UBC Fleet Management Department: Developing Strategies to Meet and Exceed Emission Goals

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COMM 486M

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GREEN FLEET CONSULTING

A STRATEGY FOR UBC FLEET MANAGEMENT

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EXECUTIVE SUMMARY

ABOUT THE CLIENT

UBC ‘s Fleet Management Department manages two-thirds of UBC’s vehicles. They procure, maintain, and manage their inventory of assets while optimizing costs through established connections with suppliers. One of UBC Fleet Management’s highest priorities is to minimize GHB emissions and in 2014 they received the E3 (Energy, Emissions, and Excellence) Fleet Platinum Ranking. However, the Fleet Management department needs to continue to improve to hit their 2020 goal of a 67% reduction of emissions and a 100% reduction by 2050.

With their “Project Pegasus”, UBC Fleet Management took several steps towards hitting its emission goals. This project put in place several successful polices including; rightsizing, standardizing the feet, alternative fuels, and a fuel-efficient driving policy. Our recommendations will build upon the Pegasus Project instead of trying to radically change it. We believe that UBC Fleet Management is already very strong with their management of fuel emissions but we have identified several areas where they can still improve.

ANALYSIS

Before developing our strategy, we did an analysis on the Fleet Management department’s current position and the surrounding macro environment. We evaluated the strengths of UBC Fleet Management and listed some of the opportunities that the department could take advantage of. We found that car share technologies are not a viable option because they are too high of a cost to operate when compared to owning or leasing a vehicle and they do not fit the operational requirements of UBC. We also identified and evaluated several emission reduction technologies that are available.

THE STRATEGY

Green Fleet Consulting has developed a short and long term strategy that we believe will allow the Fleet Management Department to meet and exceed these emission goals while simultaneously reducing fuel costs. Since Fleet Management has a set budget any recommendation we considered needed to be cost neutral meaning the initial cost needed to be completely offset by the reduction in fuel costs. We are recommending two pieces of technologies to adopt in the short term and a switch to a fully electric fleet in the long term.

The first piece of technology is direct fired heaters which is an example of anti-idling technology. The direct fired heaters keep the cabin of the vehicle warm without using the engine of the vehicle. This dramatically reduces fuel costs and would be most effective when installed on large vehicles like garbage trucks. The second technology is electrically assisted diesel particulate filters. This technology uses electricity rather than fuel to filter fuel in diesel vehicles. While this piece of technology has not yet come to market, it could dramatically reduce emissions and would be effective on any diesel vehicle.

We identified several case studies which corroborate our findings and lead us to believe that our technologies would be very effective if implemented. We also performed financial analysis to show how this change could be done on a cost neutral basis, and an environmental analysis to see what our tactics could do to reduce emissions. We also looked at some vehicles that might be better options for each vehicle category.

Keeping in mind the need to make changes on a cost neutral basis, we developed a decision-making process that will identify when electric vehicle technology has advanced to the point where electric vehicles can meet the operational requirements of UBC, and when the reduction of fuel costs offset the higher initial price compared to a traditional gasoline vehicle. We tested this decision-making process on a new electric van that will be introduced to North America and determined that this van does not meet our decision-making criteria.

IMPLEMENTATION

We provided a timeline to show how and when our recommendations could be implemented and we based our timeline around the two future emission goals. We understand that any strategy is not without risks, so we have identified several possible risks and show how the Fleet Management department could mitigate these potential pitfalls. Finally, we have identified several financial and environmental metrics that should be monitored to determine the success of our strategy.

Ultimately, we believe that our recommendations will make a meaningful impact on UBC Fleet Management’s emission footprint, and the success of our initiatives will allow UBC Fleet Management to hit its ambitious future goals.

UBC Fleet Management

Green Fleet Consultation

COMM 486M Section 201 – Team 7

UBC SAUDER SCHOOL OF BUSINESS

Lucky Number 7 Consulting Team

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Focus: Business Environment, Electric Vehicles, Risk Analysis

Arman Mazhari
Focus: Strategy, Tech Tactics, Implementation Plan

Steven Petterson
Focus: Key Issues, Financial and Environmental Analysis

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Focus: Business Environment, Vehicle Replacement, Success Metrics

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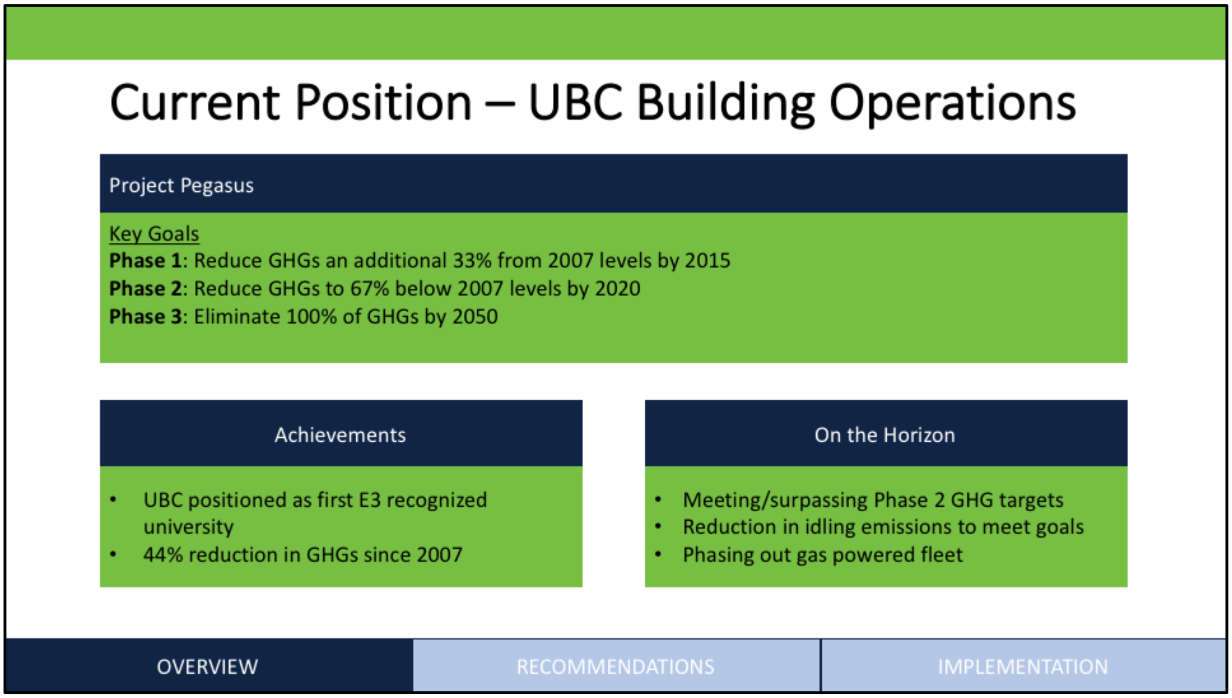
Focus: Business Environment, Tech Tactics

Our team has been tasked with the mission of improving UBC's vehicle fleet efficiency from a financial, social, and environmental perspective. Throughout this presentation, you will learn of the many ways our research of the current situation, key issues, and potential solutions has indicated how this is possible. The goal of this project is to set up a framework of evaluation criteria for UBC to use in the future when considering different options to increase fleet efficiency. We have included strategic and tactical recommendations of our own to give these findings a more practical direction. Alongside our recommendations, we have conducted financial feasibility and environmental impact analyses, along with risk considerations, success metrics, and an implementation schedule to make this plan comprehensive. We hope you find value in our work and look forward to hearing back from you.



Since former UBC President Stephen Toope announced the school's aggressive Climate Action Plan targets of 2010, many steps have been taken to increase the efficiency of the campus vehicle fleet. Since the announcement, GHG emissions are down an estimated 44% on 2007 figures - 11% further than targeted. Also since the 2010 announcement, 125 fleet vehicles have been replaced with more efficient counterparts.

UBC is the only university campus with E3 (energy, environment, excellence) status, earned through meeting the high standards of E3s fleet review and fleet rating process.

UBC is on its way to becoming a world leader in vehicle fleet operational efficiency and is actively surpassing target goals. However, with diminishing marginal GHG emission reductions (13%, 8%, 6% reduction changes for 2014, 2015, 2016 figures respectively), it appears unlikely UBC can achieve its Phase 2 goals of a 67% decrease on 2007 GHG emission figures in the next 3 years (by 2020) without implementing exploratory pilot tactics. Further, in order to eliminate 100% of GHGs UBC must shift its focus to a complete overhaul of its fleet over the next 30 years.

Targets

Emission Goals (using 2007 emissions of 833 tCO2e as baseline)

- 33% by 2015 (target = 558 tCO2e) ✓
- 67% by 2020 (target = 275 tCO2e)
- 100% by 2050

Fleet goals by 2016

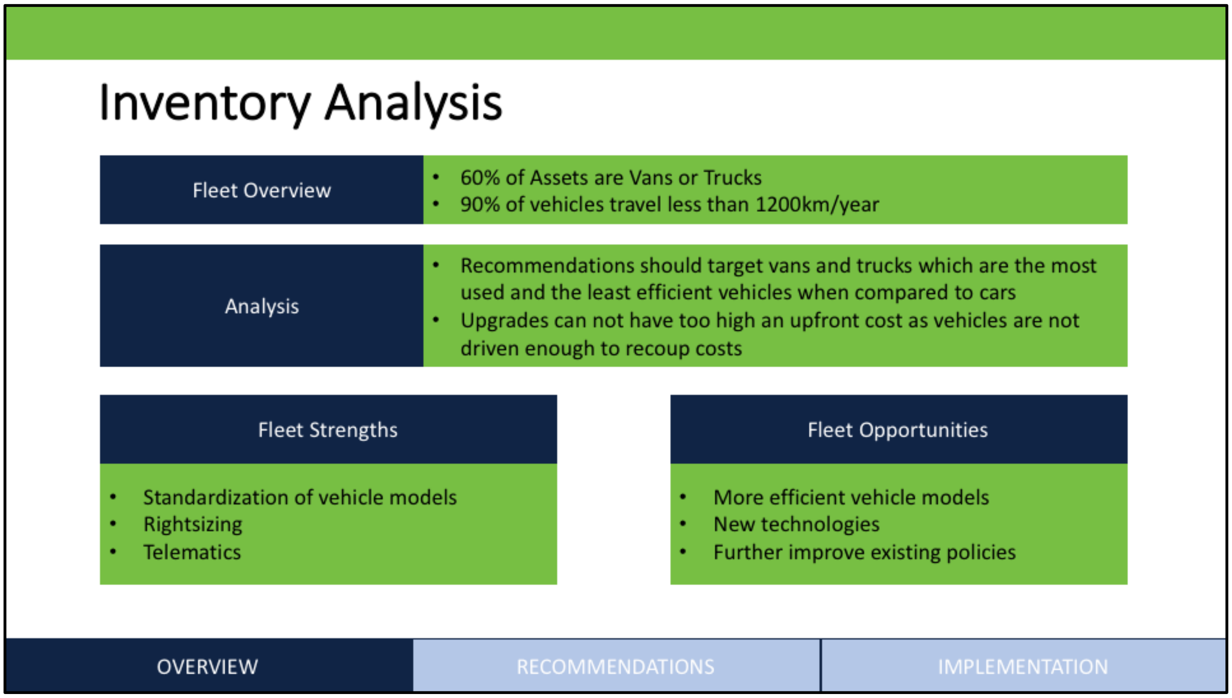
- 20% of the fleet electric ✓
- 80% of the fleet replaced ✓
- Average age of fleet < nine years ✓

Idling (Using 38 tCO2e per annum as baseline)

- 25% reduction by 2014
- 50% reduction by 2015
- 75% reduction by 2020
- 100% reduction by 2025

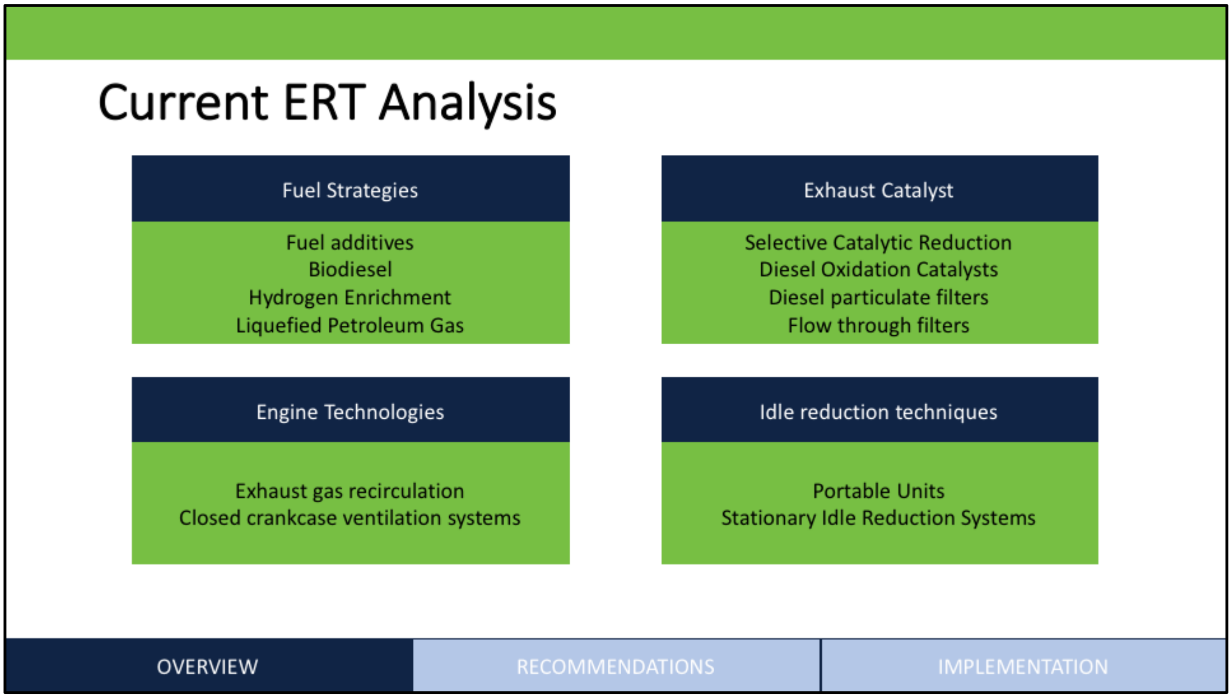
It is interesting to note that 690 tonnes of GHG emissions were recorded in 2012. In the same year, the idling baseline estimate was 43 tonnes of GHG emissions.

43t/690t = **6.2% of total GHG emissions were a result of idling in 2012.**



After an analysis of UBC Fleet's inventory we noticed a couple of key pieces of data that guided our analysis. The first being that the clear majority of assets are large vehicles like vans or trucks. These vehicles tend to be less fuel efficient then cars, and have less electric alternatives available. Another thing to note about the inventory is that over 90% of assets travel less than 1200 Km's a month. We are not going to recommend something that has a very large upfront cost because these vehicles aren't driven enough to recoup that cost, even if the cost of operation is dramatically reduced.

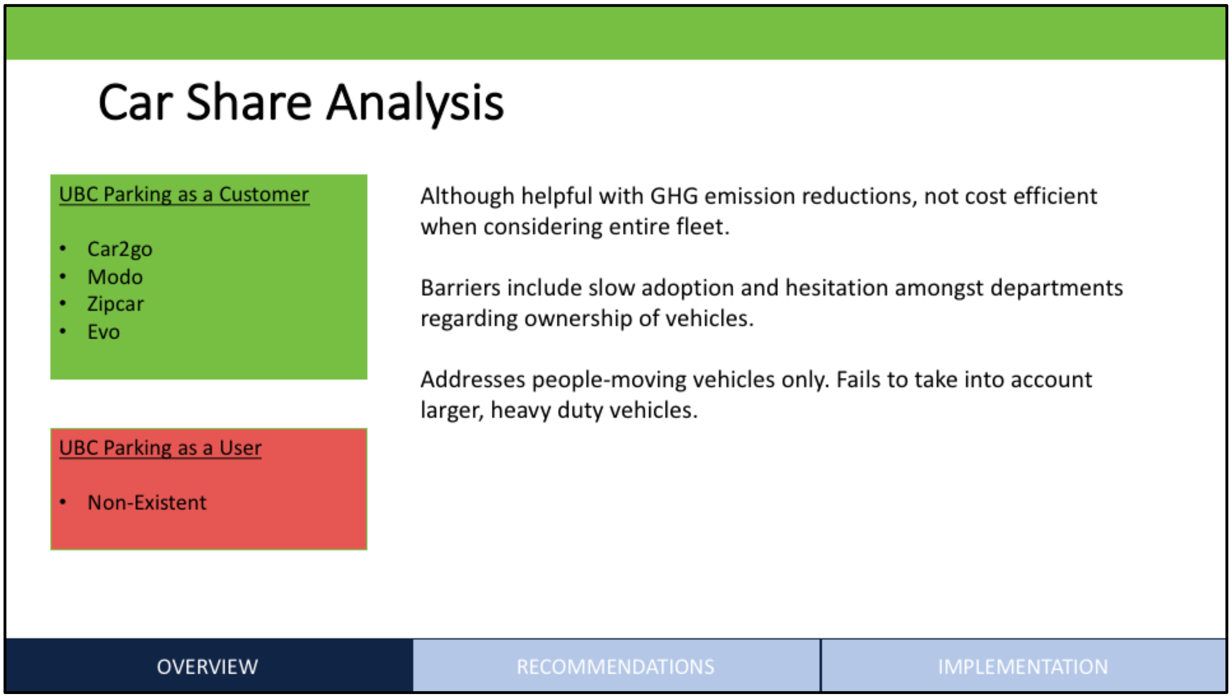
We noticed a few polices that we really like and we aren't going to change. To start, we want to keep a standard model for each vehicle category. This reduces the cost of repairs and maintenance because the mechanics only need to have parts for those few models. UBC also has a rightsizing policy which is also something that makes the fleet more efficient. It's important to have the right vehicle for the job so you don't have too many vehicles that you don't need or use a large vehicle when a smaller, more fuel-efficient vehicle would suffice. Telematics are a technology that UBC should continue to invest in. They allow data collection to further improve existing polices and guide new ones.



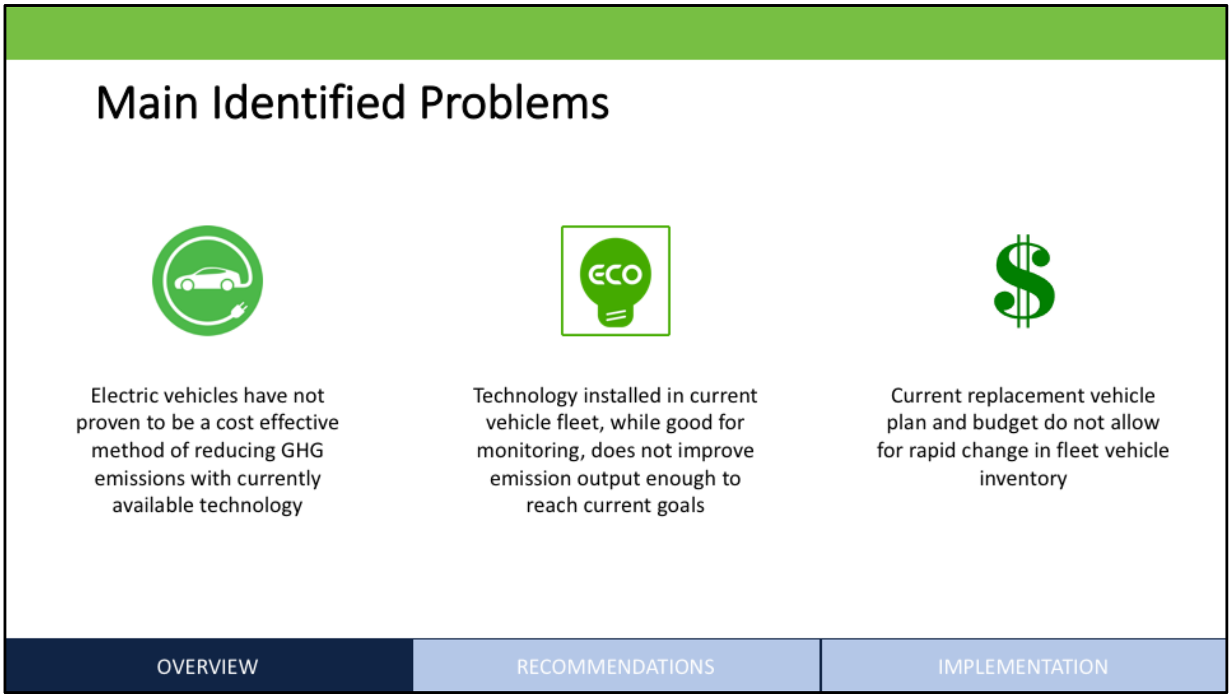
With regards to evaluating new technologies, we factored in all possible and popular ERT technologies currently being used in the industry. The table depicts all current ERT technologies as highlighted in the Transportation Research Record Journal by academics Dr. Mohamadreza Farzaneh, Gokhan Memisoglu, and Kiavash Kianfar. As seen above, there are 4 main technology categories. Having extensively analyzed our primary and secondary research data, we have focused our efforts and chosen two main categories which would help achieve our goals. These are Exhaust Catalysts and Idle Reduction technologies. We believe both these categories are a strategic fit for the company and satisfy our decision criteria, which is fundamentally rooted in achieving our target of creating a significantly more efficient and cost effective fleet of vehicles, while simultaneously dramatically reducing fleet vehicle greenhouse gas emissions.

The reason why we have not chosen engine technologies and fuel strategies are two fold; the setup costs are high as the technology itself is difficult to install as it requires either "rebuilding", "repowering" or "replacing". In addition, there is not enough data to suggest that these two technology categories are effective in reducing GHG emissions. For instance, EGR's may increase PM, HC and CO emissions and biodiesel can increase NOx emissions according to the Transportation Research Record Journal.

With regards to the two categories we have chosen, both clearly satisfy our decision criteria. The data indicates that there are significant fuel savings, a measurable impact of the reduction of GHG emissions and both technologies are easy to implement in all current and future vehicles. Our priority was that there would be a short payback period and that the technology can be easily retrofitted. Thus we recommend implementing the anti idling technology of Direct Fired Heater in 85% of the diesel vehicles by 2020 and Electrically Assisted Diesel Particulate Filters in 85% of the diesel cars by 2030 (assuming technology becomes available).



Currently, we see that UBC has formed a partnership with car-sharing companies like car2go, Modo, Zipcar, and Evo. These companies specialize mostly in everyday use, people-moving vehicles. Models include Smart fortwo, Mercedes Benz CLA/GLA, Toyota Prius Hybrid, etc. Although research has shown great promise for car-sharing in terms of GHG emission reductions, there are various barriers that lead us to believe that car-sharing will not be a prominent part of UBC's plan towards eliminating 100% of GHGs by 2050. With the current landscape of UBC Parking & car-sharing companies, this solution only addresses a portion of the campus' vehicle fleet. As a majority of the fleet and the fleets overall GHG emissions larger vehicles such as vans, trucks, and other municipal heavy-duty vehicles, it is not fully tackling the issue at hand. Additionally, when considering the opinions and adoption of users, another large barrier within this fleet option is the hesitation amongst different departments regarding ownership and sharing of vehicles.



Electric Vehicles

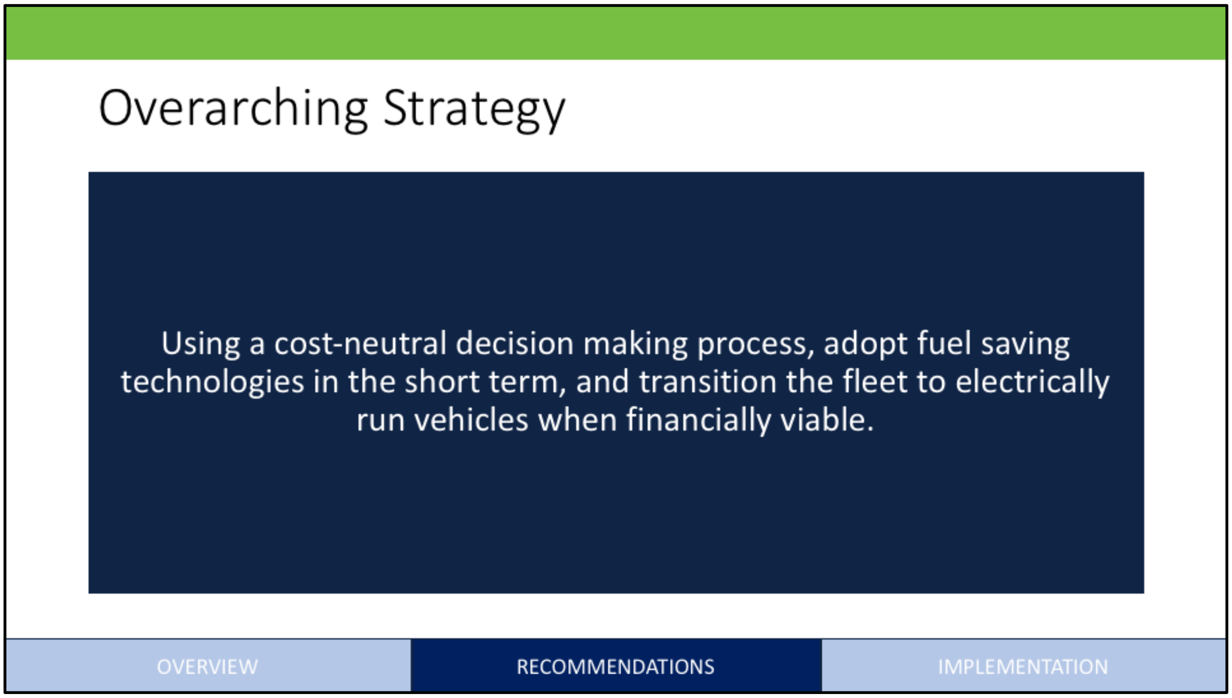
As of today, electric vehicles – unless fully utilized – represent a cost-negative approach to reducing GHG emissions as part of an organization's green fleet plan. While it may appear to be the trendy option currently, many other Green Fleet plans have found that the purchase or leasing of electric vehicles has not improved their GHG emissions effectively relative to the necessary costs of infrastructure and the vehicles themselves:

City of Toronto Consolidated Green Fleet Plan 2014-2018: "Most of the plug-in hybrid electric vehicles (PHEV) and battery electric vehicles (BEV) that have been added at Centrally-Managed Fleet would require higher utilization than they have had, in order to reach their potential for reducing fuel consumption and lowering the total cost of vehicle ownership. In real-world conditions, particularly in a climate with extreme temperatures, adequate range in BEVs is an impediment to high utilization that needs to be managed"

City of Seattle Green Fleet Plan 2014: "In order to expand our EV fleet, we need to strategically establish a comprehensive charging infrastructure network. Some of the current challenges to doing so include funding the initial capital installation cost, lack of electrical capacity in buildings and establishing the roles and responsibilities of planning, acquisition, ownership and maintenance between FAS, Facility Operations, City departments and Capital Development"

Current Technology

Currently, the vast majority of UBC Building Operation's fleet only use telematic reporting and monitoring. Hybrid vehicles have idle-stop technology and all vehicles have Geomatics installed for monitoring purposes. While this array of technology is certainly helpful in identifying issue areas we believe these alone will not allow UBC Building Operations to reach their 2020 emission reduction targets.



UBC is a world class institution that is well on its way to becoming a leader in green campus operations. Over the last 7 years, it has set and achieved its GHG emission and fleet efficiency goals through continually renewing its fleet along with adopting effective technologies (such as Geotab) to increase fleet information and efficiency. We believe this to be a sound strategic vision moving forward, however at the current rate UBC is facing diminishing marginal emission reduction returns and we only expect these to continue this trend. We believe aggressively pursuing a new set of audacious, specific goals to be an effective way UBC can rekindle the Pegasus Project and see significant GHG reductions in the future. Our vision is simple:

Project Pegasus Goal: create a significantly more efficient and cost effective fleet of vehicles, while simultaneously dramatically reducing fleet GHG emissions.

Our Strategy: Continue to proactively integrate the best available technologies wherever financially viable.

Idling at UBC

36,611 litres wasted

- Least fuel efficient units – waste management, hard landscape, soft landscape
- 85% energy is wasted
- Anti-idling technology reduces fuel use by 80%

OVERVIEW | RECOMMENDATIONS | IMPLEMENTATION

In the Pegasus 5.0 report, it states that “idling wastes 35,611L of fuel each year for forty three tons of GHG emissions”. Therefore, it is imperative to reduce idling by modifying driver behavior and enforcing anti idling policy. However, these solutions work best when policies and behavior based approaches have the correct anti idling technology to complement it.

Drivers tend to keep their vehicles idle to either keep the heating on to defrost their windshields, keep the engine warm, for driver comfort and to provide electrical power to truck mounted equipment. Our client, the Fleet Manager at UBC, has stated that “Waste Management, Hard Landscape and Soft Landscape have a number of specialized units and therefore typically fall outside of our standardization program. Due to payload requirements with the work performed, these are some of the least fuel efficient units.”. Therefore it is imperative to target these vehicles to achieve our emission targets.

The reason why we believe policy is not enough is because even though it states that drivers are not allowed to be idle more than 3 consecutive minutes in a 60 minute interval, the fact is that even more than 10 seconds of idling burns more fuel than starting up or shutting down the engine according to a literature review conducted in a paper published in the Journal of Energy Conversion and Management. In addition, the idling policies in place at UBC have several idling exceptions that include idling for safe operation (defrosting windshield), allowing equipment to be warmed up and motor vehicles that have equipment requiring power from the engine. Therefore certain vehicles are required to idle due to the nature of the job and this therefore contributes to GHG emissions. Thus, anti idling technology targets this deficiency.

It is also estimated that heating the cab by idling the vehicle wastes over 85% of the energy in the diesel fuel. Idling costs 3.2 litres of fuel per hour according to the Federation of Canadian Municipalities report on Enviro Fleets. Highlighted in a report by the Central Fleet Advisory Committee, City of Hamilton, anti idling technology can cut fuel use by more than 80% compared to idling and save wear and tear on the engine and therefore has the potential to decrease maintenance costs.

Professor Alan Mckinnon in his book “Green Logistics: Improving the Environmental Sustainability of Logistics” states that hybrid vehicles and anti idling technologies are relevant to light duty vehicles and vans “due to the high proportion of operations carried out in stop start environments and multi drop delivery rounds.” He also states that these technologies will becoming increasingly popular in the near future and will be incorporated with fleet management systems.

Senior experts in the field, Dr. I. Shancita, H.H. Masjuki, M.A. Kalam, I.M. Rizwanul Fattah, M.M. Rashed, H.K. Rashedul who have published their paper in the Journal of Energy Conversion and Management, have shown that “energy consumption with IR technologies is much lower than those without idling technologies, and even the least-efficient option still exhibited an almost ternary reduction in fuel usage.” Thus, despite the enforcement of anti idling policies in UBC, we believe that the technology is crucial for the policy to be effective to address the issue of GHG emissions on campus.

Anti-Idling Technology Analysis

Anti Idling Technology	Fuel Savings (%)	Reduction of GHG Emissions	Ease of Implementation	Fuel Use (l/h)
True APU	YES	YES	GOOD	0.3-1.14
Fuel Cells	NO	NO	BAD	1.51-45.42
Direct Fired Heater	YES	YES	GOOD	0.15-0.61
Automatic Shutdown/Startup	YES	YES	BAD	0.57-151
Electric Shorepower Solutions	YES	YES	BAD	0.79-12.87
Energy Recovery System (ERS)	NO	NO	BAD	N/A

OVERVIEW RECOMMENDATIONS IMPLEMENTATION

In the meta analysis paper in the Journal of Energy Conversion, all current IR technologies have been considered, evaluated and discussed. The table above shows the current and popular anti idling technologies available commercially in the market. For all practical purposes, only a few of the technologies have been presented based on immediate requirements of the client and decision criteria fit. The technologies present also provide a rough idea of all the different varieties of technology available in the anti idling technology category. For instance, many of the other IR technologies have a negligible impact of GHG emissions and fuel savings. For a more detailed table with all IR technologies listed, please refer to Appendix X.

Auxiliary Power Units - Small engines that provides power to heat and cool the vehicle.
Direct Fired Heater - Supplies heat from a combustion flame to a heat exchanger.
Automatic Shutdown/Startup systems - Starts or stops the engine based on defined parameters
Fuel Cells- Uses a Proton Exchange Membrane Fuel Cells (PEMFCs) or a Solid Oxide Fuel Cell (SOFC) to supply energy to the vehicle.
Electric Shorepower Solutions - Provides plug in electric power.
Energy Recovery Systems - Supply electric power for heating.

From the table above it is clear that Direct Fired Heaters (DFH) use the least amount of fuel compared to other IR technologies. In addition, True Auxiliary Power Units (APU) and Direct Fired Heaters are the two technologies that best fit our decision criteria. Automatic Shutdown/Startup Systems, for instance, are hard to find commercially, electric Shorepower solutions have high installation costs and Energy Recovery Systems do not provide enough warmth for driver comfort.

It is also important to note that Solar Powered APU's and hybrid solutions were considered but there was not enough data for these emerging technologies to recommend them to our client. We believe that the risk is too high although these technologies claim to provide substantial benefits. When more tests are conducted and as these technologies become more mainstream, these technologies can then be reconsidered.

Based on the table above, we further analyzed and compared True APU's and DFH's to see which one is more effective with regards to achieving our target set by our client. We looked at Fuel savings, Reduction of GHG emissions, Ease of Implementation and an additional criteria, compatibility with future vehicule types/technology.

Why Direct Fire Heater?

	Fuel Savings (%)	Reduction on GHG Emissions	Ease of Implementation	Compatibility with future tech
True APU	76%	NOx - 50-97% CO2 – 60-85%	Small and light Easy to Install	Compatible with future tech
DFH	94%	NOx - >99% CO2 – >95%	Small and Light Easy to Install	Compatible with future tech

OVERVIEW | RECOMMENDATIONS | IMPLEMENTATION

According to a paper in the Journal of Energy Conversion and Management which did a meta analysis looking at all the studies with anti idling technology in the last 15 years, the paper shows that DFH's are the best option to reduce GHG emissions and improve fuel economy. The paper analyzed 10 different anti idling technologies in several different controlled scenarios and outlined the respective technology's measurable impacts on GHG emissions and fuel economy. According to Enviro Fleet report, APUs can cost from $3,500 to $10,000. The average cost is $7,750 as reported by The Canadian Trucking Alliance. Annual maintenance cost is estimated to be approximately $500.

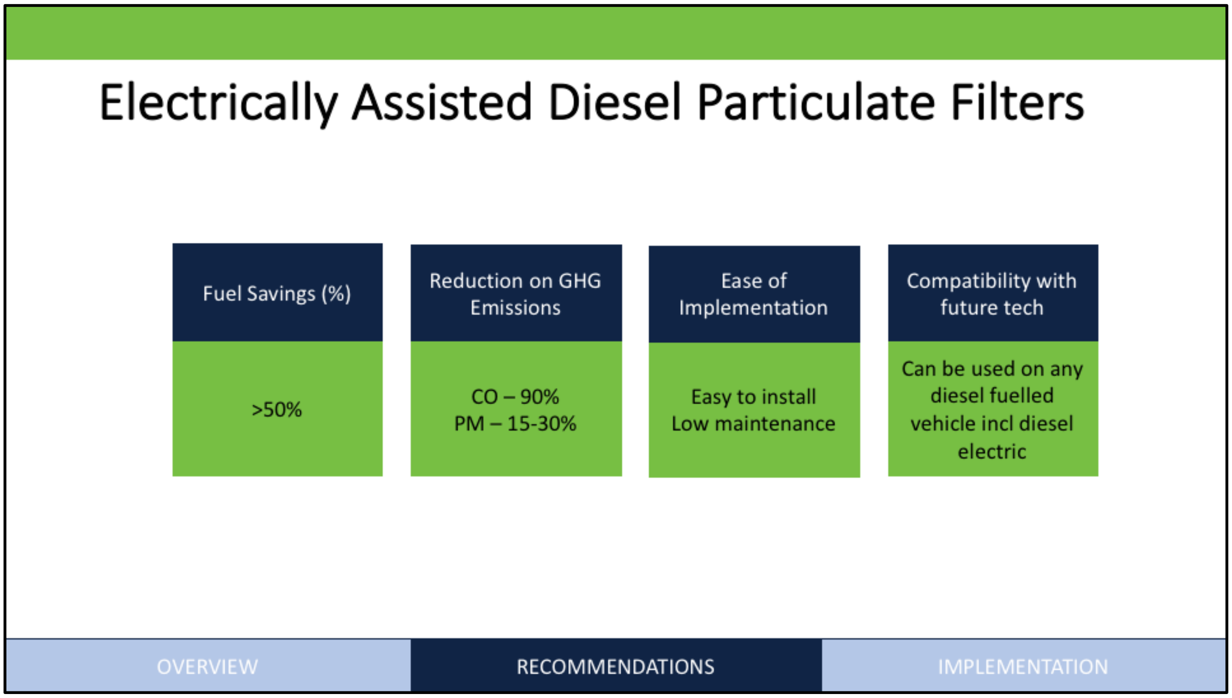
Different types of DFH's cost different amounts. We recommended DFH's that are powered from the vehicle's battery and diesel fuel which cost $1,600 although considering budget constraints, one powered solely from the vehicle's battery should suffice as well. DFH's that are powered solely through the vehicle's battery cost under $600 and are small and lightweight. It burns no fuel, draws less than an amp from the battery and can keep the cab warm for 4.5 hours. These DFH's are recommended to be implemented in light duty vehicles. DFH's that are powered from the vehicle's battery and diesel fuel include the same advantages provided by the cheaper DFH in addition to automatic temperature controls and can operate on 20 hours on less than 4 litres of fuel. This type of DFH is recommended to be implemented in vehicles that require more idling time. Annual maintenance cost is estimated at $110.

Since DFH's fuel consumption is typically 0.15 L/h (Lim, 2002) and 0.23 L/h (Espar), an average value of 0.19L/h represents a 3.0 L/h, or 94% fuel savings over idling compared to 2.4 L/h from True APU units that provide fuel savings of 76%. Dean Lande, APU business manager for Carrier Transicold states that "Payback periods can be relatively short on an APU – less than three years, based on fuel savings alone".

DFHs performed the best with regards to reducing fuel wastage as the findings reveal that DFHs results in 94–96% reduction of fuel consumption. This is followed by Shorepower (SP) which reduces the fuel consumption by 74%. Then, APU has been found to produce 36–85% reduction in fuel consumption. Other technologies examined in the comparative review are not popular due to poor performance in reducing fuel consumption. Other findings in the paper are that DFHs are the best option to reduce idling emissions. DFH's emit less NOx and CO2 than any other options. According to the paper, "DFH's reduce NOx and CO2 emissions by 99% and 94–96% respectively. It also reduces CO and HC significantly."

The paper also states that the True APU is worse than DFH when it comes to reducing NOX and CO2 emissions. The researchers conclude that DFH reduces fuel consumption and NOx, CO, HC, and PM emissions more than APU does in all cases. Rest of the idling options do not provide significant emission reduction potential compared to true APU's, DFH's and electric Shorepower solutions. Unlike several IR technologies, Direct Fired Heaters are also compatible with future technology and easy to implement. The small and lightweight nature of the product ensures that setup costs and maintenance costs are low. DFH's are easy to install and in fact, in our research, we were exposed to several websites and tutorials that taught people how to install DFH's in their respective vehicles. Additionally, it is highly effective in stop/start situations, which is particularly relevant to UBC Building Operations and adds to driver comfort by providing heat in cold weather.

To further strengthen our recommendation, we looked at real life case studies in which the technology has been implemented. In a report by the Federation of Canadian Municipalities on Enviro Fleets, the City of Toronto used heaters in a significant portion of its fleet vehicles such as aerial trucks, garbage trucks and cube vans. The cube vans were used by Toronto's water services division and the technology heated the cab space allowing work crews to warm up on cold days. It was reported that the heaters were a huge success, reducing both emissions and fuel consumption according to Sarah Gingrich, Business Development & Improvement Analyst Fleet Services, City of Toronto.



Our team also looked at exhaust catalyst technology to help achieve our target of reducing GHG emissions. Diesel Particulate Filters are retrofit technology that's widely. While the current technology is effective in reducing GHG emissions, it requires extra fuel to perform a regeneration cycle by creating heat therefore burning more fuel resulting in lower overall fuel economy. Our team thus decided to invest in researching alternate technologies ways that address this problem. We found that General Motors has been creating an after treatment system that incorporates electricity rather than fuel to raise the temperature in the diesel particulate filter. This technology has been hailed by Truck Trend as "the next generation of Diesel Particulate Filter Technology". There are significant benefits that could be realized from this technology such as Fuel savings and reduction in GHG emissions. It is also extremely easy to implement as it would come with the engine factory installed or retrofitted. The initial tests of the EADPF system was conducted using a four cylinder 1.9L CDTI Fiat/GM engine. This means that this technology could be used on V-6 and V-8 engines thus retrofitting in a variety of GM vehicles, from the Chevrolet Spark to Escalade SUVs.

Tests by General Motors in the Oakridge National Laboratory have shown that the Electrically – Assisted Diesel Particulate Filter (EADPF) technology results in a 50% reduction in fuel penalty compared to conventional DPFs and other fuel-based regeneration techniques. Most importantly, the regeneration time is reduced by 60% with the EADPF which is particularly beneficial for vehicles that are in stop and start city environments as there are frequent active regeneration intervals which reduce the fuel economy. The tests revealed that regeneration took 4 to 6 minutes and eliminated 80-90% of the trapped soot which results in greater emission reduction than traditional DPFs.

While exact costs are unknown for this technology, we used several marketplace websites such as eBay to come up with an estimation with how much a normal DPF costs. Our research showed that the costs would range from $400 to $3000 depending on the vehicle. We believe this would give us a rough idea as to how much EADPF's would cost. It was anticipated that GM would implement this technology in their 2017 models but it has been delayed. Therefore, our team has decided to retrofit 85% of diesel vehicles with this technology (provided its available) by 2030. Nevertheless, the technology is expected to come fully installed in the vehicle. According to the Enviro Fleet Report by the Federation of Canadian Municipalities, normal diesel particulate filters "can remove up to 90 per cent of carbon monoxide and hydrocarbons, reduce particulate matter by between 15 and 30 per cent, and reduce noise". Thus, an EADPF could do this and add to the fuel economy and increase savings.

Implementing this technology is easy as it can be used on any diesel fueled vehicle, low sulphur or ultra low sulphur diesel and is compatible with biodiesel. More importantly, the EADPF design can be adapted for use with future diesel technologies such as automatic start/stop technology and be retrofitted in diesel electric cars. It can theoretically be used in Chevrolet Sierra 1500 hybrid pickup trucks, a diesel powered electric hybrid such as the Chevrolet Volt, diesel electric hybrid such as the Chevrolet Cruz or diesel electric powered Chevrolet Colorado.

Replacement Vehicle 2

	Ford Transit	Nissan NV200
Estimated Annual Fuel Cost ($/yr)	$1934	**$1748**
CO_2 (g/km)	244	**220**
Alternative Fuel	CNG , Biodiesel, E85	**CNG**
Ranking (NRC Consumption Guide)	510	**331**

	Toyota Tundra	Toyota Tacoma	Chevrolet Colorado	GMC Canyon
Estimated Annual Fuel Cost ($/yr)	$2641	$2083	**$1938**	**$1938**
CO_2 (g/km)	334	263	**255**	**255**
Alternative Fuel	CNG	CNG	**B20-Capable Diesel**	**B20-Capable Diesel**
Ranking (NRC Consumption Guide)	923	651	**359**	**359**

2017 models

Address parallel fleet replacement problems

Streamline standardization of vehicle fleet

Invest in alternative fuels

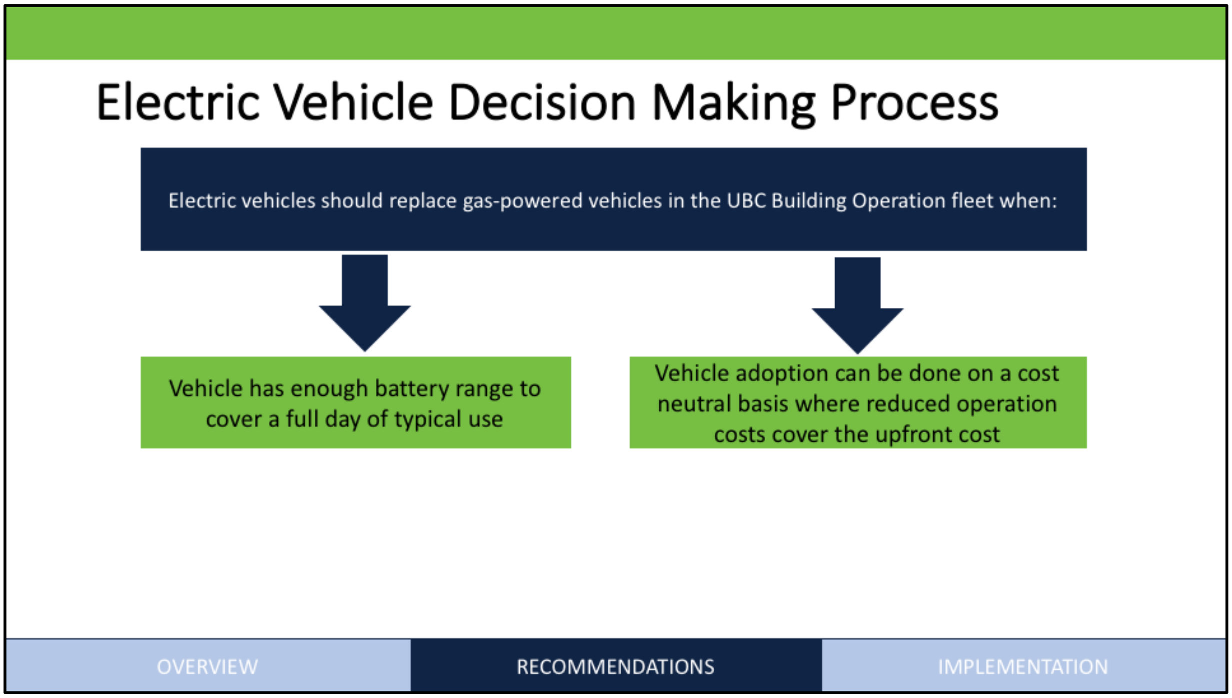
OVERVIEW | RECOMMENDATIONS | IMPLEMENTATION

The second part of our recommendation involves the streamlining of UBCs current fleet through strategic replacements. As part of our three-fold recommendation, we found that this option acts as an effective and efficient short-term solution of optimizing the fleet in terms of fuel economy.

We found that keeping a standard fleet based on vehicle type was an effective way to remain as cost efficient as possible through the simplification of maintenance and operations. Through our analysis of the standardized fleet ranging from vans, trucks, and compact vehicles, we identified areas UBC is excelling in as well as others with potential room for improvement. Overall, UBC Building Operations are effectively evaluating future vehicle replacements by considering important factors such as fuel consumption and GHG ratings. Through further analysis of rankings on the Natural Resources Canada Fuel Consumption Guide, however, there are some existing models that could potentially replace current vehicles within the fleet. Specifically, we wanted to look further into our replacement options for current inventory of Ford Transits, Toyota Tacoma's, and Tundra's.With improvement in van and medium-sized pickup truck inventory, there is great potential to reduce GHG emissions through the streamlining of the standardized fleet.

To determine whether these recommendations were viable options, we considered the following decision criteria: Estimated annual fuel cost, estimated CO_2 emissions, alternative fuel options, and rankings amongst the Natural Resources Consumption Guide. These criterion were based on the standardization requirements as well as the deciding factors of purchasing models outside of the current selector outlined in the Pegasus report. Our findings led us to 3 potential options for replacement vehicles.

When considering the alternative option for vans, we found that the Nissan NV200 exceeded the Ford Transit in three out of four areas. Although the estimated cost does not directly relate to UBCs case as the university purchases fuel in bulk, it still shows that overall fuel costs are lower for the Nissan van than the Ford. Additionally, with the lower GHG emissions and higher NRC ranking shows great promise for fuel efficiency. The case for pickup trucks is similar as the Chevrolet Colorado and GMC Canyon, both equally fuel-efficient, lead in the rankings compared to the fleet's current vehicle choices. Although these alternatives may not yet be using CNG, the overall use of GHGs still remains lower than current operations.



The 2050 goal for the Pegasus project is for CO_2 emissions to be 100% eliminated. The only way for that to happen is to adopt a 100% electric fleet. Keeping in mind the desire to standardize the make of vehicle for each category of vehicle, electric vehicles will be adopted when they pass a test for viability.

The range of the electric vehicle's battery has to be large enough to last what the daily requirement of the vehicle is. A EV battery usually takes multiple hours to charge so if a battery can't last all day, there will either be a need for multiple vehicles to be rotated, or an interruption in work

Currently Electric Vehicles cost substantially more than a regular vehicle, but cost substantially less to operate. When the cost to operate an electric vehicle over its lifetime is the same as a gas vehicle, those electric vehicles should be adopted.

For vehicles like garbage trucks, the advantage of lower costs of operation is more prominent because garbage trucks need more fuel to operate. However, it will likely take longer before technology advances to the point where a fully electric vehicle with capable range is available. For smaller vehicles like the Ford Transit Connect, electric vehicle technology is already available in certain countries. However, analyzing the use of these vehicles reveal that the lower cost of operation doesn't offset the higher initial cost quite yet.

Electric Vehicle Decision Making Process

Example: Is the Nissan e-NV200 an appropriate acquisition in the current market?

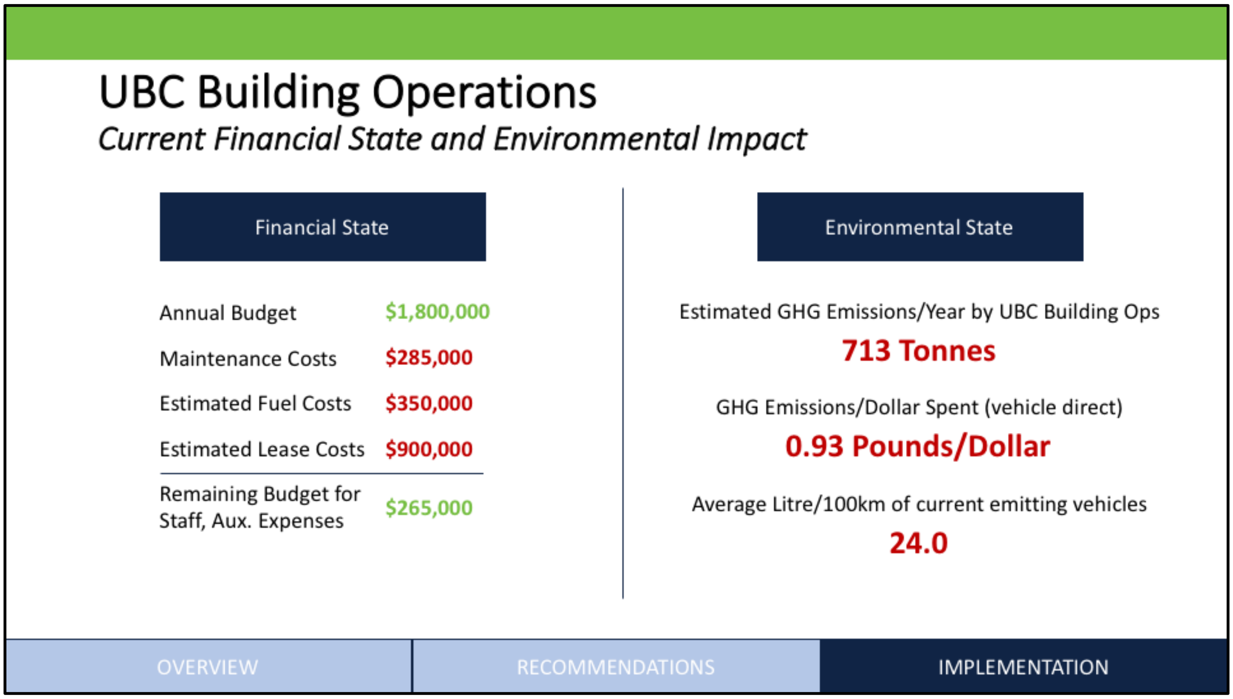
Vehicle has enough battery range to cover a full day of typical use

Vehicle adoption can be done on a cost neutral basis where reduced operation costs cover the upfront cost

Vans would have to be operated for 23 to make the switch cost neutral. Electric vans have to drop to around $22,000

OVERVIEW | RECOMMENDATIONS | IMPLEMENTATION

We are going to use a new piece of EV technology, the Nissan e-NV200, that is available in Europe and Asia as an example. The e-NV200 is a small electric van that could replace the Ford Transit trucks that currently occupy around one fifth of the current UBC fleet.
The first part of our process is to determine if the vehicle has enough battery range to last over an average work day. The Nissan e-NV200 has a range of 170kms on one battery charge. After an analysis on the use of Ford Transit vans we determined that on average a van travels 3700 Km per year and the furthest traveling vans cover around 13000km a year. Assuming that there isn't too much variation in the amount that a truck is used on a day to day basis, that means the Nissan e-NV200 has more than enough battery range to last over an average day.
Now next to the second part of the process, the cost calculation. We found that there are no vehicles that would benefit on a cost basis from the switch to electric vehicles. UBC simply does not drive their vans enough to make the lower cost of operation worth the expensive cost at the outlay. We found that the average van would have to be used for 23 years to make the investment cost neutral, or electric vans need to drop in price to $20,000 to make this upgrade make financial sense. Thus, the Nissan e-NV200 does not pass our decision process and we recommend waiting for cheaper electric vehicles to come available.



In order to assess the cost effectiveness and environmental implications of our recommended solutions it is first important to understand the assumptions laying beneath our analysis of UBC Fleet Management's current state. For our calculations we used current fleet numbers for all vehicles with a planned replacement after 2015/2016 and we used replacement vehicle numbers for all vehicles with a planned replacement during the 2015/2016 period or earlier. Our assumption was that these replacements did in fact happen.

Financial State

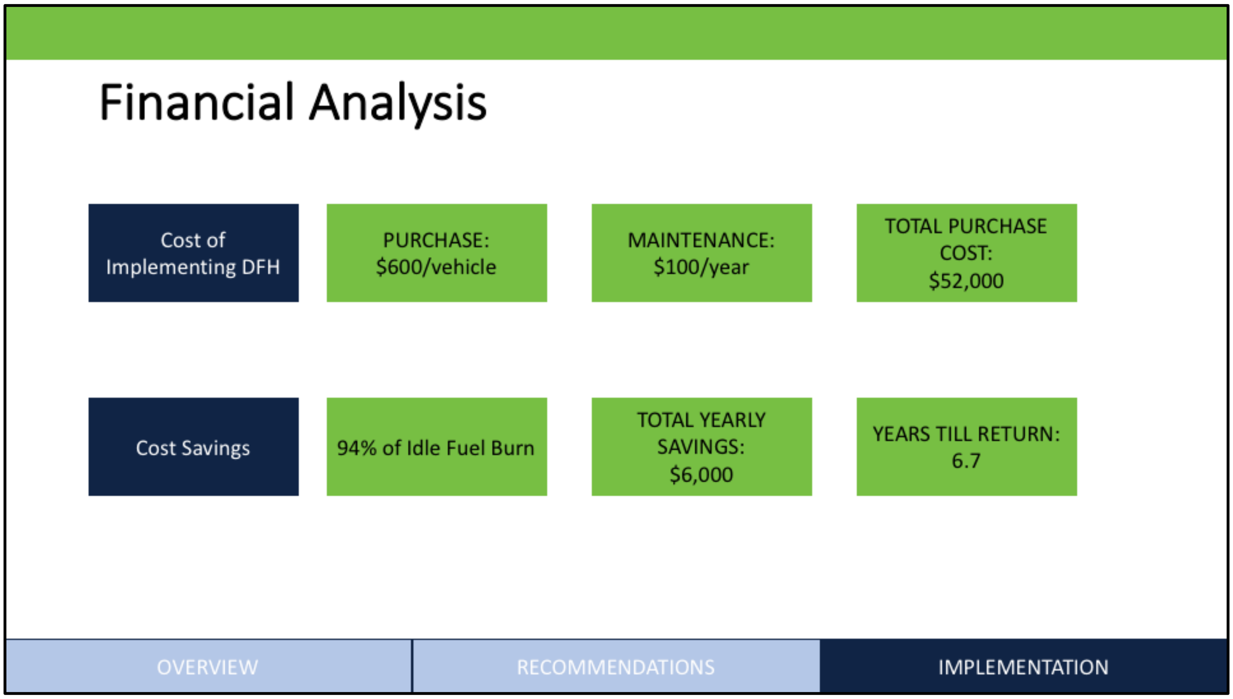
Annual Budget: As described by the Fleet Manager during the question period, the annual budget for UBC Fleet Management is [redacted]

Maintenance Costs: Since there were no maintenance cost numbers provided for replacement vehicles, we used the old vehicle maintenance costs as a placeholder. Naturally, we would assume that this number will, in reality, be lower – but not significantly lower where it will make a difference in our analysis.
Fuel Costs: Our Fuel Cost Estimation was done by pricing the existing 'Litres Consumed' annually for each vehicle at $1.29, the current cost of gas in Vancouver.
Lease Costs: The Lease Cost was calculated by taking all existing leases, determining their monthly cost, and transitioning this to a yearly amount.

This leaves roughly $265,000 in the annual budget which we assume is used for staffing and auxiliary expenses.

Environmental State

Total GHG Emissions annually were calculated using a 20 pounds of C02/litre of gas and/or diesel. In reality, gas emits slightly less than 20 pounds per litre on average, while diesel burns slighter more than 20 pounds per litre on average. Overall, we believe our 20 pound assessment is fair, and if anything is slightly on the high side. When calculating our emissions/dollar spent we *did* include smart cars and low emission vehicles. However, when determining the average litre/100km used in the fleet we did not. We believe this gives us a better understanding of how clean technology can help those vehicles in our analysis.



In order to reach a return on capital expenditures when purchasing DFH technology, the technology should only be installed on the highest utilization vehicles. We have identified 73 vehicles in the fleet that are high emitters of emissions and that use a significant amount of fuel throughout the year. A list of these vehicles is supplied in the appendices.

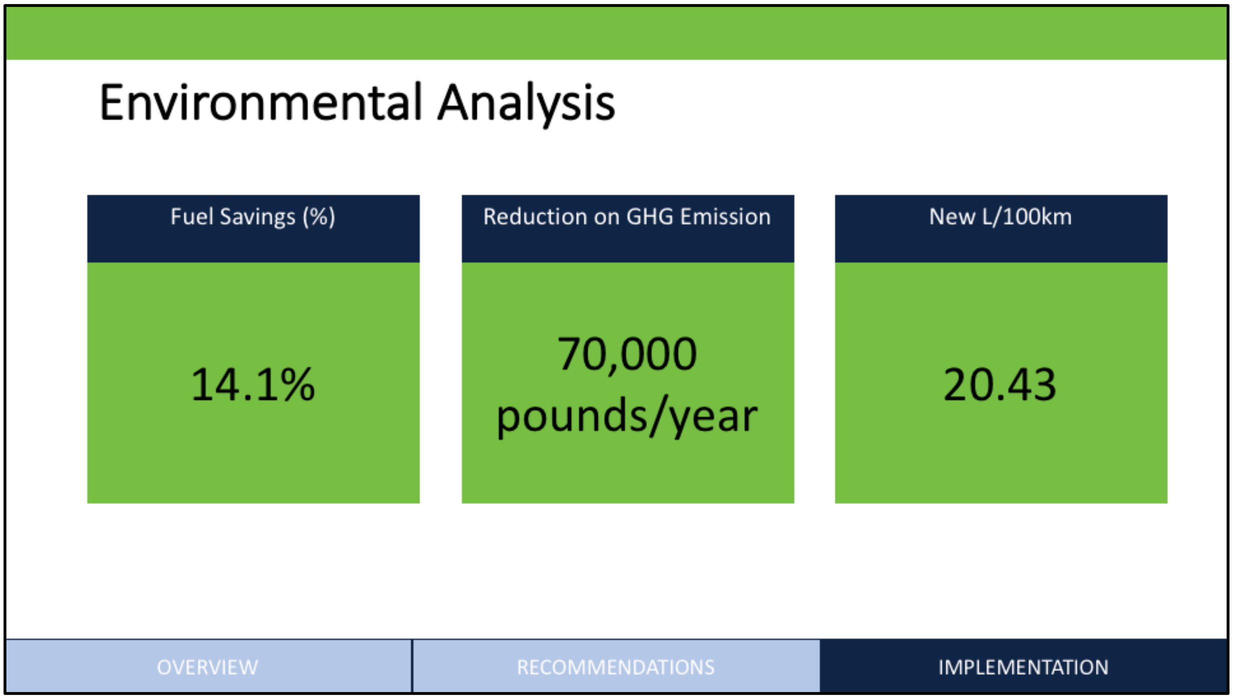
We estimate that these vehicles idle for approximately 15% of the time that they are in use.

Yearly maintenance costs for 73 vehicles installed with DFH technology costs $7,300.

The overall cost savings from lower fuel usage equates to approximately $13,000/year.

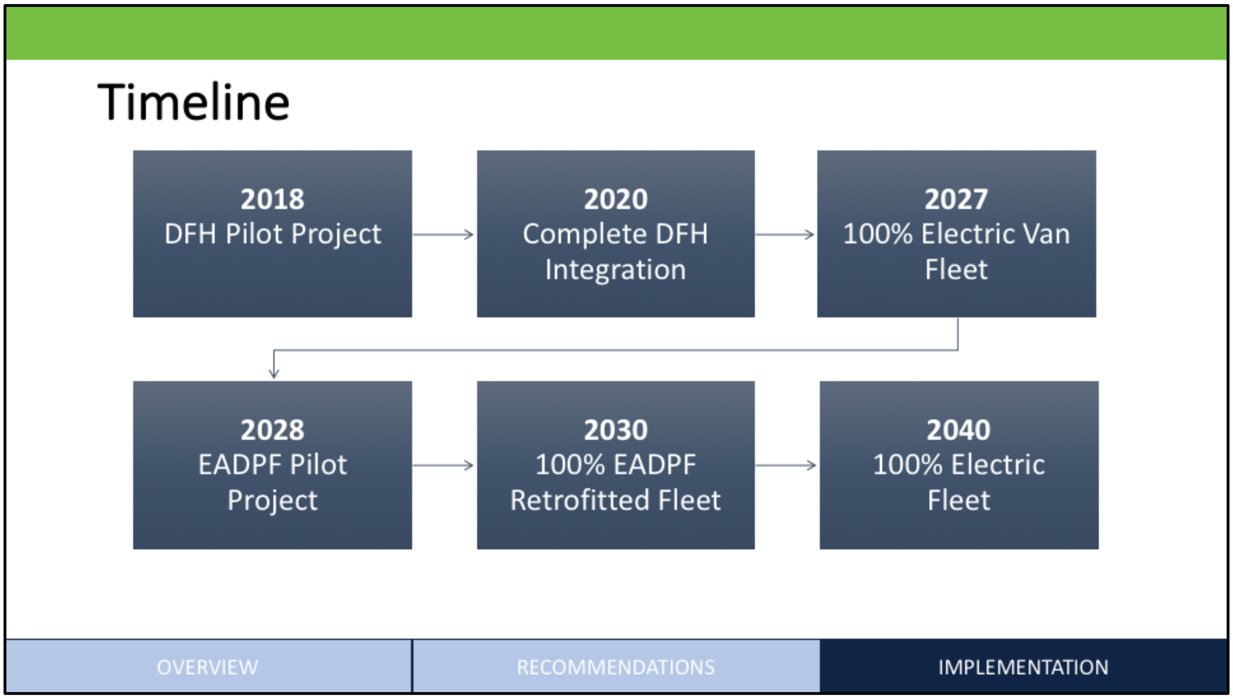
With 6.7 years till return on implementation we believe this technology is a viable solution that provides cost-neutral expenditures while delivering improved GHG emission reduction over the suggested (6-10) lifetime of UBC Fleet Management vehicles.

Due to the unknown nature of EADPF technology we have not completed financial analysis of implementation as we view this as a mid-long term solution. We acknowledge that the EADPF technology would need to be installed in only high utilization vehicles in order to prove a cost-neutral solution



The introduction of DFH technology can deliver significant results in both the short term and long term. By installing DFH into the 73 vehicles identified we are able to see positive GHG emission related results after just the first year.

For the 73 vehicles with DFH installed, they will see a 14.1% decrease in the amount of fuel used over the course of a year. This amounts to 70,000 pounds/year, or a 5% reduction in overall GHG emissions put out each year by UBC Fleet Management. When compared to a 0.2% of the overall budget we feel this is a significant return on investment.



Since the aggressive Climate Action Plan targets of 2010, UBC has consistently met the audacious goals set for itself. Building Operations in particular has consistently strived for the utmost in efficiency while its minimizing environmental impact. Over the next 30+ years, we believe UBC should set the bar even higher for itself, and broaden its strategic vision to involve more specific goals and figures. We believe the following timeline can help achieve exactly that.

2018: DFH Pilot Project

Before undertaking experimental technology adoption completely, we recommend UBC conduct a small pilot project on no more than 3 individual vehicles and track their progress over a 3 month period. Because UBC has not yet used Direct Fire Heater technology, it is advisable to test the project on a small scale before full scale implementation.

2020: full DFH Installation

After gathering information of the DFH pilot project through Geotab technology, UBC would have the figures necessary to determine if full scale implementation of DFH technology is feasible and its potential effectiveness.

2027: 100% Electric Van Fleet

Because vans account for more than 25% of UBC's campus vehicle fleet, because of their homogeneousness, and because of their extensive use on campus, we recommend complete electric van implementation sooner than other vehicles in the fleet.

2028: EADPF Pilot Project

Electrically Assisted Diesel Particulate Filters (EADPF) are again, an experimental technology UBC has yet to incorporate into its operations fleet. Because of this, we recommend a small scale retrofit of 2-5 vehicles prior to commencing full-scale implementation, in order to gather more information and consider the financial feasibility of the move with information gathered from pilot vehicles.

2030: 100% EADPF Retrofitted Fleet

With collected data, UBC will be able to make an informed decision on moving forward with retrofitting the entire fleet with EADPF technology.

2040: 100% Electric Fleet

Our analysis points to 100% electric vehicles in the UBC operations fleet by 2040 – 10 years ahead of schedule.

Risks and Mitigation

Risk	Probability	Severity	Mitigation
Vehicles and Drivers have no room for improvement	Mid	High	Test recommendations with a small pilot group before fully implementing fleet wide
A reduction of UBC Fleet Services Budget	Low	Mid	Communicate the value of the services that UBC Fleet Services provides
Electric Vehicle technologies do not advance	Low	High	Communicate demand to supplier and manufactures
More departments decide to handle their own vehicle operations	Mid	Mid	Communicate the value of the services that UBC Fleet Services provides

OVERVIEW | RECOMMENDATIONS | IMPLEMENTATION

There is the risk that vehicles and drivers are already fully optimized and the technology we are recommending will not have any positive impact on gas costs. Although there already is technology and policies in place, there is always room for improvement. Our mitigation to this risk is to test these technologies in a small number of vehicles first before expanding to the rest of the fleet.

The second risk is that UBC will reduce UBC Fleet Service's budget. This has a low severity because UBC fleet has such an essential mandate and it's not really something UBC can live without. To mitigate this risk UBC Fleet Services should continue to become more efficient on a cost and emissions basis and communicate these successes.

The next risk is that Electric Vehicle Technologies do not advance and/or become cheaper. This risk has a low probability because the demand for large electric vehicles is so high. In addition, most estimates show that there will be a large reduction in prices for electric vehicles over the next few decades.

The last risk is that more faculties decide that they are better off on their own and take care of their own vehicle services, reducing the effectiveness of any UBC Fleet Services initiatives. To mitigate this risk UBC Fleet Services should communicate their successes and show departments the value they create by optimizing costs and reducing emissions.

Metrics

MEASURE	KEY QUESTIONS	SUCCESS INDICATORS
Fuel Efficiency	Are we bettering our gas mileage?	Average L/100km for emission vehicles lower than 24.0
Cost Efficiency	Do capital expenditures we make now save money in the future	Realized rate of return on clean tech/vehicle purchases
GHG Emissions	Does reduction in idle time significantly improve our GHG emissions/vehicle?	Emission output year over year on monitored vehicles
Effective Purchasing	Are we making efficient decisions when purchasing clean technology	Reduction in GHG Emissions/Dollar Spent

OVERVIEW | RECOMMENDATIONS | IMPLEMENTATION

Developing relevant metrics is crucial when implementing a new strategy. We believe we have identified four metrics that will help UBC Fleet Management understand the effect that our recommended suggestions have in both the short term and long term:

Fuel Efficiency

There are many metrics that can help tell us whether we are becoming fuel efficient, but we prefer to continue using the standard L/100km metric that is already being measured by UBC Fleet Management to track success here. Currently vehicles that emit emissions in the fleet use 24 litres per 100 kilometres. Our goal for this metric is to see a decrease in both the short term and long term. A decrease in the amount of gas/diesel used per kilometre means both lower costs for gas in the future and also lower emission output.

Cost Efficiency

UBC Fleet Management needs to ensure that the purchases they are making result in cost savings in the long run while reaching cost-neutral in the short run. The best way to do this would be to track cost savings vehicle-by-vehicle. When technology has been installed in a vehicle, how much less does that vehicle cost the fleet over the next 5-10 years in maintenance and fuel. This number should be compared to the initial capital expenditure to ensure that money is being spent wisely.

Efficient Purchasing

This ties in with cost efficiency. While we want to make sure we are getting a return on our purchases, we also want to ensure that these purchases are leading us to over emission reduction goals. The best way to monitor this is to track our overall emission reductions throughout the entire fleet and compare this with the cost of upgrading the fleet. Currently UBC Fleet Management emits 0.93 pound of GHG emissions per dollar spent on direct costs to the fleet (maintenance, fuel, leasing). We believe that reducing this number is an excellent way to understand whether money is being spent efficiently and effectively on fleet upgrades.

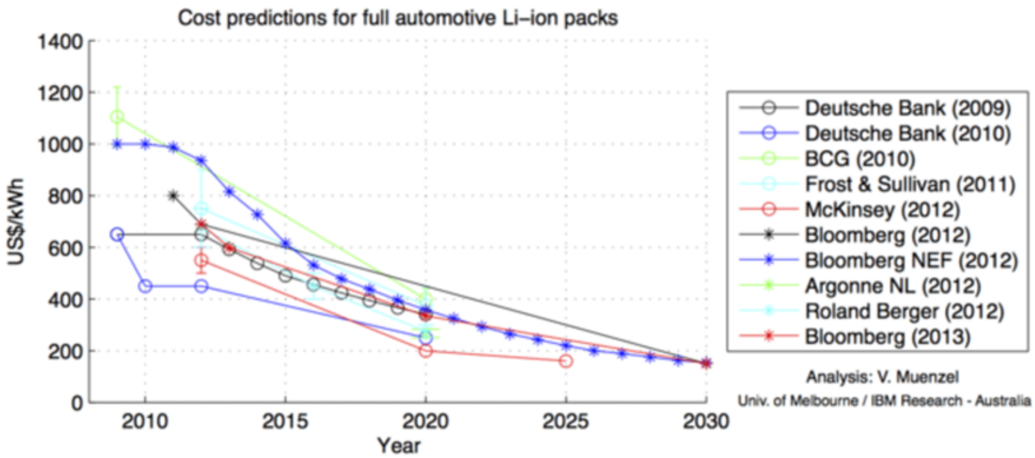
GHG Emissions

One of the underlying goals of the Pegasus project is to reduce emissions by the stated goals. Therefore, continuing to monitor emissions on monitored vehicles year by year is crucial to realizing our goals. By continuing to monitor this we will better understand whether the implemented technology we suggest is making a difference in reality.

Appendix

Li-Ion Pack Predictions	Ballpark Ideas	EC assumptions
EADPF	DFH types	Anti-Idling Tech
Idling Rates	SWOT	Strategy Canvas
NRC 1	NRC 2	PESTLE
Vehicles Used		

Cost Predictions – Li-Ion Packs



APPENDIX

Ballpark Ideas

WRIGHTSPEED POWERTRAINS

UBC does not utilize their garbage trucks at a high enough rate to make the $200,000 investment viable

APPENDIX

Assumptions for EV Calculations

- Average distance traveled = 3700 km
- Fuel efficiency = 19 km / 100 L
- Cost of e-NV200 = 35000
- Salvage value of Ford Transit = 12500
- Cost of electricity for one battery charge $2
- Cost of gas per L = $1.3

APPENDIX

EADPF

EADPF DEMONSTRATES 50% REDUCTION IN FUEL PENALTY

	EADPF Regen	Fuel-Based Regen
Soot Loaded, g/l	4	4.9
Soot Regenerated, %	85	112
Extra Fuel, g	195.5	426.8
Extra Fuel Energy, kJ	8,389.00	18317 (~50% Fuel Penalty Reduction)
Electric Energy, kJ	654.6	NA
Total Regen Energy, kJ	9,044	18,317
E-Energy fuel equivalent, g	15.3	NA
Extra Fuel Total, g	210.8	426.8
Time Required, min	8	20

APPENDIX

Types of direct-fired heaters

Table 7

Types of direct-fired heaters

Type	Powered solely from the vehicle's battery	Powered by both battery and diesel fuel	Relies on a battery pack to run both a heater and an air conditioner
Operation	• Circulates the heated coolant from the engine to the heater coils, which can keep the cab warm for up to 4.5 hours. • Includes a temperature sensor and a voltage sensor. • Burns no fuel, and draws less than an amp from the battery.	• Typically operates for about 20 hours on less than four litres of fuel. • Includes automatic temperature controls, and is completely separate from the vehicle's heating system.	• Runs for 10 hours, and requires four to six hours for a full recharge.
Weight	About 1.3 kilograms		Over 91 kilograms
Cost	Under $600	About $1,600	About $4,000

APPENDIX

Anti Idling Tech

Table 6
Choices of technology to reduce idling in diesel and gasoline engine.

Idle reduction technology	Function	Advantages	Disadvantages	Fuel use (l/h)	Technology status	Refs.
Auxiliary power unit (APU)	Power for auxiliaries, heat for engine and heating and air-conditioning for cab/sleeper	Suitable for using at any stop for heating, cooling and auxiliaries, recovers waste heat for space heating, serves as survival system	Heavier and larger than direct-fired heater, sometimes require separate sleeper air conditioner	0.30–1.14	Commercial	[12]
Fuel Cells	Heating or cooling, supplies energy to vehicle's electrical system	Can use on board storage fuel for the fuel cell system and also serve as a generator, battery charger and heat supply, low noise	High initial cost, unavailability of suitable fuel, integration of units with on-board truck systems	1.51–45.42	At or near commercial, Commercial in other applications	[61,62]
Direct-fired heater	Heating for cab/sleeper and/or engine	Suitable for using at any stop for heating, small and lightweight	Cannot provide cooling, needs battery power and unreliability arises when not equipped by engine with automatic starting	0.15–0.61	Commercial	[12,63]
Thermal storage	Heating and air conditioning for cab/sleeper only	Driver comfort	Does not provide heat for engine, relatively large space requirement to accommodate, performance depends on the use of truck Heavy	N/A	At or near commercial. Commercial in other applications	[12,64]
Battery-powered heating/AC	Heating and air conditioning for cabin	Provides all needs, zero emissions	Requires battery power	0–0.64 (depending on configuration)	Commercial	[65,66]
Direct heat with thermal storage cooling	Heating and air conditioning Of cab/sleeper and heat for engine	Suitable for using at any stop for heating and cooling	Low driver acceptance	0.38	Commercial	[12]
Automatic Shutdown/Startup Systems	Starts/stops the engine based on a set time period or on ambient temperature and other parameters (Example: battery charge)	Low cost. Available from engine manufacturer	Not available everywhere	0.57–1.51	Commercial	[65,66]
Shorepower Solutions	Provides plug-in electric power all along the way for on-board convenience appliances where AC power and other services are available for drivers	Avoid maintaining another engine by using idle free battery powered units with shore power and can run the HVAC system and hotel loads such as microwaves, TVs and laptops and keeps the truck engine warm when the engine is off with an endless supply of power	High installation cost and complex design to manufacture	0.79–12.87	At or near commercial	[13,67,68]
Cab Comfort System (CCS)	Tie into the truck engine's cooling system to maximize heating efficiency and minimize fuel consumption, provide back-up alternators and air conditioner's compressors for emergencies	At least 4 times as efficient as the main engine and extend intervals between oil changes and engine overhauls		2.27	Commercial	[13,69]
Energy recovery system (ERS)	Keeps a vehicle warm using vehicle's heat transfer system	Can provides heat without a separate hater, no maintenance required after installation	Energy recovery systems typically do not provide enough warmth to be a sole source of overnight heat	N/A	Commercial	[13,70,71]
Truck stop electrification	Supplies electric power for heating, air conditioning and auxiliaries	Ensures power for heating, cooling and auxiliaries	Choice for overnight location is limited, requires separate sleeper air conditioner and electricity driven heater, requires additional infrastructure at the truck stops	0.87–1.14	Not commercial. Commercial in other applications	[12,72]

I. Shancita et al./Energy Conversion and Management 88 (2014) 794–807

APPENDIX

Idling Rates

Table 2
Rates of idle emissions of pollutant for different type of vehicle on average [49].

Pollutant	Units	LDGV[a]	LDGT[b]	HDGV[c]	LDDV[d]	LDDT[e]	HDDV[f]	MC[g]
VOC	g/h	2.683	4.043	6.495	1.373	2.720	3.455	19.153
	g/min	0.045	0.067	0.108	0.023	0.045	0.058	0.319
THC	g/h	3.163	4.838	7.260	1.353	2.680	3.503	21.115
	g/min	0.053	0.081	0.121	0.023	0.045	0.058	0.352
CO	g/h	71.225	72.725	151.900	7.018	5.853	25.628	301.075
	g/min	1.187	1.212	2.532	0.117	0.098	0.427	5.018
NO_X	g/h	3.515	4.065	5.330	2.690	3.705	33.763	1.625
	g/min	0.059	0.068	0.089	0.045	0.062	0.563	0.027
$PM_{2.5}$	g/h	N/A	N/A	N/A	N/A	N/A	1.100	N/A
	g/min	N/A	N/A	N/A	N/A	N/A	0.018	N/A
PM_{10}	g/h	N/A	N/A	N/A	N/A	N/A	1.196	N/A
	g/min	N/A	N/A	N/A	N/A	N/A	0.020	N/A

[a] LDGV: Light-duty gasoline-fueled vehicles, up to gross vehicle weight (GVW) 6000 lb (e.g. gasoline-fueled passenger cars).
[b] LDGT: Light-duty gasoline-fueled trucks, up to GVW 8500 lb (e.g. pick-up trucks, minivans, passenger vans, sport-utility vehicles, etc.).
[c] HDGV: Heavy-duty gasoline-fueled vehicles, over GVW 8500 lb (e.g. gasoline-fueled heavy-trucks).
[d] LDDV: Light-duty diesel vehicles, up to GVW 6000 lb (e.g. diesel engine passenger cars).
[e] LDDT: Light-duty diesel trucks, up to GVW 8500 lb (e.g. diesel engine light-duty trucks).
[f] HDDV: Heavy-duty diesel vehicles, over GVW 8500 lb (e.g. diesel engine heavy-duty trucks).
[g] MC: Motorcycles (gasoline-fueled, certified for highway use).

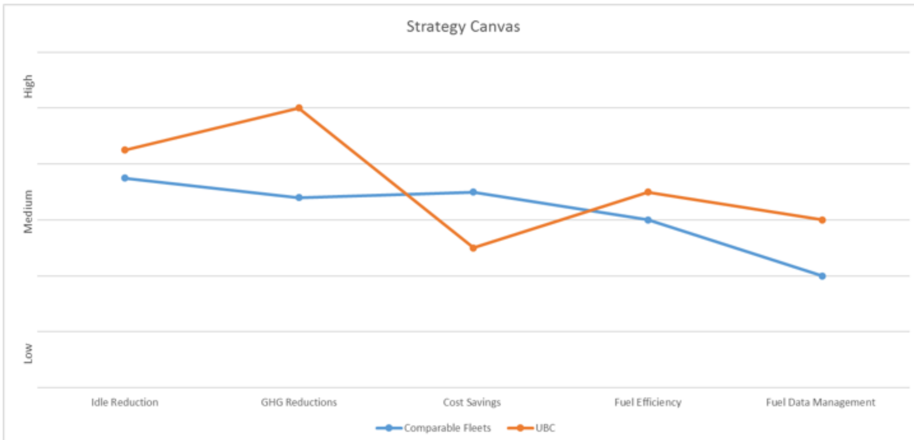
APPENDIX

SWOT

Strengths • Standardization of vehicle models • Rightsizing • Telematics • Driver Training Policies • 20% electric	**Weaknesses** • Not all Vehicles are under Fleet Management Control • A wide range of different types of vehicles that need to be provided • More data would be nice
Opportunities • More efficient vehicle models • New technologies • Further improve existing policies • More Departments could join the Fleet Management Umbrella	Threats • More departments could leave • A reduction in budget • Technologies could not advance to the level we hope

APPENDIX

Strategy Canvas



APPENDIX

NRC Rankings 1

Light trucks		
Vehicle class	**Conventional vehicle**	**Advanced technology vehicle**
Pickup Truck: Small	Chevrolet Colorado 2.8 L, 4 cylinder diesel, 6-speed automatic GMC Canyon 2.8 L, 4 cylinder diesel, 6-speed automatic	n/a
Pickup Truck: Standard	Ford F-150 2.7 L, 6 cylinder, 6-speed automatic with select shift	n/a
Sport Utility Vehicle: Small	Nissan Rogue Hybrid 2.0 L, 4 cylinder hybrid, continuously variable	n/a
Sport Utility Vehicle: Standard	Lexus RX 450h AWD 3.5 L, 6 cylinder hybrid, continuously variable	Tesla Model X 75D 386 kW electric motor, 1-speed automatic
Minivan	Mazda5 2.5 L, 4 cylinder, 5-speed automatic with select shift	Chrysler Pacifica Hybrid 89 kW electric motor, 3.6 L, 6 cylinder plug-in hybrid, continuously variable

NRC Rankings 2

The most fuel-efficient vehicles for model year 2017

Cars		
Vehicle class	**Conventional vehicle**	**Advanced technology vehicle**
Two-seater	**smart fortwo cabriolet** 0.9 L, 3 cylinder, 6-speed automated manual	n/a
Minicompact	**Fiat 500 Hatchback** 1.4 L, 4 cylinder, 5-speed manual	n/a
Subcompact	**Ford Fiesta SFE** 1.0 L, 3 cylinder, 5-speed manual	**BMW i3** (60 Ah) 125 kW electric motor, 1-speed automatic
Compact	**Toyota Prius c** 1.5 L, 4 cylinder hybrid, continuously variable	**Ford Focus Electric** 107 kW electric motor, 1-speed automatic
Mid-size	**Toyota Prius** 1.8 L, 4 cylinder hybrid, continuously variable	**Nissan LEAF** 80 kW electric motor, 1-speed automatic

APPENDIX

PESTLE Analysis

Political	Economic	Social	Technological	Legal	Environmental
• External partnerships • E3 Certification and rating requirements	• Rising prices of gasoline • Vehicle salvage value • High maintenance costs • Alternative fuel pricing	• User adoption (departments) • Training	• Advancement of fuel consumption technology • Anti-idling technology • Limited infrastructure on-campus (ex:/ Charging stations, CNG stations) • Emergence of electric vehicles	• Fleet partnership with Automotive Resources International expiring in 2018 • UBC Parking partnerships with car-sharing companies	• Decrease GHG emissions • Decrease fuel consumption

APPENDIX

Vehicles Used For Analysis

Vehicle	Fuel Used Idling
Trash Truck	875.74
2013 S7B TRANSIT CONN	525.41
2014 CY5F1T TUNDRA	522.47
2014 CY5F1T TUNDRA	518.82
2014 CY5F1T TUNDRA	494.03
2013 S7B TRANSIT CONN	405.31
2010 TRANSIT CONNECT	404.35
Small Dump	367.95
2013 S7B TRANSIT CONN	338.73
Tacoma	337.91
Small Dump	290.49
2013 25C144 SPRINTER	279.93
Transit Cargo	256.41
Tacoma	255.24
Transit Cargo	247.71
Tacoma	234.26
2013 S7B TRANSIT CONN	233.58
2010 TRANSIT CONNECT	231.15
2010 TRANSIT CONNECT	231.15
Small Dump	227.15
Transit Wagon	225.32
Small Crane	223.74
Small Box Truck	223.50
Small Dump	218.08
Tacoma	209.21
Transit Cargo	207.25
Transit Cargo	206.64
Tacoma	203.96
Tacoma	200.74
2013 S7B TRANSIT CONN	199.21

Transit Cargo	185.59
2013 S7B TRANSIT CONN	181.40
Tacoma	178.36
2013 S7B TRANSIT CONN	172.54
Transit Cargo	164.41
2013 S7B TRANSIT CONN	163.37
2013 25C144 SPRINTER	146.03
2014 3C1444 SPRINTER	145.17
2013 TX4CNP TACOMA	144.17
2013 TY5F1T TUNDRA)	143.73
2013 S7B TRANSIT CONN	138.15
2013 TACOMA	128.73
2013 S7B TRANSIT CONN	127.03
2013 25C144 SPRINTER	126.31
2010 TRANSIT CONNECT	123.13
2013 S7B TRANSIT CONN	121.44
2013 S7B TRANSIT CONN	119.66
Tundra	117.76
2013 S7B TRANSIT CONN	112.71
2013 S7B TRANSIT CONN	109.97
2013 S7B TRANSIT CONN	106.59
2013 S7B TRANSIT CONN	103.58
2013 S7B TRANSIT CONN	100.41
2013 S7B TRANSIT CONN	97.35
2013 S7B TRANSIT CONN	96.05
2013 S7B TRANSIT CONN	94.30
2010 TRANSIT CONNECT	88.57
2013 S7B TRANSIT CONN	87.05
2013 S7B TRANSIT CONN	86.09
2013 S7B TRANSIT CONN	83.21
2013 S7B TRANSIT CONN	80.23
2013 S7B TRANSIT CONN	77.81
2013 S7B TRANSIT CONN	75.49

2013 S7B TRANSIT CONN	72.96
2013 S7B TRANSIT CONN	71.62
2013 S7B TRANSIT CONN	60.78
2013 S7B TRANSIT CONN	60.15
2013 S7B TRANSIT CONN	59.79
2013 S7B TRANSIT CONN	42.52
2013 S7B TRANSIT CONN	35.14
2013 S7B TRANSIT CONN	32.52
2013 S7B TRANSIT CONN	31.92

APPENDIX

These vehicles were used in our analysis.

The criteria for selecting included:
- Newer than 2010 Vehicle
- High fuel usage while idling (>100L)
- Standardization (all 2013 Transit Connects despite low fuel usage)

These are an example of the potential vehicles. Further analysis would be required to select the final vehicles