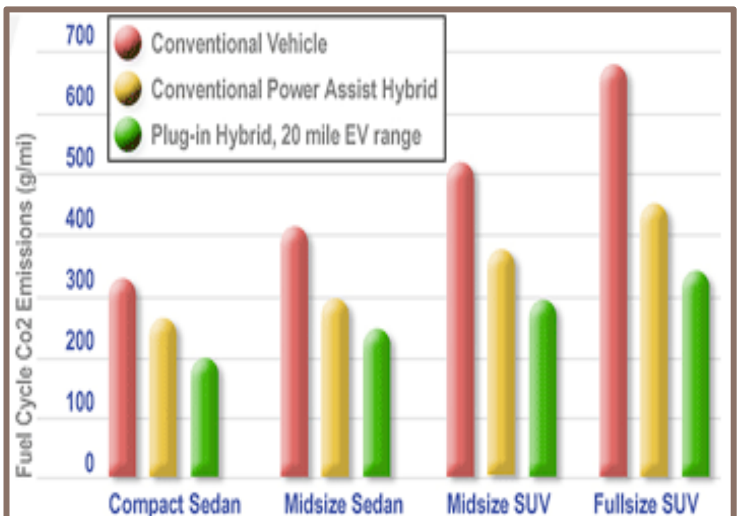
Plug-in Hybrids

Plug-in hybrids are vehicles that you charge by plugging them into a standard 220-volt outlet inside a garage. This is the main difference between a plug-in hybrid and a conventional hybrid. With a plug-in you also have a combustion engine except that engine is only used once the battery from the hybrid can no longer power the car. This is different from the conventional hybrid because the conventional ones use the battery only until it reaches a certain speed than it switches automatically to the internal combustion engine.

The production methods of a plug-in hybrid versus a normal hybrid or even a vehicle with an internal combustion engine are virtually the same with the main difference being the production of the storage batteries in the plug-ins. This is also the case when you are comparing prices of the three types of vehicles. The reason why the plug-ins are more expensive is because of the additional cost of that extra battery needed to operate the plug-in hybrids (Meisterling, 2008).

One of the biggest issues with Plug-in hybrids is the type of electricity used when charging the vehicles. Most homes in Nova Scotia generate their electricity from coal burning power plants. Nova Scotia power is the largest air polluter in the province with over 80% of the total air pollution in the province coming out of just four of their generating stations (Pollution Watch, 2003). Plug-in hybrids are a good idea in theory but if they are being charged with dirty electricity they are not doing a lot of good for the planet.

Another issue with plug-in hybrids is that people are charging them at peak hours of the day (Apt, 2011). When someone drives their plug-in hybrid to work they will usually charge it as soon as they get there which is not a huge deal but if everyone does that then it creates a problem. The answer to this is not charging batteries but rather replacing the batteries when your old one looses its charge. In the case of the Dalhousie Fleet, you would set up a battery exchange centre close to where the vehicles are stored. This issue would not be too huge in regards to Dalhousie because they would have multiple vehicles and not all of them would be used at the same time. However, a battery exchange centre would still be recommended. As soon as a battery is close to loosing its charge you simply switch it out for a fully charged one and then wait until it is not peak hours to recharge the old battery.



Electric Power Research Institute

There are indirect costs to every type of alternative fuel vehicle discussed in this report such as production costs, production pollution, etc. If you are talking solely about the carbon dioxide gas emissions emitted from the use of the vehicle then plug-in hybrid vehicles emit less than conventional and even standard hybrids. This savings in emissions grows as your move through the classes of vehicles. As you can see from the graph below, there is little difference in from the emissions of a plug-in hybrid versus a conventional vehicle in the compact sedan category but as you move into the full size SUV category you see a drastic change in the $C0_2$ emitted between the conventional vehicle and the plug-in hybrid.

To reduce greenhouse gas emissions further, you can use alternative fuel sources such as biodiesel instead of gasoline. This would be beneficial for long trips. Of course this is not usually the case for the Dalhousie Fleet of vehicles but it is something worth mentioning.

Plug-in hybrids generally cost between 10-20% more than traditional hybrids. An American organization in California called Calcars is an organization that aims to narrow this cost difference through "incentives, subsidies and rebates while making the case for paying extra to gain access to car-pool lanes, spend less time at gas stations, get home backup power, lower maintenance costs, and, most importantly, benefit society by reducing oil imports, greenhouse gases and pollution" (Calcars, 2011).

Plug-in hybrids will, for the foreseeable future cost more than traditional hybrids because of the cost of the battery. However, improvements in technologies and increasing demand will drive the price of these batteries down thus making plug-in hybrids a more viable option.

Currently many auto manufacturers have tested plug-in hybrids in private shops. Daimler-Chrysler has already publicly tested many of their vehicles as well they are in the process of converting 40 of their 15-person vans to plug-in hybrids (Calcars, 2011). General Motors announced that they are going to mass produce two plug-in hybrids (Chevrolet Volt and Saturn VUE SUV). These two vehicles could both potentially be used in a future pilot project for the Dalhousie Fleet Vehicles.

Natural Gas Vehicles

Compressed – Compressed natural gas is made by compressing natural gas that is mostly composed of methane (CH4) to less than 1% of the volume it occupies at standard atmospheric pressure (Consumer Energy Center, 2006). It can be used in place of gas, diesel or propane. The combustion of compressed natural gas still produces greenhouse gas emissions, however it is much cleaner than gas, diesel or propane. If there was a natural gas spill, it is lighter than air, so it evaporates rapidly. A compressed natural gas vehicle needs a larger amount of fuel storage space than regular vehicles (Canadian Natural Gas Vehicle Alliance, 2011). The Southern California Gas estimates that compressed natural gas would cost 40% less than gasoline (Consumer Energy Center, 2006). Canada has only developed compressed natural gas engines that are available for buses, larger trucks, and some taxis. The availability of compressed natural gas is limited to larger cities (Canadian Natural Gas Vehicle Alliance, 2011). This option would be feasible if Dalhousie Campus had larger vehicles in their fleet. There are currently no natural gas refueling stations in Nova Scotia (Canadian Natural Gas Vehicle Alliance, 2011)

Liquefied – Liquefied natural gas is natural gas that has been converted to liquid form for means of transportation (CLNG, 2011). Liquefied natural gas is an odorless, non-toxic and non-corrosive. Like compressed natural gas when a spill occurs it would evaporate quickly. Studies have shown that liquefied natural gas produces two and a half times less greenhouse gas emissions than coal. Liquefied natural gas is increasing in popularity, however, the availability of fleet options are limited to mostly heavy operating vehicles (CLNG, 2011). There is also no public liquefied natural gas refueling stations in Nova Scotia (Canadian Natural Gas Vehicle Alliance, 2011).

Propane Vehicles

Propane is currently the most commonly used alternative fuel vehicle in Canada (Propane Gas Association of Canada, 2011). Propane gas contains low levels of sulphur, which would decrease the acidity of rain in the area if it were more commonly used. Propane prices are influenced by the price of crude oil and natural gas prices, so as those prices increase, it increases as well (Propane Gas Association of Canada, 2011). The carbon footprint of propane is much smaller than other fuels, including some renewable (PERC, 2009). Currently in Canada there are no options for propane-powered vehicles that can be purchased from a manufacturer. The vehicles would have to be converted to run on propane. The average cost of converting the vehicle to run on propane can easily be more than $4000 (Propane Gas Association of Canada, 2011). Since there are no available options in Canada for public purchase, this option would not be a feasible option for Dalhousie.

Low emission Vehicles

A low emission vehicle is a vehicle that emits a low amount of greenhouse gas emissions (EPA, 2010). A low emission vehicle emits less than 120 g/km of carbon dioxide. In Canada, manufacturers have low emission vehicles in their showroom. This type of vehicle would be easily obtained and produces fewer emissions than the standard car. By buying smaller cars for Dalhousie, it would be easy to reduce its carbon footprint. The low emission vehicle standard has been put into place for every lightweight vehicle made after 2004 (JD Power, 2011). These vehicles would be currently available to the Dalhousie fleet.

Fuel efficient Vehicles

There is no clear definition of a fuel-efficient vehicle. However, advanced fuel technology allows at least 10% reduction in fuel than a standard vehicle (America Gov, 2009). Canada has many options for fuel-efficient vehicles, many which would be readily available to the Dalhousie fleet. Currently, the most fuel-efficient vehicle in Canada is the Honda CR-Z, in a city it would get 5.6L/100KM and the annual fuel cost is $1113. The carbon dioxide emissions would be approximately 2438kg per year. This car only contains two seats and would probably not meet the needs of Dalhousie. Canada's most fuel efficient truck is a Toyota Tacoma, in a city, it would get 10L/100KM, the annual fuel cost is estimated at $1869 and the carbon dioxide emissions are 4094kg per year (Natural Resources Canada, 2010).

Ethanol Or E85 (At least 85% with 15% Gasoline)

Ethanol has become an increasingly popular alternative fuel based on its environmentally friendly features, as it is generated "biochemically through photosynthesis and fermentation and is therefore a completely renewable resource" (Pietro, 2009, 579). However there have been questions raised as to whether or not Ethanol is truly better than gasoline as they both produce high amounts of acetaldehyde and formaldehyde (Cunningham, 2007). Some studies have shown that large-scale use of E85 could in fact increase asthma, hospitalizations and death caused by ozone exposure created by large releases of these carcinogens (Cunningham, 2007).

Socially and economically ethanol is a viable option as most Latin American countries that have adopted E85 on a fairly large scale have experienced increased savings and a large increase in job opportunities by way of new ethanol distilleries/plants (Economist, 2007). The availability of E85 in Halifax remains an issue, especially due to the fact that there is only two E85 stations in Canada and they are located in Ontario (Vancouver Sun, 2008). Thus right now ethanol fuel supply would have to come from the south and a fueling station would have to be built to sell to the general public and Dalhousie which would cost USD $30,000 to convert one single gasoline pump to accommodate E85 (Vancouver Sun, 2008). If and when this is done however there are a wide range of "flex-fuel" vehicles that Dalhousie could run. A total of 28 different models are readily available for Canadians, most from Daimler Chrysler, Ford and GM. A very viable option for security cars and commuter vehicles would be the 2011 Chevrolet Malibu which runs on a smooth, quiet 4-cylinder engine and gets 15/23 miles per gallon (city/highway). This car in particular ranges between USD $21,975-$27,015 for the E85 Model. For larger vehicle replacements such as pickups the Dodge Dakota, a compact pick-up, would be a good choice. It ranges between USD $23,110-$33,535 and gets 9/13 miles per gallon (city/highway).

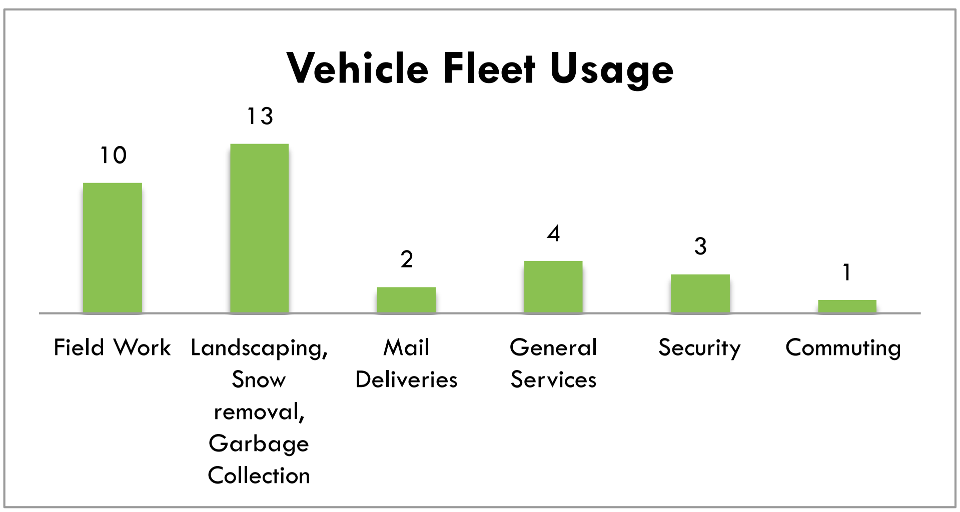
Hydrogen Fuel Cell

By converting Dalhousie's vehicle fleet to accommodate hydrogen fuel cells run by steam reforming of natural gas, wind electrolysis or coal gasification it would eliminate all emissions produced by conventional gasoline vehicles (Jacobson et al., 2005). The environmental impact would be extremely high. The economic impact is also high as, a hydrogen fuel cell today is approximately USD $250,000, this high cost is due to the transportation and storage of the hydrogen as its extremely combustible (Rogers et al, 2007). Thus the social impact on hydrogen fuel cells is one of concern and high risk as other alternative fuels are much safer to use. While the re-fueling and hydrogen distribution is a very site-specific process, Dalhousie campus would have to acquire facilities s that could accommodate the safe and efficient fueling of these types of vehicles (Demirbas, 2007). As of right now hydrogen cars only exist as demonstration models and for lease in limited numbers, they have not been released to the general public yet.

INTERVIEWS AND SURVEY

From the interviews and surveys that were conducted, comprehensive data was collected to better understand the purpose and make-up of Dalhousie's current vehicle fleet. The survey helped in finding that the vehicles that make-up this fleet consist of the following classes: van, pickup, sports utility vehicle (SUV), sedan, truck, loader, and tractor. The years these vehicles were made ranges from 1989-2009. Of these 33 vehicles, only 6 were fueled by diesel the rest were fueled by gasoline. Furthermore, the majority of the vehicles in Dalhousie's fleet had been purchased new; those that were purchased used were noted to have a fairly low current resale value. As for daily use our findings revealed a wide range of uses, from fieldwork to landscaping, mail deliveries, general service, security and commuting (see. Fig.1). With regards to daily kilometer use, it was difficult to determine, as responses were extremely varied, some vehicles were used daily, especially those used for landscaping, security and mail delivery. While vehicles used by some researchers in the biology department, it was found that they only drove their vehicles 10-15 times a year, strictly for fieldwork and long distance trips to remote locations such as Labrador and other eastern coastal regions. As for vehicle up-keep and maintenance costs it was established that all vehicles used for on campus purposes such as landscaping, security and mail delivery were paid for by the school, while maintenance costs of those vehicles which belonged to certain individuals were paid for by the user. Lastly those Dalhousie employees who took the survey reported no major problems with regards to car performance and upkeep.

Fig 1.



Our interview process aimed to achieve a more in depth analysis of the future of alternative fuel vehicles at Dalhousie and how those who use the current fleet felt about such technologies. The results were less enthusiastic than we had anticipated, as most interviewees felt that alternative fueled vehicles were a feasible idea, just not for their respective departments. Although on a positive note, the landscaping, security and other on campus use vehicle owners were open to alternative fuel vehicles, as long as they could continue to do their jobs properly and efficiently. The negative responses came mostly from those researchers who used their vehicles for long distances as they felt that it was not possible to replace their current vehicles for something more environmentally oriented. Their concerns were based on issues of safety, performance, hauling capacity and re-fueling capability. Furthermore concerns with cost were a high occurrence amongst all those interviewed. Therefore most of them were hesitant in saying they would be interested in a pilot project due to the high costs associated. With that said we did hear interest from both facilities management, as well as professor Lukas Swan. If funding were able to be found both parties would be introducing a pilot program and study. So there are possibilities to develop and implement alternative programs at Dalhousie.

DISCUSSION

The purpose of this study was to determine the social, economic and environmental costs and benefits of a variety of alternative fuel options in order to see which one would be best for implementation at Dalhousie. After having taken into consideration the various alternative fuels explored in our literature and journal review and accounting for the needs of the current users of these vehicles we have made some significant findings as to what options will in fact be the most feasible.

The results of our study provided us with three top choices for alternative fuel vehicles. These choices are as follows: Hybrids, neighborhood electric vehicles and electric cars. The rest of the vehicles were eliminated as potential options due to their lack of availability, extremely high price and/or lack of refueling ability in Halifax.

Although, not traditionally considered an Alternative Fuel Vehicle, Hybrids are an ideal choice for future vehicles at Dalhousie. They are a proven technology, which most importantly is readily available in Nova Scotia and are produced by a wide range of auto manufactures. Although the prices of hybrids have gone down, the price still remains a significant barrier in the purchasing process. Also, the fact that most auto manufactures only offer light trucks and compact cars raises a problem for replacing large pickup trucks with vehicles that do not meet the demands of those who use them. This is especially a concern for those fleet users that require their cars to travel through unforgiving terrain, off-road and in conditions that a smaller hybrid model may break down in. Which means in order to meet some of the vehicle needs on campus we would have to invest in heavy-duty hybrid technology. Which is very costly. However, hybrids vehicles should be seen more as a stepping-stone towards developing sustainable fuel vehicles.

Our second choice for an alternative fuel vehicle is a neighborhood electric vehicle. There are currently a variety of makes and models available which would be able to fit the needs of Dalhousie. Mainly those models which have flatbed backs and tie downs for transporting equipment around campus such as the NEVs built by GEM. This would reduce the number of ½ ton pickups needed to transport maintenance staff around campus, as a result significantly reducing $CO2$ emissions produced by the fleet as a whole. However, the most significant barrier to neighborhood electric vehicles is that in Nova Scotia they are currently not legal on the roads.

Our last recommended option is electric vehicles, with the help of professor Lukas Swan (See Appendix 4) we were able to develop a frame work to measure C02 emissions and compare both electric and gasoline powered vehicles. Once the calculations had been made it was discovered that electric vehicles came out on top as more environmentally friendly than petrol/diesel cars. This option at first glance would appear to be the best, however issues surrounding price and availability moved lower in preference. As of right now the limited availability of electric vehicles in Canada goes not provide Dalhousie with many options, however with cars like the Chevrolet Volt and Nissan Lead this may become a viable option in the very near future.

A close contender for the top three options was Biodiesel; therefore we feel it is necessary to mention it as a possible option, because it is an alternative to diesel fuel made from vegetable oils, and waste cooking oil; all of which are abundantly available on campus. Compared to conventional diesel, biodiesel combusts better and produces fewer GHGs and particulate emissions. Currently the Dalhousie fleet does not have a significant population of Diesel vehicles. But Biodiesel is a proven alternative.

CONCLUSION

In conclusion, based on the findings from our literature review, survey and interviews we have concluded that a combination of three options, hybrid, NEV and electric vehicles will be the most feasible for replacing Dalhousie's existing vehicle fleet. By choosing to use one, or all of these alternatives Dalhousie's vehicle fleet would significantly reduce its carbon footprint. To further this positive environmental change we have made some suggestions for further action. The first being the implementation of a pilot program to further study the impact that alternative fuel vehicles would have on those who use the vehicles and the change in impact on the environment. Secondly we suggest the implementation of a more comprehensive and formal fleet management system, as it has to the potential to improve efficiency and productivity while reducing costs for the Dalhousie fleet. Fleet management software can help to manage more effectively all aspects of the vehicle life cycle, from acquisition through maintenance to disposal. It can generate profiles of individual drivers, vehicles, and trips, as well as monitoring vehicle efficiency and tracking, via GPS or other means, individual vehicles in the fleet. Most importantly it allows for mileage and fuel consumption to be easily monitored in order to reduce costs. Our last recommendation supports an effort to reduce fuel consumption as a whole by the installation of an on campus fuel station as currently Dalhousie fleet vehicles obtain their gas from a station which requires them to travel approximately 4 km to refuel.

Overall the process of switching Dalhousie's existing vehicle fleet to one that allows for these more sustainable, alternative fueled vehicles to be used is going to be a gradual transition. With no current "green" or alternative fuel vehicle initiatives on campus it is crucial for the University's image that they establish themselves as leaders in the green movement and create an example for other institutions to follow in hopes of creating environmentally sustainable vehicle fleets worldwide.

APPENDIX 1

VEHICLE SURVEY

We are a group of Dalhousie students exploring the ecological, economic, and social costs and benefits of converting Dalhousie's current vehicle fleet into more sustainable forms of transportation. The purpose of this survey is to gather information on how Dalhousie employees interact with their department's vehicles on a daily basis in order to better understand what requirements must be met by new technology that could replace existing vehicles. We thank you for your time and cooperation as we can assure you that this information will be kept confidential and used strictly for this feasibility study. The client for our project is the Vice-President of Finance and Administration.

Vehicle Identification	
Make	
Model	
Year	
Engine	
Transmission	
Type	
Department	

Vehicle History	
Purchase Mileage	
Current Mileage	
Purchase Cost	
Estimated Resale Value	

Maintenance Cost	
Oil Changes	
Tires	
Mechanical Issues	
Other	

Daily Use	
Typical Daily Mileage	
Daily Tasks	
Typical Daily Fuel Costs	

Q1 Is this vehicle up for renewal?

Q2 Does the vehicle use change with seasons? If so how?

Q3 Would you be interested in taking part in a pilot program for a alternative fuel vehicle?

Q4 Who is in charge of purchasing new fleet vehicles?

APPENDIX 2

INTERVIEW QUESTIONS

We are a group of Dalhousie students exploring the ecological, economic, and social costs and benefits of converting Dalhousie's current vehicle fleet into more sustainable forms of transportation. The purpose of this interview is to gather information on how Dalhousie employees interact with their department's vehicles on a daily basis in order to better understand what requirements must be met by new technology that could replace existing vehicles. We thank you for your time and cooperation as we can assure you that this information will be kept confidential and used strictly for this feasibility study. The client for our project is the Vice-President of Finance and Administration.

Q1 How do you feel about hybrid/electric vehicles as replacements for existing fleet vehicles?

Q2 Are any vehicles in the fleet due to be replaced soon?

Q3 Would you be interested in participating in a pilot project for an alternative fuel vehicle?

Q4 Who is responsible for purchasing new fleet vehicles? What are the associated protocols?

Q5 Are you willing/able to share vehicles with other users/departments?

Q6 Are there any fleet vehicles that could be replaced with smaller vehicles?

Q7 Would you be interested in exploring options for alternative fuel vehicles? If not, what are you concerns/reservations?

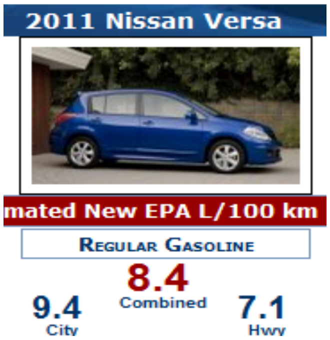
APPENDIX 3

CURRENT DALHOUSIE VEHICLE FLEET

Make	Model	Class	Year	Fuel Type	Contact - Source
Ford	E-150 Club Wagon	Van/MiniVan	1989	Gas	Jean Nisbet
GMC	Sierra Cab	Pickup	1998	Gas	John Batt
GMC	Suburban 4x4	SUV	1996	Gas	Bob Scheibling
GMC	Sierra 1500	Pickup	1998	Gas	Jeff Hutchings
Ford	F150 Extended Cab	Pickup	2004	Gas	Daniel Ruzzante
Dodge	Caravan	Van/MiniVan	2002	Gas	Paul Bentzen
Ford	Econoline Club	Van/MiniVan	1995	Gas	Elizabeth MacDonald
GMC	C6500	Truck	2006	Gas	Mike Wilkinson
Chevrolet	Silverado 1500	Pickup Truck	2005	Gas	Mike Wilkinson
Ford	Ranger R10	Pickup	2008	Gas	Mike Wilkinson
Dodge	RAM 1500	Pickup	2009	Gas	Mike Wilkinson
Chevrolet	Silverado 1500	Pickup 4x4	2009	Gas	Mike Wilkinson
Dodge	RAM 1500	Pickup	2003	Gas	Mike Wilkinson
Chevrolet	Express 2500	Van/MiniVan	2004	Gas	Mike Wilkinson
Chevrolet	Express 2500	Van/MiniVan	2004	Gas	Mike Wilkinson
GMC	C4500	Pickup	2006	Gas	Mike Murphy
GMC	C6500	Truck	2006	Gas	Mike Murphy
GMC	G2500	Van/MiniVan	2006	Gas	Mike Murphy
Dodge	RAM 2500	Pickup	2003	Gas	Mike Murphy
Chevrolet	Express 2500	Van/MiniVan	2004	Gas	Mike Murphy
Chevrolet	Impala	Sedan	2008	Gas	Sandy MacDonald
GMC	Savana 1500	Van/MiniVan	2004	Gas	Sandy MacDonald
Chevrolet	Silverado 1500	Pickup	2009	Gas	Leigh Horne
Dodge	Ram 2500 Quad Cab	Pickup	2004	Gas	Dr. John Newhook
Chevrolet	Silverado 1500	Pickup	1999	Gas	Sean Hartwell
Lexus	ES350	Sedan	2007	Gas	Bonnie Van Buskirk
Subaru	Forester SpeedWagon	Sedan	2007	Gas	Robert Baird
Ford	E450	Truck	2002	Diesel	Mike Wilkinson
Bobcat	S185	Loader	1989	Diesel	Mike Wilkinson
Bobcat	753	Loader	2003	Diesel	Mike Wilkinson
Ford - New Holland	TZ-25 DA	Tractor	2007	Diesel	Mike Wilkinson
John Deere	2320	Tractor	2007	Diesel	Mike Wilkinson
John Deere	2320	Tractor	2007	Diesel	Mike Wilkinson

APPENDIX 4

VERSA VS LEAF EMISSIONS



Safety	**NA**
Size Class	Midsize Cars
Engine Size (liters)	1.6
Cylinders	4
Transmission	Automatic 4-spd
Drive	Front-Wheel Drive
Gas Guzzler	no
Turbocharger	no
Supercharger	no
Passenger Volume	2.7 m^3 (4D)
Luggage Volume	0.4 m^3 (4D)
Engine Characteristics	NA
Trans Characteristics	NA

	1.8 S Hatchback	1.8 SL Hatchback
Wheelbase	2600 (102.4)	2600 (102.4)
Overall length	4295 (169.1)	4295 (169.1)
Overall width	1695 (66.7)	1695 (66.7)
Overall height	1535 (60.4)	1535 (60.4)
Track width (front)	1480 (58.3)	1480 (58.3)
Track width (rear)	1485 (58.5)	1485 (58.5)
Head room (front)	1031 (40.6)	1031 (40.6)
Head room (rear)	972 (38.3)	972 (38.3)
Leg room (front)	1053 (41.4)	1053 (41.4)
Leg room (rear)	966 (38.0)	966 (38.0)
Hip room (front)	1239 (48.8)	1239 (48.8)
Hip room (rear)	1200 (47.2)	1200 (47.2)
Shoulder room (front)	1360 (53.5)	1360 (53.5)
Shoulder room (rear)	1287 (50.7)	1287 (50.7)

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- The following compares the 2011 Nissan Versa (gasoline) and Leaf (electric) from an emissions perspective using the Nova Scotia Electricity Utility.
- Note from the "Versa" and "Leaf" worksheets that the combined passenger and luggage volumes of the Leaf are greater than the Versa (3.2 m^3 vs 3.1 m^3).
- Note from the "Versa" and "Leaf" worksheets that the exterior dimensions of the Leaf are greater than the Versa.
- Therefore, the comparison favors the Nissan Versa, as it is a slightly smaller vehicle than the Leaf.
- This analysis is conducted with a scope that ends at the gasoline dispensing station and electricity generating station.
- Note that the gasoline vehicle analysis is done solely for CO2, whereas the electric vehicle analysis is done for CO2e (including methane, nitrous oxide, and sulphur hexafluoride), thereby favoring the Nissan Versa.

GASOLINE VEHICLE		
Carbon in Gasoline (g C / usgal)	2421	http://www.epa.gov/oms/climate/420f05001.htm
CO_2 after burning Gasoline (g CO_2 / L)	2325	99% converted, CO_2=44, C=12, 3.78 L per usgal
Nissan Versa (combined L / 100 km)	8.4	See "Versa" worksheet
Nissan Versa (g CO_2 / km)	**195**	

NOVA SCOTIA ELECTRIC VEHICLE		
NS Power (g CO_2e / kWh)	840.06	http://www.nspower.ca/en/home/environment/emissions/archived/totals.aspx
Transmission loss factor	2.71%	http://oasis.nspower.ca/en/home/default/systemreportsandmessages/default.aspx
Estimated Distribution loss factor	4.29%	
Nissan Leaf (combined kWh / 100 km)	21.1	See "Leaf" worksheet
Nissan Leaf (g CO_2e / km)	**190**	

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