ELECTRIFICATION FEASIBILITY REPORT 2020

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Is it feasible to electrify the University of Toronto Mississauga's Campus Fleet?

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Executive Summary

This project was designed to determine if it was feasible to electrify the University of Toronto Mississauga (UTM) Campus fleet vehicles. The following research report looks into several cost-benefit analysis and comparison of the vehicles currently on the campus fleet in order to determine if electrification of a variety of campus fleet vehicles is feasible. Information was gathered from a variety of sources including, but not limited to, stakeholders, peer reviewed journal articles and a variety of other reports. It can be concluded that it is feasible to electrify UTM's campus fleet vehicles. Based on the report research findings it was found that the UTM's campus police vehicle was the most utilized on campus and would have the most return, in terms of all three dimensions of sustainability, if it were to be electrified first. Additionally three of the purchased vehicles in 2000 for UTM's ground team are not actively in use due to maintenance costs and inability to function. We specifically recommend a transition from the currently used 2016 internal combustion engine Ford Explorer police cruiser to a plug-in hybrid electric 2020 Ford Explorer vehicle to determine the best pathway for other UTM fleet vehicles. As well as adapting the three sit on lawn mowers purchased in 2000 with the RYOBI 38-inch 48V Electric Riding Lawn Mower and the Chevy HD 4x4 pick up truck purchased in 2002 with the upcoming 2020 Ford F-150 PHEV pickup truck. The following report outlines the research that was conducted in order to approach this verdict.

Introduction

Electrical vehicles have become increasingly popular as the price of gas inflates and the desire to become more eco-friendly grows. Electric cars in particular have evolved within the past few decades. Today a variety of different electric vehicles are available on the market ranging from hybrid vehicles to fully electric vehicles. UTM has adopted a green initiative for all of its current projects, including building development, transportation, energy conservation and a variety of other areas (University of Toronto Mississauga Sustainability Office, 2001). In the essence of going green, the push for campus fleet vehicles to be electrified increases. As UTM advances in reducing its carbon footprint, it is important that the feasibility of the electrification of the campus fleet is considered. This report goes further and outlines the advantages and disadvantages of each of the different electric vehicles and determines which are suitable for the UTM Campus along with those that are not.

Currently the stakeholders contributing to this particular initiative include UTM's Grounds team, UTM's Campus Police, as well as the Sustainability Office at the University of Toronto Mississauga. Adapting an electric campus fleet service will impact all the above listed stakeholders in a variety of ways. A collaborative effort of all stakeholders is needed in order to implement a fully electric and ultimately sustainable fleet. Analysis of multiple factors were applied to current fleet vehicles on campus to aid in considering the lifespan and durability of electric vehicles, a comparison between gas and diesel vehicles all with respect to vehicle costs. This is the largest factor when deciding the feasibility of the project as it goes hand in hand with the cost of the vehicles. A cost-benefit analysis was additionally conducted to determine whether or not current fleet vehicles on campus should be replaced via electrification; if it's feasible. This will be determined and calculated by finding the approximate point of intersection for the point in time where the price of gasoline vehicles is equal to the price of electric vehicles. The recommendation that follows within this report is designed to reduce carbon emissions and increase campus fleet vehicle efficiency (by reducing cost and increasing life span of the vehicles).

Goals

To determine the feasibility of adapting an electric campus fleet at UTM campus that could sustainably reduce the university's carbon footprint and emissions. This encompases the reduction of all campus fleet vehicles, specifically the UTM's ground vehicles and UTM's campus police vehicles.

Objective

Provide a recommendation that reduces the emissions of UTM, while allowing the new recommendation to increase vehicle lifespan, reduce maintenance costs, and have greater return if electrified. The report is intended to identify and evaluate current campus fleet vehicles and UTM policies in order to successfully adapt to a fully electrified campus fleet. The objective to describe the recommendations found, supplemented and supported by additional research, and present it to stakeholders.

Recommendation

The recommendation are as follows:

1. Adapting the current campus police vehicle, 2016 Ford Explorer, with a 2020 plug-in hybrid electric Ford Explorer (refer to table 2 in appendix)
2. Replacing the three sit on lawn mowers purchased in 2000 (refer to table 1 in appendix) with the RYOBI 38-inch 48V Electric Riding Lawn Mower.
3. Replacing the Chevy HD 4x4 pick up truck purchased in 2002 with the upcoming 2020 Ford F-150 PHEV pickup truck.

4. Based on the performance and reliability of each of the previous transitions, UTM as a whole can make further decisions concerning the transition of other fleet vehicles.

Background Information

Overview

As of 2018 according to the University of Toronto's sustainability office that is responsible for promoting and maintaining a broad range of sustainability initiatives through the engagement of the UTM community. The UTM's sustainability office is responsible for promoting and maintaining a broad range of sustainability initiatives through the engagement of the UTM community. In order to determine an appropriate recommendation, research on barriers of electrification, the different types of electric vehicles and different charging stations was conducted. The barriers consist of economy, society and environment. To determine the feasibility of electrifying UTM's campus fleet, research on four different types of electric vehicles within three different charging stations is sufficient. The following slides will outline the information that was obtained from each of the primary background research that was conducted.

Barriers of Electrification

There are various types of barriers/obstacles when it comes to adopting electric vehicles, many of which can be categorized as either economic, social, or environmental. The barriers focused on throughout this project include: the initial and continued cost of the vehicle, the necessary infrastructure to support the vehicle; both under the economic dimension. As well as the variety of vehicle options and the mindset of the consumer under the social dimension, and finally the emissions and the increased demand from consumers within the environmental dimension (Figure 1 in Appendix).

The first barrier to consider is economic, specifically the initial and continued cost of the vehicle and the necessary infrastructure to support that vehicle. The initial cost of an electric vehicle (EV) can be concerning for many potential consumers, in almost all cases. An EV usually has a greater initial cost than its non-EV competitors; one example being a Standard Tesla Model 3 ($35,000) compared to an Acura ILX Premium ($27,650) or a Honda Accord Hybrid ($25,320). These vehicles all have similar 0-60 mpH and passenger and trunk/frunk space. However, with reference to the continued cost of these vehicles after savings, the price for the Standard Tesla Model 3 decreases to $26,950 USD, whereas the other two vehicles remain the same. These savings stem from the inability for EVs to function on gasoline ($2.85/gallon), which becomes very expensive, along with a tax credit given to EV owners ($3750) (Shahan, Z., 2019). Using the previously referenced sources, the comparison between an Acura ILX to a Standard Model 3, clearly states that there are some key differences, the Acura has a 13.2 gallon fuel capacity which costs approximately $37.62 to fill and has a range of approximately 370 miles; whereas the Model 3 has a 75kWh battery capacity which costs $11.47 to fully charge at home resulting in a 310 mile range. Although these savings give an advantage to EVs, consumers find it difficult to get over the fact that the Tesla battery needs to be replaced after 300,000-500,000 miles for $3000-$7000 USD (Miley, J., 2019).

The infrastructure needed to support EVs is also a potential barrier in terms of economics as there are various costs and development concerns associated with it. For Tesla EVs, long distance trips require Tesla Superchargers, which are basically gas stations for EVs. These units are however much smaller and more often seen in parking lots of larger malls and plazas, they cost approximately $208 per unit, and charge the user around $0.26 per kWh. Additional infrastructure required to support EVs are power grids, which have the ability to store, transport and potentially generate electricity. These grids can potentially cost millions if not hundreds of millions of dollars. In an urban area like UTM in

Mississauga, power grid infrastructure is a matter of access costs, usually 12 cents per kWh (Jiang, J., 2011).

Social barriers also exist when dealing with the transition from fossil fuel burning vehicles to EVs, specifically the variety of vehicle options and the mindset of the consumer. The variety of vehicle options, when it comes to EVs, is currently lackluster, as there are many more fossil fuel burning vehicles compared to EVs. Although there is greater emphasis on the release of EVs, consumers are still limited by the supply and can feel as though they do not have a good enough option in the market, along with their accessibility to charging units along the road of prolonged trips. This also deals with the mindset of potential consumers, as they are comfortable in a certain way of purchasing vehicles, almost as though it is a tradition, perhaps within the family's generations. The purchasing of more developed vehicles like those with internal combustion engines, may give a sense of security both physically (i.e. safety/reliability on the road), and mentally (i.e. absence of negative judgement of friends and family).

The final dimension of barriers to consider for EVs is environmental, both the emissions and the increased demand from consumers. Heavy emphasis has been set on EVs to decrease the amount of greenhouse gas emissions (i.e. CO_2) from vehicles, however, consumers may feel misinformed by companies like Tesla, when coming to the understanding that the materials need to be manufactured, specifically the various parts of the EV, along with the lithium ion batteries, which are disposed of and harmful to the environment and the biodiversity reliant upon it. In addition, with a drastic change in lifestyle, like the transition from fossil fuel burning vehicles to EVs, there is an increase in demand in various aspects like the product itself (increased manufacturing and emissions), greater energy demand (increased electricity consumption), the maintenance of EVs, and the overall disposing of fossil fuel burning vehicles.

Many of these barriers exist within a broad range of larger urban regions, however, the University of Toronto Mississauga falls within that category, with close to 20,000 people (University of Toronto Mississauga, 2020), students, staff and faculty on campus; not to mention the surrounding urban setting UTM lies within, the city of Mississauga.

Different Types of Electric Vehicles

There are currently four different types of electric vehicles on the market; hybrid electric vehicles (HEV), plug-in hybrid electric vehicles (PHEV), battery electric vehicles (BEV) and fuel-cell electric vehicles (FCEV) (Canadian Automobile Association, n.d.). The common feature in all of these vehicle classes is that each utilizes an electric motor either partially or entirely to travel. Currently the UTM's current vehicles in their campus fleet can be classified as an internal combustion engine vehicle (ICEV) (Canadian Automobile Association, n.d.). A typical ICEV has only 20% efficiency, the remaining 80% is heat energy that is transmitted into the atmosphere, making them very inefficient (Pollution Probe et.al, 2018). Although they are inefficient and produce high amounts of pollution they are still utilized around the globe and at UTM.

HEV: Is a vehicle that utilizes a standard ICEV, a gasoline engine and fuel tank, with the combination of a propulsion system (Pollution Probe et.al., 2018). This propulsion system is an electric motor and battery. Both the engine and motor work simultaneously, it goes through cycles of an electric mode and gasoline mode, by generating electric energy from braking (Canadian Automobile

Association, n.d.). It can not be recharged using a standardized power grid like PHEV and BEV (Canadian Automobile Association, n.d.). This type of vehicle obtains modest reduction of emissions.

PHEV: This vehicle class is an HEV vehicle with the option to externally charge the battery (Pollution Probe et.al., 2018). They are able to travel 20 to 80 km in distance for their electric range, and can utilize petroleum if they require more distance (Canadian Automobile Association, n.d.)

BEV: Vehicles in this class contain only an electric motor and battery propulsion system (Canadian Automobile Association, n.d.). On a full charge BEV are able to travel 500 km in distance (Canadian Automobile Association, n.d.). Although they are high in initial cost, they have the most return in reducing carbon footprint and emissions, and have the longest vehicle life span.

FCEV: FCEV are vehicles that have an electric motor system that is powered by fuel cells and hydrogen gas. This vehicle is the newest electric vehicle to be placed on the market. Although experts say it is the best electric vehicle out there, there are only two fuel cell charging stations that are available in Canada, making it not sufficient for the purpose of being an electrified vehicle at UTM.

Based on the research it was determined the UTM's campus fleet should utilize a plug-in hybrid electric vehicle.

Different Charging Levels

Table 3 (Appendix) compares the three levels of charging stations on the basis of cost, charging time, power supply, etc. Electric vehicles are becoming increasingly popular as a sustainable alternative to gasoline engine vehicles. As this demand grows, the need for having equipment to charge electric vehicles and hybrid vehicles grows. There are three different levels of charging stations that can be used to charge electric vehicles. This includes level 1 charging station, level 2 charging station, and level 3 charging station. The university currently has three level 1 charging stations that can serve upto six vehicles. It allows for free charging upto four hours, after which it charges 5 CAD per hour. The three charging stations are located on the lower deck of the P8 parking that is near the Recreation, Athletic, Wellness & Fitness Centre (Eligh, 2019).

Level 1 Charging Station: A level 1 charger is best described as a regular plug outlet that would be available at any house and hence, does not require the installment of any additional equipment. The chargers use a 120 V AC plug and provide up to 8 kilometers of range per hour of charge (Energysage, n.d.). It can charge all types of electric vehicles. It takes upto 18 to 22 to charge the vehicles to its full capacity. A level 1 station is recommended for those who drive up to 45 to 65 kilometers a day, as it would only have to charge overnight to be charged sufficiently for the next day (Saxton, 2011). However, if the driver covers way more than 65 kilometers daily, it would require an eighteen hour charge, which would not be practical, making a regular gasoline car the better option. However, the level 1 charging method is the least expensive option of the three levels and since the campus fleet vehicles won't be covering more than 65 kilometers a day, it could suit the stakeholder's needs and be feasible to implement. The only disadvantage is that it takes the longest to charge (Saxton, 2011).

Level 2 Charging Station: The level 2 charger falls between the level 1 charger and a DC charger (level 3 charger). It has the potential to charge all types of electric vehicle up to a range of 30 kilometres for an hour of charge and takes around 8 hours to change the vehicles up to its full capacity (Sinek, 2019). The station charges the vehicle through a 240 Volt AC plug ("Levels of Charging," n.d.). The level 2 charging station is also safer than the level 1 charger, as it sends the electricity through the cord only once it is plugged in (Saxton, 2011). The only disadvantage is that it costs between 2000 to 4500 CAD for the purchase and installation (Argie, n.d.). But there are federal incentives, which will provide a rebate of 5,000 CAD if the vehicles cost below 45,000 CAD (Coxon, 2019). However, the prices can vary as they depend on the age of buildings, where the charger is being placed, etc. Hence, the price could also be lower or higher than that mentioned (Argie, n.d.). It is recommended that if a person covers more than 65 kilometers daily in their electric vehicle, they should install a level 2 charger, as it is capable of providing 60 kilometers of range in approximately two hours. (Saxton, 2011). The stakeholders should take into consideration the speed at which the vehicle can charge and consider the cost of the charger as a part of the vehicle's cost.

Level 3 Charging Station (DC): The level 3 charger, also known as DC fast charging, is the fastest mode of charging an electric vehicle. It is also the costliest, costing upto $100,000 USD or approximately 140,000 CAD per station (Saxton, 2011). They also require more power than an average person's house to operate. The station uses a 480 Volt DC plug to charge the vehicle ("Levels of Charging," n.d.). The charging station is supposed to provide 65 kilometers of range for every 10 minute and on a full charge, which takes upto 30 to 40 minutes, can provide upto 250 kilometers of range ("Levels of Charging," n.d.; Saxton, 2011). Although the DC charging method is extremely quick, the disadvantages of a high cost and high power requirements outweigh the advantages and wouldn't be very feasible or practical for University of Toronto Mississauga to implement, as their fleet won't be covering more than 65 kilometers a day. Another disadvantage is that currently only certain battery powered vehicles can use the level 3 charging station ("Types of Electric Vehicles," n.d.).

An important factor to note with the charging stations is that during the winter, the charging stations will take longer to charge the vehicles and at times, might also provide less range (Erwin, 2019).

To conclude we can say that UTM has three particular options to accept which are based on three situations. The situations are as follows:

1. If the stakeholders conclude that their vehicles won't be covering more than 65 kilometers a day and are fine with the overnight charge for daily use or 18 to 22 hours for a full charge, UTM can continue to add more level 1 charging stations.
2. The second case is, if the stakeholders conclude that their vehicles will be covering more than 65 kilometers a day or are unhappy with speed of the level 1 charger that are currently in use , they could opt to replace the current level 1 charging stations with level 2 charging station as the vehicles can get up to 30 kilometers of range in one hour and would also offer safer charging methods.
3. This third option is to have both level 1 and level 2 charging stations. This would be economical, practical and would provide the stakeholders with more options depending on situations.

Statement of Problem

The main goal of this project is to reduce or achieve zero carbon emission by implementing fuel vehicles into electrification, and to find out the feasibility of implementing the electrification of fleet vehicles in the University of Toronto Mississauga (UTM) campus. Electrify vehicles able to minimize Greenhouse gases (GHGs) emission, which can result in mitigating environment change. As UTM only produces 9% of GHGs emission compared to other two campuses, it is still a significant amount of emission produced, since the campus uses fleet vehicles regularly to clean up litter and to patrol that to keep the campus' safety. The outcome of this project will ultimately benefit UTM students, staffes, and faculty in the campus, but also neighbours who live around the campus as a whole. The end goal of the project is to achieve sustainable development and to improve the situation from the current status and to perform better. Thus, it is essential to have electrified vehicles on the campus that are able to cut down the current source of emission. Additionally the campus can have a decreased amount of expense on purchasing fossil fuel and maintenance. This compared to an electrical vehicle which can have an additional longer life span for the cost of purchasing it. To carry out the implementation will need to face challenges on economic aspects, like choosing the vehicle model, having the right level of charging station on campus, and managing the cost-benefit analysis.

Methods

In order to determine the feasibility of electrifying UTM's campus fleet vehicles preliminary, primary and external secondary sources were utilized. In order to obtain the data, answer to the following questions were needed:

1. Which campus fleet vehicle was used the most?
2. Which areas and infrastructures were being allocated for the new vehicles?
3. Which electric vehicles to introduce to the fleet?
4. What was the most efficient charging method to implement?

The following section will further break down the method utilized to gather all data for this report. A breakdown of each of the data methods can be seen in Figure 4 (Appendix).

Preliminary Data

The preliminary research method helped us form the base for the project and gave us direction for our primary and external secondary research. Information was gathered from our stakeholders with various departments; Sustainability Office (Chelsea Dalton), Grounds (Kris Horvath) and the Campus Police (Robert Messer) through emails. The data gathered from our stakeholders was used to develop a basic understanding about the campus electric vehicles, charging stations and space allocation. Once we gathered the results from the preliminary research, it was combined with the Cost benefit analysis results and was used to help recommend the charging stations and electric vehicles that UTM could implement.

Limitations to this particular method did exist. All communication took place over email, there were instances where there were delays in meeting certain deadlines, as at times, it would take several days to get a reply from the stakeholders, and at times faced a problem with miscommunication.

However, this technique can be justified, as its advantages outweigh its disadvantages. Communicating over emails allowed the group to save time and due to this, there was no additional difficulty in finding a time that worked with stakeholders and group members to meet and discuss face-to-face. Though we faced difficulties with delays in getting responses, we managed to meet every deadline. We were also able to fix the problem of miscommunication by ensuring that all the emails were clear and simple to understand.

Primary Data

The primary data was used to gather information about the campus fleet vehicles like the models of the vehicles, the year they were purchased and the number of vehicles in the fleet, etc. It was gathered from the UTM campus by visiting the grounds team. The primary data allowed us to understand the status of the campus fleet and identify key components of the project, such as which vehicles were still in use.

The primary data method did have its limitations. The process of gathering information about the model, year of purchase, etc, was time consuming. We used the method, since this method allowed us to have complete control over the data and its accuracy, in order to ensure the cost-benefit analysis was correct.

External Secondary Data Sources

External secondary data was used to collect information on the charging stations, electric vehicles, barriers to electrification as well as others. To be more specific, we used both research reports, such as case studies, scholarly articles and unpublished data, such as articles from automotive websites, for our project. A variety of different search engines and tools were used to find the necessary information.

In order to understand the feasibility of electrifying the campus fleet we used the gathered data to analyse two of the project's key components; the electric vehicle that would replace the campus fleet vehicles ; and the charging station level that would be the most suitable. Analysis of each of the two key components areas was based on practicality, costs and most importantly, on emission reduction.

Once the data was gathered and analysed, it was used to evaluate the different electric vehicles and charging stations, which helped the team to shortlist our options and ultimately come to a decision. The results were used to recommend the stakeholders the electric vehicles they could include in the campus fleet and the charging station that would be suitable for the electric fleet.

Limitations with this particular method existed as well. Since the concept of electric vehicles is relatively new as compared to gasoline engine vehicles, we did not have sufficient amounts of data to work with. Another problem we faced, particularly with the charging stations, was that the websites provided different values for the amount of range provided per hour by the level 1 charging station.

We stood by this method of research, as its advantages outweigh its disadvantages. Using secondary data was time efficient, as we did not have to put in any time or effort in the preparation of a survey, as the group solely relied on the internet for information. This method also eliminated the chance of any error that would have arisen while recording primary data. In addition, certain limitations that were previously mentioned were relatively easy to rectify, for example, with the level 1 charging station, we decided to display the values as a range, so that it would give an overview rather than just focusing on one particular number.

Data Report

Cost-benefit Analysis

Table 1 (Appendix) indicates the cost-benefit analysis of all UTM's Campus Fleet Vehicles. UTM grounds campus fleet consists of nine main vehicle and equipment types, with several different trucks, small utility vehicles, golf carts, Toolcat work vehicles, front end wheel loaders, large sidewalk plows, small sidewalk plows, large turf tractors, and ride-on mowers. Majority of UTM's equipment was purchased around 2015, with few purchases occuring in recent years. UTM bought three vehicles in 2000, none of which are currently in active use, two of them being small zero turn mowers.

The least expensive of these vehicles were the golf carts, which range in price from $2,500 to $5,000. The most expensive vehicle on the fleet is the large loader of front end wheel loaders, which is worth around $1 million. *Truck 7 Chevy 3500HD Pickup Diesel* and *Truck 3 GMC C6500 3 ton Dump truck diesel* have the highest and lowest price in the trucks section with around $31,000 and $24,000 respectively. Five small utility vehicles are having the same price of $22,000. Toolcat work vehicles that purchased from $30,000 to $50,000 cost approximately ten times as much as golf carts. The cost of large sidewalk plows(around $28,000) is on average $12,000 higher than that of small sidewalk plows. The unique large turf tractor costs $34,200. The price of ride-on mowers has the largest fluctuation, which varies from $2,000 to $20,000 depending on the size of the equipment.

According to the investigated information in the table, the *Cat 908* of front end wheel loaders has the largest fuel tank capacity which is 78L. The toolcat work vehicles and large sidewalk plows have 75.7L capacity. The ride-on mowers have a relatively smaller capacity than that of previous equipment to contain the fuel, with the smallest 10.6L in *Vacuum Mower 1&2 - Walker*. The larger tank capacity by definition could contain more fuel. The carbon emission of *Cat 908* is around 400 grams per mile. However, trucks emit the most amount of carbon among all UTM grounds vehicles and equipment, which average to 500 grams per mile. The lowest level of carbon emission due to the smallest fuel tank capacity which indicates *Vacuum Mower 1&2 - Walker* emits around 44 grams per mile.

Table 2 (Appendix) indicates the cost-benefit analysis of UTM's campus police vehicles. The UTM campus police has a total of four fleet vehicles. These are all campus police vehicles, and they all have the same 2016 Ford Explorer model. They cost roughly $46,799 each, but can range anywhere from $33,999 to $59,599, making it relatively expensive in comparison to other fleet vehicles on campus. This is best compared to fleet trucks on campus, since both are street vehicles that can be purchased by the general public. However, the Ford Explorer has an edge when it comes to greenhouse gas emissions. The carbon emission by grams per mile for these campus police vehicles is 410g/mile, which is comparatively high when comparing it to the rest of the campus fleet vehicles, but relatively low to moderate when comparing fuel tank capacities. The 2016 Ford Explorer has a fuel tank capacity of 70.4L, which is respectively high in comparison to the rest of the fleet vehicles on campus. This makes it an environmentally efficient vehicle relative to its large fuel tank capacity, however economically inefficient.

Map of Potential Charging Stations

Figure 3 (Appendix) outlines a map of the UTM campus with clear labels indicating where new charging stations should be located. Referring to the section about *Different Charging Levels*, UTM currently has three level 1 charging stations all located in the lower level of the P8 parking lot. This allows for up to 6 vehicles to charge at a time. Level 1 charging stations can take 18 to 22 hours for a full charge, however at the P8 parking lot drivers can charge their vehicles for up to 4 hours with no cost. After the 4 hours period, there is a fee of 5$ per hour. Evidently, these level 1 stations are put in place to provide a temporary charge, not a full one.

With this in mind, as well as the cost of level 2 charging stations, it would make sense to place another level 1 charging station in the P9 parking lot. Both P8 and P9 parking lots are very busy, and are almost fully occupied during busy hours. Also, the P9 parking lot is located far enough from P8. For these reasons, it would make a lot of sense to place another three level 1 charging stations in the P8 parking lot. Both P8 and P9 charging stations would be for temporary charging.

Lastly, we recommend the addition of level 1 charging stations in the P5 parking lot. The reason for this is again location, but more so because it is residential parking. Many University of Toronto Mississauga residents park their vehicles at the P5 parking lot. Level 1 charging stations make the most sense here. Since this is primarily for residents, these vehicles can be left overnight in the charging stations, allowing for a full vehicle charge. In the P5 parking lot, we would recommend three to six level 1 charging stations, half for full overnight charging, and half for temporary charging as is in the P8 and P9 parking lots.

Data Analysis

Recommendation and Conclusion

With reference to the various findings within the completed research, a final recommendation concerning the feasibility of the electrification of the University of Toronto's Campus fleet vehicles can be offered.

It was determined that it is feasible to electrify UTM's campus fleet vehicles. This recommendation is specifically based on the findings such as the fact that nine different types of vehicles within the fleet, ranging from campus police vehicles to lawn mowers, were purchased at least 5 years ago in 2015, including some which were purchased 20 years ago in 2000. These older vehicles, like the small zero turn riding mowers and the Chevy HD 4x4 pick up truck purchased in 2002 are no longer actively in use and have potentially higher service/repair costs. This makes it more feasible to purchase a newer vehicle in replacement of these old and deteriorated models.

The vehicles purchased in 2000 were deemed unusable during the cost-benefit analysis (Table 1 in Appendix). As they are unusable it was determined that it would be beneficial to also electrify them first so they are able to be placed back into service as working vehicles and part of UTM's active campus fleet. The three riding lawn mowers purchased in 2000 can be replaced with the RYOBI 38-inch 48V Electric Riding Lawn Mower. This vehicle is currently priced at $4,098. The Chevy HD 4x4 pick up truck purchased in 2002 can eventually be replaced with the upcoming 2020 Ford F-150 pickup truck which is capable of " ...towing a million pounds of train cars." (Brzozowski, 2019).

In addition, with the determination of the most used vehicle at the UTM campus, the UTM's campus police cursor, it is important to consider a viable alternative for them, specifically a similar plug in electric hybrid vehicle (PHEV). With reference to the *Different Types of Electric Vehicles* section under *Background Information*, it was determined that PHEVs were the most suitable alternative for the extensively used police vehicles since they are compatible with certain charging stations currently present on campus, refer to the charging location map; they can also manage the required distances travelled by campus police vehicles at UTM, at up to 80 km with extra fuel reserves for longer trips if needed. Not only do these vehicles offer a practical use at UTM, they also allow for the three different dimensions of sustainability to be met, economic, social and environmental. The current cost for a 2020 Ford Explorer PHEV starts at $45,199 (Figure 2 in Appendix) (Ford, 2020) compared to the cost of UTM's current police vehicle, a Ford Explorer at ~$46,799, refer to Table 2., with additional savings, both short and long term, refer to the *Barriers to Electrification* section, the PHEV 2020 Explorer offers a greater return on investment as grants will be provided by the Government along with other savings like on gas. The same make and model of vehicle will allow for fleet vehicle users to expect similarities in terms of comfort and reliable performance, not to mention the major decrease in emissions, specifically less than a quarter of current CO_2 emissions per mile of the ICEV Explorer at 410 grams of CO_2 per mile.

This information collected allows for a priority to be set on the transition of the most used fleet vehicle, the police vehicles, in terms of ICEV to PHEV. Based on the change, UTM will be able to make further decisions concerning whether or not the remainder of the fleet should be changed to electric vehicles. These decisions will be made based on the positive aspects found throughout this project along with the benefits gained within all three dimensions of sustainability through the use of the PHEV 2020 Ford Explorer.

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Appendix

Table 1. The below table indicates the cost-benefit analysis of all UTM's Grounds Fleet Vehicles. The highlighted columns in red column shows the vehicles that are no longer in use, the blue column indicates the new purchases of the vehicles and the yellow highlighted column demonstrates the vehicles that are seldom used. An analysis of findings can be found in the above Data Report section found on page 16.

UTM Grounds Vehicles and Equipment	Unit	Cost (CAD)	Life-span (year purchased)	Fuel tank capacity (L)	Carbon emission (grams per mile)
Trucks	Truck 1 Chevy H.D. 4x4 Pickup diesel	N.A.	2002	N.A.	N.A.
	Truck 2 Chevy Silverado Pickup unleaded	~ $24,795	2009	N.A.	450 - 555
	Truck 3 GMC C6500 3 ton Dump truck diesel	~ $24,000	2009	N.A.	444 - 494
	Truck 4 Chevy 3500 HD pickup diesel	~$26,795	2012	N.A.	423 - 575
	Truck 5 Chevrolet Silverado 3500HD crew cab pickup unleaded	~ $26,000	2015	N.A.	447 - 537
	Truck 6 Chevy 3500 Pickup diesel	~ $29,700	2016	N.A.	447 - 537
	Truck 7 Chevy 3500HD Pickup diesel	~ $31,100	2018	N.A.	447 - 523
Small Utility Vehicles	RTV 1	~ $22,000	2010	30	~ 138
	RTV 2	~ $22,000	2013	30	~ 138
	RTV 3	~ $22,000	2014	30	~ 138
	RTV 4	~ $22,000	2015	30	~ 138
	RTV 5	~ $22,000	2019	30	~ 138
Golf Carts	Golf Cart 1 Club Car	$2,500 - $5,000	bought used 2011	19	87 - 102
	Golf Cart 2-7 Club Car	$2,500 - $5,000	bought used 2015	19	87 - 102
Toolcat Work Vehicles	Bobcat Toolcat work vehicle 1	$30,000 - $50,000	2011	75.7	348 - 417
	Bobcat Toolcat work	$30,000 -	2013	75.7	348 - 417

	vehicle 2	$50,000			
	Bobcat Toolcat work vehicle 3(New 2020)	$30,000 - $50,000	2020	75.7	348 - 417
Front end wheel loaders	Cat 908 (Large loader)	$800,000 - $1 million	2011	78	358 - 430
	Bobcat S590 (small skid steer)	$130,000 - $180,000	2016	30.3	~ 140
Large Sidewalk Plows	1 B3030 Kubota	$23,600 - $29,000	2010	75.7	348 - 417
	2 B2650 Kubota	$21,900	2015	75.7	348 - 417
	3 B3350 Kubota	$28,000 - $38,000	expect Jan 2019	75.7	348 - 417
Small Sidewalk Plows	1 F3560 Kubota	~ $13,488	2009	31	~140
	2 F2690 Kubota	~ $15,905	2015	31	~ 140
	3 F2690 Kubota	~ $13,917	2016	31	~ 140
Large Turf Tractor	M5700 Kubota	~ $34,200	2000	65.1	298 - 358
Ride On Mowers	Large Area Mower -Jacobson 951	~ $2,799	2014	43.5	199 - 240
	Vacuum Mower 1 - Walker	~ $8,000	2011	10.6	48 - 58
	Vacuum Mower 2 - Walker	~ $9,276	2015	10.6	48 - 58
	Large Zero Turn Mower 1 - Kubota	~ $20,586	2011	45	~ 230
	Small Zero Turn Mower 1 - Kubota	~ $4,722	2015	25.7	~ 131
	Small Zero Turn Mower 2 - Ryan Bobcat	N.A.	2000	N.A.	N.A.
	Small Zero Turn Mower 3 - Ryan Bobcat	N.A.	2000	N.A.	N.A.

Table 2. The below table indicates the cost-benefit analysis for the UTM's Campus Police Fleet Vehicles. An analysis of findings can be found in the above Data Report section found on page 16.

UTM Campus Police Vehicle	Unit	Cost (CAD)	Life-span (year purchased)	Fuel tank capacity (L)	Carbon emission (grams per mile)
UTM Campus Police Cruiser	SUV 1 Ford Explorer	~$46,799	2016	70.4	410
	SUV 2 Ford Explorer	~$46,799	2016	70.4	410
	SUV 3 Ford Explorer	~$46,799	2016	70.4	410
	SUV 4 Ford Explorer	~$46,799	2016	70.4	410

Table 3: The table is a comparison of the three different levels of charging stations. It compares the three levels of charging stations on the basis of cost, charging time, power supply, etc.

	Level 1 charging station	Level 2 charging station	Level 3 charging station
Cost	0 CAD	2,000-4,500 CAD	140,000 CAD
Power supply	120 V	240 v	480 V
Current type	AC	AC	DC
Range per hour of charge	8 km	30 km	Approximately 380 km
Total charging time	18-22 hours	8 hours	30-40 minutes
Type of EVs supported	All EVs	All EVs	Only BEVs
Requirement for charging	Standard Electric outlet	240 V electric outlet	A fixed charging station

Source of Data: ("Levels of Charging," n.d.; Argie, n.d.; Saxton, 2011; Voelcker, 2017; "Types of electric vehicles," n.d.)

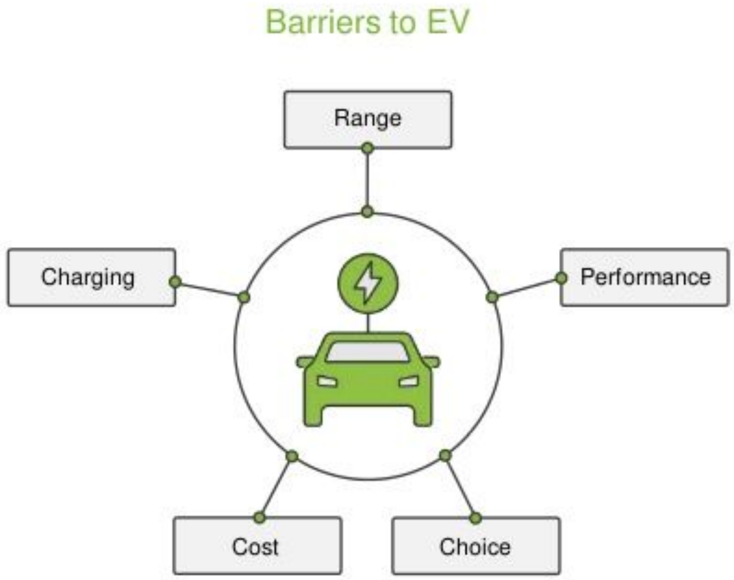

Figure 1. The diagram above highlights the various obstacles within the decision making process of consumers when considering the purchase of an electric vehicle.

Figure 2. The image above showcases the recommended PHEV, the 2020 Ford Explorer, to replace the current Police ICEVs.

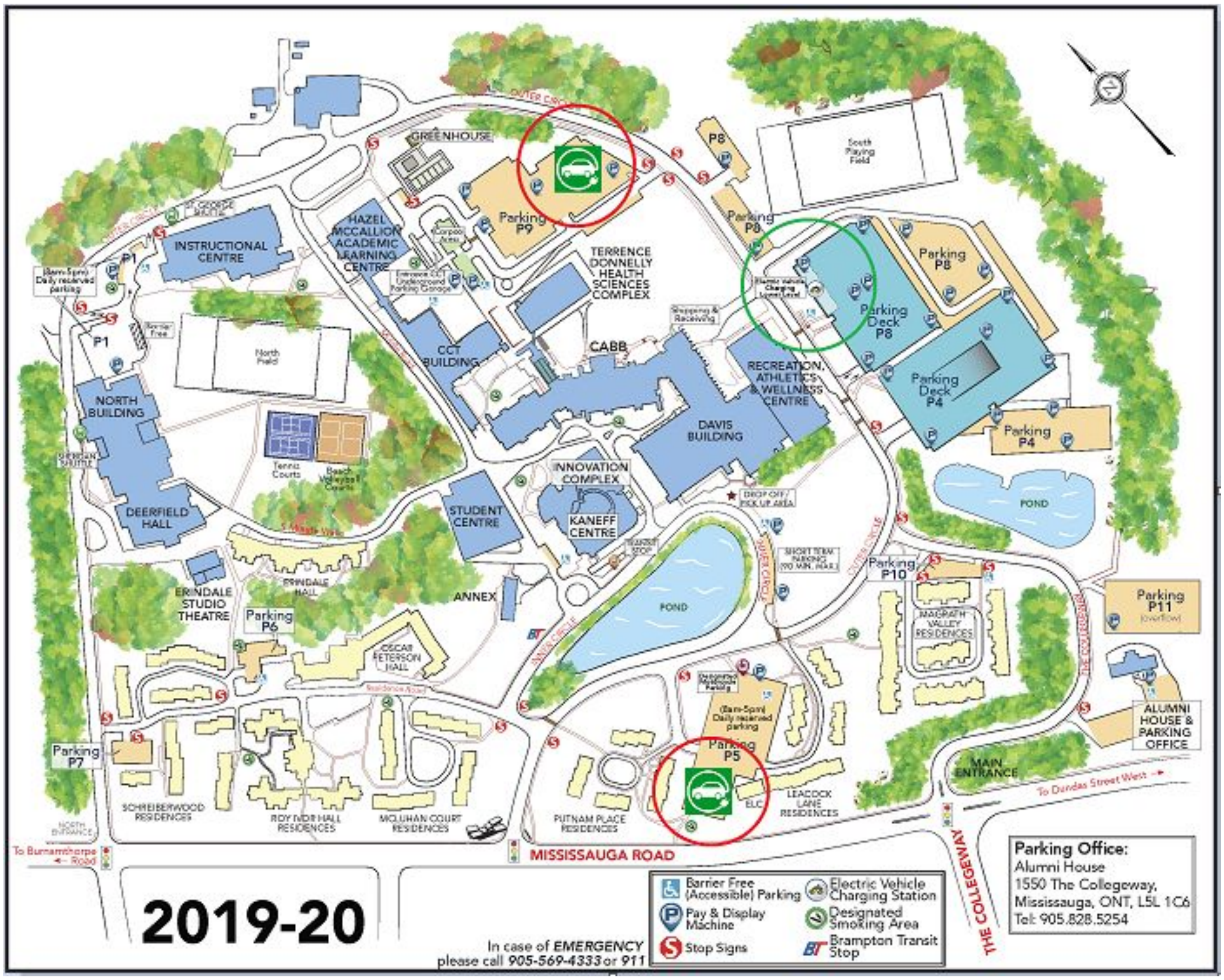

Figure 3. Shows a map of potential charging stations across the UTM campus. The green circle indicates existing electric vehicle charging stations. The red circles indicate recommended areas to implement new electric vehicle charging stations.

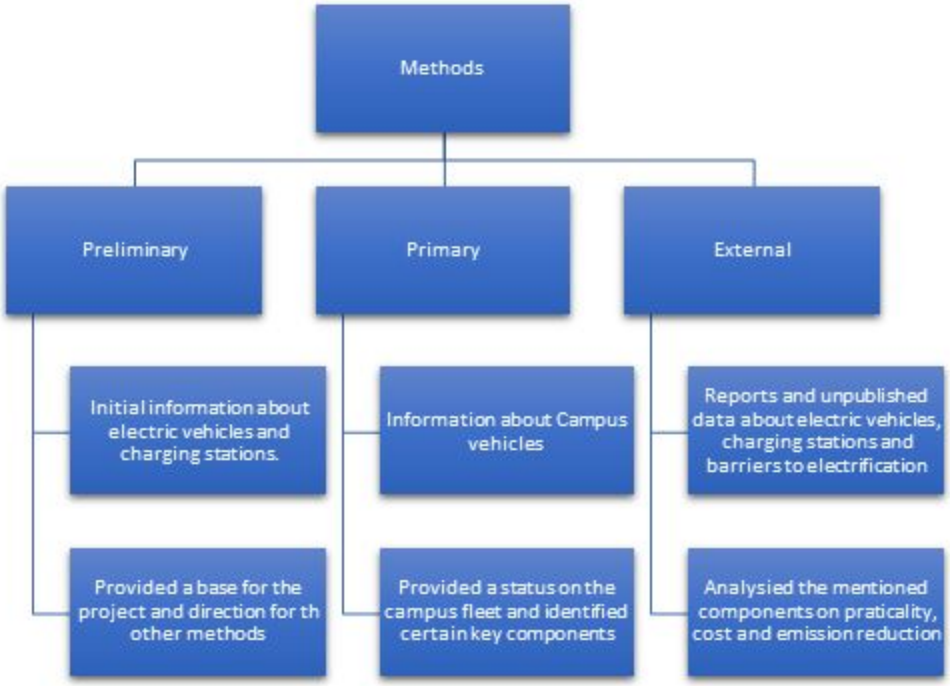

Figure 4. Highlights the components of each data method for the methodology