Quantification of the Greenhouse Gas Emissions of the UBC Vancouver Vehicle Fleet: A Baseline Survey

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COMM 490

June 22, 2013

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TABLE OF CONTENTS

Background

Climate change is a great environmental, economic and political concern which has become a major issue of public debate. However, appropriate action has yet to be taken in many sectors. For instance, in 2004, transportation represented the second most important source of Greenhouse gasses in Canada sector after stationary combustion sources (Environment Canada, 2007). As emissions trends show a general increase, in 2006 the transportation sector still represented an important source of greenhouse gases (Environment Canada, 2006).

The web of influence of a university can impact a diverse audience from youth to experts in many fields. The University of British Columbia (UBC) has the responsibility of creating feasible, effective environmental programs on which other entities can model their own programs. University transportation fleets are considered essential for proper university function; they often represent a significant contributing factor to campus greenhouse gas emissions.

Universities have a responsibility to create environmentally sound policy. However, even well intentioned policy is frequently skewed by bureaucracy. Therefore, it is increasingly important to create executable policy which leaves little space for misunderstanding.

UBC's Environmental Protection Compliance is one of the policies put in place to ensure environmental responsibility within the university (Environmental Protections Compliance, 2005). Developing programs to prevent pollution and to monitor and audit procedures effective to a university setting are amongst the main purposes of the policy.

More specifically, it is critical to consider this policy when developing strategies to reduce vehicle emissions at UBC.

The UBC vehicle fleet consists of 389 emissions producing vehicles and machinery such as tractors (UBC Treasury, 2007). A baseline survey of greenhouse gas emitted by the UBC transportation fleet is required to determine current emission levels. Such a study will provide a starting point from which emissions can be lowered and operating practices improved. A survey was conducted by obtaining information on fuel consumption from vehicles owned by the university, used by staff, faculty and students for business of the University at the Vancouver campus. Land and Building Services, Housing, Food Services, Security and individual faculties were contacted to determine average annual fuel consumption of the transportation fleets; the fuel consumption was then used to generate estimates of the greenhouse gas emissions of the fleet. Where information was not available, the fuel consumption was modeled to determine a realistic estimate of fuel consumed and consequent vehicle emissions.

Establishing relevant strategies is another hurdle which is often encountered after correct mandates and policy have been put in place. Strategies for improvement are examined while considering constraints and financial limitations of the faculty. To reduce vehicle emissions, it is first necessary to implement an effective monitoring system. This study will therefore explore auditing technologies and reduction strategies for the purpose of improving the environmental responsibility of the UBC transportation fleet in accordance with the Environmental Protection Compliance Policy.

Between 2003 and 2005 there were notable increases in the total level of greenhouse gases emitted from the national transportation sector (Environment Canada, 2006). However, other emitting sectors such as agriculture and stationary combustion sources experienced a decrease in emissions, offsetting the increase (Environment Canada, 2006).

Table 1: Canada's Greenhouse gas emissions by Gas and Sector, 2005:

Greenhouse Gas Categories	**GHG Totals (Kt CO_2 eq)**
Energy	
a. Stationary Combustion Sources	346 000
b. Transportation	200 000
c. Fugitive Sources	65 700
Industrial Processes	53 300
Solvent and Other Product Use	180
Agriculture	57 000
Waste	28 000

(Environment Canada, 2006)

Of particular importance is the rise of over 109% from 1990 to 2005 in emissions from light duty gasoline trucks, reflecting the growing popularity of sports utility vehicles (Environment Canada, 2006). Transportation is a notable source of emissions at UBC, making it a large source for potential emissions reductions.

Objective

This study was conducted with several key objectives in mind. Firstly, the study aims to determine an effective tracking method for greenhouse gas emissions form the UBC vehicle fleet. The study then seeks to quantify the emissions from the fleet to provide a baseline of emissions over a one-year time period. The study will then provide an initial exploration with goals of developing relevant strategies for emissions reduction at UBC. Finally, this study will explore the existing constraints when considering the possibility for "carbon neutrality" and the UBC Vancouver campus transportation fleets. The findings of this study will be presented to SEEDS (Social, Ecological, Economic Development Studies) initiative at The UBC Sustainability Office.

Methodology

Experimental Design

In order to review the greenhouse gas emissions associated with the transportation sector at the University of British Columbia, a list all vehicles and machinery covered by the university insurance policy was used. It was assumed that all vehicles at UBC Vancouver campus were listed under this policy, and no information was provided to contradict this assumption.

The greenhouse gas emissions were evaluated for the period of one year from April 1st, 2006 to March 31st, 2007. The time period was deemed appropriate as it covered all academic sessions (summer session and winter session) and also corresponded with the institution's financial year.

Vehicles were separated into three categories: vehicles that are fueled only on-campus, vehicles that are fueled off-campus, and vehicles that use both services. Vehicles and machinery fueled on campus used the Land and Building Services Fuel Station located at the LBS building, while off-campus fueling was done at a variety of different fuel stations for which information was not available. The product usage summary from Land and Building Services of unleaded gasoline and bio-diesel was obtained for the vehicles which fueled at the LBS fuel station. However, as the p-card system, a credit card used for university business, is used to purchase fuel at this fuel station it was not possible to identify for which vehicle the fuel was purchased. As p-cards are often shared within a department, the assumption that a certain p-card is used solely by one vehicle is not reasonable, making it difficult to separate fuel from the LBS fuel station into vehicle categories.

It was assumed that Plant Operations vehicles are part of the first category of vehicles; those which only fuel on-campus (UBC Building Services, 2007). Faculties, Housing, Food Services and Security were contacted to determine to which categories vehicles belonged.

When no information was available, the emissions were modeled to provide the most precise estimate. In the model, it was assumed that the vehicles unaccounted for were functioning at similar consumption levels as other campus vehicles. The average gasoline and bio-diesel consumption for a vehicle over a year was calculated and it was inferred that vehicles with no data associated with them were consuming fuel at these average levels. Although the assumption that all vehicles will consume fuel at these average levels is likely violated, the model provides a viable estimate for the fuel consumption of these vehicles (Appendix A).

It was assumed that the values calculated were not exactly the fuel consumed; therefore a 10% margin of error was suggested for the actual value. The error was only applied to the estimated values as it was assumed that collected data were accurate. However, this may also be untrue, as occasionally supporting documentation did not exist for fuel consumption values given. In addition, the sample of vehicles was not random;

vehicles for which there were no data belonged to a particular sector and not a random assortment of all sectors. It is likely that as these vehicles had diverse uses, their fuel consumption varies greatly. This model produced a range of values for the amount of fuel consumed; however, the estimates produced lack precision as some of the assumptions made were probably violated.

Greenhouse Gas Quantification

Three greenhouse gases are emitted by the combustion of fossil fuels: carbon dioxide (CO_2), methane (CH_4) and nitrous oxides (N_2O). Emissions of all three greenhouse gases were calculated but converted into the standard unit of carbon dioxide equivalents (CO_{2e}) to facilitate comparisons (Table 2).

Table 2: Carbon Dioxide Equivalents

Greenhouse Gas	**CO_2 Equivalents**
Carbon Dioxide (CO_2)	1
Nitrous Oxide (N_2O)	21
Methane (CH_4)	310

(Transport Canada, 2007)

The carbon dioxide emissions from gasoline were calculated using U.S. EPA (Environmental Protection Agency) guidelines. As stated by the Intergovernmental Panel on Climate Change, an emissions factor must be applied to the carbon content as not all of the carbon is oxidized into carbon dioxide (EPA, 2007). The oxidation factor used is 0.99; that is, one percent of the carbon content in gasoline is not oxidized into CO_2. The carbon dioxide equivalents were calculated for all other greenhouse gases using the Global Warming Potentials listed in Table 1. This is relevant as many gases have different impacts with respect to climate change. This conversion allows the generation of a cumulative figure for greenhouse gas emissions of the UBC vehicle fleet as opposed to numerous non-comparable figures (Environment Canada, 2006).

The bio-diesel sold at the UBC Land and Building Services Fuel Station is a soy-based fuel supplied by Canadian Biofuels in North Vancouver. The fuel is 20% bio-diesel in the summer months but 10% bio-diesel in the winter (UBC Building Services, 2007). The emissions factor for a 15% corn-based ethanol blend provided by the Urban Transportation Emissions calculator is 354 g CO_2/ L of bio-diesel. This is considered to approximate emissions of the fuel used at UBC. Bio-diesel carbon dioxide emissions are similar to those of regular diesel. However, using bio-diesel will decrease emissions of other greenhouse gases by 20% with a 20% blend (EPA, 2007). Although there is some variability between emissions factors of different bio-fuels, corn ethanol is most widely used and will provide the most accurate estimate.

This survey found that there were six insured propane fueled vehicles on campus. Of these six vehicles, fuel consumption information was available for only two vehicles. Although the greenhouse gas emissions were still calculated for the propane fleet, these figures should be viewed with some caution. The assumptions made in calculating the estimates were almost certainly violated as the sample size was so small; therefore, there is a high degree of uncertainty in the values calculated.

When possible, vehicles were separated by class to determine the most appropriate emissions factor. However, this was often not possible as many of the figures obtained were cumulative figures for consumption of a percentage of the fleet. Three classes were proposed for evaluation: passenger gasoline vehicles, light duty gas trucks, and heavy duty diesel trucks (GVRD, 2007). The carbon dioxide emissions factor used was standard across the different classes; the EPA emissions factor of 19.4 pounds/gallon or 2.23 kg/L. However, the nitrous oxides and methane emitted from vehicles did vary between classes (Table 3).

Table 3: Emissions Factors by Vehicle Class

Vehicle Class	**g N_2O/L of fuel**	**g CH_4/L of fuel**
Light Duty Gasoline Passenger Vehicles	0.37	0.189
Light Duty Gasoline Trucks	0.613	0.285
Heavy Duty Diesel Trucks (bio-diesel 15% blend)	0.092	0.043

(Transport Canada, 2007)

In the case of propane vehicles, all vehicles were assumed to be light duty and therefore only one emissions factor was required; 1500 g of CO_2/L of propane was the emissions factor provided by Transport Canada (2007).

As most vehicles in the survey were newer than 1990, the emissions factors used did not consider older vehicles with less efficient technologies.

When it was not possible to differentiate which vehicles had consumed a certain amount of fuel, emissions were calculated for Light Duty Gasoline Trucks and Light Duty Gasoline Passenger Vehicles and a range was presented. This was done as it was not possible to separate vehicles into classes.

When only a monetary sum was available to determine fuel consumption, the average monthly regular unleaded gasoline price for self service in Vancouver was used. The average sum spent on fuel over twelve months was used to generate a monthly average and this was assumed to be constant over the university year (April 2006- March, 2007). The average price of unleaded gasoline in Vancouver for the previous university year was 1.07$/L; this was used to estimate the amount of fuel purchased and used by the vehicle (Statistics Canada, 2007).

Results

As most figures calculated are estimates, lower and upper bound will be provided. The gasoline emissions for the UBC vehicles fleet in the 2006 fiscal year are estimated to be between 1,377.2 and 2897.9 tonnes of carbon dioxide equivalents. The bio-diesel emissions were between 97.5 and 99.2 tonnes of CO_{2e}. The greenhouse gas emissions from propane combustion for the 2006 fiscal year were estimated to be 0.67 to 0.82 tonnes of carbon dioxide equivalents. Overall the total greenhouse gas emissions for the UBC vehicles fleet ranged from 1,475.4 to 2,997.9 tonnes of carbon dioxide equivalent emitted into the atmosphere each year.

The gasoline fleet was found to have the most significant emissions; there are significantly more gasoline fueled vehicles than vehicles fueled by any other fuel type. The propane vehicles do not have a significant impact on the total emissions produced by the UBC vehicle fleet; again the number of vehicles in this category is much lower than those fueled by gasoline.

Table 3: Emissions of UBC Vehicle Fleet by Fuel Type

Type of Fuel	**Greenhouse gas emission (tonnes CO_2 eq)**
Gasoline	1,377.2– 2897.9
Propane	0.67-0.82
Bio-diesel	97.5 - 99.2

Total	1, 475.4 – 2,997.9

The bio-diesel emissions are rough estimates of actual emissions. The sample size of vehicles which were fueled with bio-diesel was smaller than that of gasoline fueled vehicles, providing a less precise estimate for vehicles without data. Further, the emission factor used in the above calculation is provided by Transport Canada for a corn-based bio-fuel, while the bio-diesel purchased by UBC is soy-based. The soy-based bio-fuel has been show to produce lower greenhouse gas emissions than the corn-based variety (Bullis, 2006). Overall, burning bio-diesel from soybeans offers a 41 percent reduction compared with regular diesel, making it a sound choice for use at UBC in terms of decreasing fleet emissions (Bullis, 2006).

Recommendations for Implementation

The reduction of greenhouse gases can be achieved effectively through the implementation of practices and technology which are more fuel efficient. While many emissions reduction strategies exist, the university is limited by practicality and fiscal constraints. In order to make drastic emissions cut-backs, there are many changes which should be incorporated into current university practices.

The control over the vehicle fleet is widely dispersed across the campus and must be centralized in order to implement rapid change. After such a change has been made, numerous emissions reduction strategies become feasible for the transportation fleet. Centralized organization of the vehicle fleet would further facilitate management and auditing of the vehicle fleet. The central administration would be responsible for all campus vehicles. Responsibilities would include maintenance and regular upkeep, fueling, emissions tracking and all vehicle and machinery related purchases or leases. Vehicles could be rented out by different administrative units for variable amounts of time exclusively for university business. By managing all these tasks in a consolidated manner, numerous potential improvements could be made which encourage the implementation of a centralized fleet administration at UBC. This framework would centralize all emissions data collected, providing a more precise estimate of campus emissions. Many universities, such as the University of Washington and University of Alberta, already function with a centralized vehicle administration.

Currently, emissions data are inaccessible as they are dispersed throughout the university in different sectors, and frequently records are not kept effectively. When records are present, there is little continuity and they are primarily kept for financial purposes. Financial records are not ideal for greenhouse gas emissions inventories as they generally do not emphasize fuel consumption.

Additionally, under a centralized vehicle administration, vehicle replacement and implementation of more fuel efficient technology would be much more cost effective and more popular than it is currently. Further, the purchase of unnecessary vehicles which are not frequently used would no longer occur saving money to individual faculties and the institution. As vehicles would be acquired in larger numbers at any one time the initial investment in a vehicle would be decreased, and individual faculties would not be required to find financing for vehicles required for research purposes.

While such a drastic change is quite difficult to implement initially, there are elements of this system which can be implemented easily and will facilitate GHG emissions tracking. For instance, records to track fuel usage could be universal to the institution, allowing for effective comparison between administrative units. The use of a separate card program for fuel purchases, accompanied by an effective data collection system, could simplify the data collection process, particularly when the card identifies the vehicle for which fuel is being purchased. However, as fuel exclusive purchase cards have been phased out and replaced with the all inclusive p-card which can be used for many different purchases, it is unlikely that the university will once again adopt this system.

Although a centralized vehicle fleet does eliminate the convenience of having a vehicle immediately at hand, there are substantial benefits to this framework. There are certain compromises, and additional planning would be required if such a system was established. Although vehicle rentals could exist for a long periods of time, such a system may complicate the ability to have field research vehicles which are not based at the UBC Vancouver campus or are away for extended periods of time. Additionally, the initial costs of developing a centralized vehicle administration are high as there is little infrastructure and person power in place to effectively run such a system. Further the financial benefits, which will likely result due to elimination of unnecessary vehicles and implementation of more fuel efficient technologies, are not immediately apparent, rendering the framework less realistic at the present time.

Tracking fuel consumption of vehicles fueling on campus would be much more effective for emissions tracking if information on the vehicle being fueled was recorded. This would be simple to implement, and would allow for effective emissions inventories to be taken on a more regular basis. Ideally, this information would be incorporated into a product usage summary, making it readily accessible. The account number recorded currently provides information only on the department to which the vehicle belongs. If implemented, a vehicle identification number could also be recorded without significant changes to the current system. Vehicles fueling off campus could use similar strategies to track fuel consumption and tie it directly to a particular vehicle, allowing for more precise emissions estimates to be made in the future.

Increasing the blend ratio of bio-diesel to diesel may also have a significant impact on greenhouse gas emissions. Such a change could be monitored to determine if impacts associated with the change were feasible and if the difference in vehicle emissions was substantial.

Although more efficient, lower emission vehicles are increasing in popularity, there are many steps which can be used to reduce emissions in older vehicles with higher emissions levels. Idling is an inefficient use of a vehicle which accelerates engine degradation. Additionally, if a vehicle is idling for more than an average of 10 seconds it will emit more GHG than if it had turned off and on again (Environment Canada, 2007). There are various technologies which will track idle time, average velocity and fuel consumption precisely. When used, these programs will provide baseline data from which improvements can be made. Currently, Land and Building Services is assessing the possibility of incorporating telematics into the plant operations fleet. Vehicle telematics is a technology which can provide information on driver-vehicle utilization and productivity data for all fleet operations. As the Land and Building Services vehicle fleet is the largest group of centralized vehicles at UBC, all vehicle maintenance, fuel tracking, and purchasing or leasing is done under one administration. Having the access to telematics data could improve fuel efficiency through driver training and provide critical vehicle productivity data, which likely will ultimately encourage a downsizing of the vehicle fleet depending on vehicle usage. The use of telematics by Land and Building Services (LBS) would provide a good sense of how a similar system would work for the entire campus. However, estimates of emissions acquired with this technology will not be useful for campus-wide estimation as the LBS fleet has different driving patterns than other transportation fleets. The campus wide implementation of telematics technology would be most effective under a centralized administration, as data collected could be used in the most effective way to decrease vehicle emissions while keeping costs at a minimum.

Telematics would further identify driver deficiencies and allow for an effective driver retraining program to be put in place. Unnecessary idling could be significantly reduced and other inefficient tendencies could be identified and corrected. The effectiveness of an education program for drivers would likely decrease vehicle emissions in the long run as many misconceptions about fuel economy currently exist. Driver training programs have been shown to produce effective results and could potentially have a considerable impact on emissions (Hayworth & Symmons, 2001).

Future Focus

The effective management of greenhouse gas emissions is dependent on their continued monitoring. Technology must be put in place to simplify this process, as currently it is virtually impossible to generate precise estimates of fuel consumption. Although, the centralization of the vehicle fleets and implementation of telematics technologies would be extremely effective tools for emissions monitoring, more accessible changes can be made in the immediate future. For instance, vehicle identification numbers could be assigned to all known vehicles and machinery. This would allow for effective fuel tracking by vehicle class. Furthermore, after a designated period of time, a fuel consumption form should be submitted to a centralized database. An online database created may simplify this process. Information such as: reporting period, vehicle identification number and license plate, fuel consumed by volume or weight, odometer readings at the beginning and end of the reporting period, and any maintenance done in the reporting period. Having this information accessible would enable frequent emissions monitoring.

Additionally, awareness amongst university drivers may effectively improve fuel efficiency. An educational campaign would likely reduce unnecessary vehicle use and encourage use of public transit system and car pooling when feasible.

Conclusions

For effective emissions auditing to occur at UBC, a number of infrastructure changes must be made to fleet administration. A database of fuel consumption information is required for frequent monitoring. As the transportation sector represents such a significant source of emissions, monitoring is critical in order to begin to implement reduction strategies.

As a leading research institution, UBC should consider it a priority to create relevant strategies to implement the environmental policy already articulated. Such measures would encourage change in other communities and effectively reduce the impact which UBC currently has on the environment.

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Appendix A - Calculations

Methodology for Estimating Fleet-wide GHG Emissions

Initially, the average fuel consumption for identified vehicles was calculated by averaging the total amount of fuel by the number of vehicles using this fuel. Here this is illustrated with gasoline:

(1) 364 796.2L /230 vehicles= 1586.1 L/vehicle

There were 149 vehicles with no data available; it was assumed that the fuel consumption of these vehicles was equivalent to the average.

(2) 1586.1 L/vehicle x 149 vehicles = 236 324.5 L

The known fuel used and the estimated amount were added to obtain the estimate for the total amount of gasoline used by the UBC vehicle fleets

(3) 364 796.2L + 236 324.5 L = 601 120.7 L

The percentage of vehicles which were accounted for was determined by dividing the number of accounted for vehicles by the total number of vehicles.

(4) (230 vehicles/ 379 vehicles) x 100 = 60.7%

A range of values was produced by assuming that there were likely errors in the calculation and producing a range of 10% plus or minus the calculated estimate.

(5) 236 324.5 L x 0.10 = 23632.4 L