GREEN FLEET CONSULTING
A STRATEGY FOR UBC FLEET MANAGEMENT

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University of British Columbia

COMM 486M

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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

Ryan Diemert
Focus: Business Environment, Electric Vehicles, Risk Analysis

Arman Mazhari
Focus: Strategy, Tech Tactics, Implementation Plan

Steven Petterson
Focus: Key Issues, Financial and Environmental Analysis

Harleen Manihani
Focus: Business Environment, Vehicle Replacement, Success Metrics

Sid Mookerjee
Focus: Business Environment, Tech Tactics

OVERVIEW | RECOMMENDATIONS | IMPLEMENTATION

Our team has been tasked w th the m ss on of mprov ng UBC's veh c e f eet eff c ency from a f nanc a , soc a , and env ronmenta perspect ve Throughout th s presentat on, you w earn of the many ways our research of the current s tuat on, key ssues, and potent a so ut ons has nd cated how th s s poss b e The goa of th s pro ect s to set up a framework of eva uat on cr ter a for UBC to use n the future when cons der ng d fferent opt ons to ncrease f eet eff c ency We have nc uded strateg c and tact ca recommendat ons of our own to g ve these f nd ngs a more pract ca d rect on A ongs de our recommendat ons, we have conducted f nanc a feas b ty and env ronmenta mpact ana yses, a ong w th r sk cons derat ons, success metr cs, and an mp ementat on schedu e to make th s p an comprehens ve We hope you f nd va ue n our work and ook forward to hear ng back from you

Current Position – UBC Building Operations

Project Pegasus

<u>Key Goals</u>
Phase 1: Reduce GHGs an additional 33% from 2007 levels by 2015
Phase 2: Reduce GHGs to 67% below 2007 levels by 2020
Phase 3: Eliminate 100% of GHGs by 2050

Achievements

- UBC positioned as first E3 recognized university
- 44% reduction in GHGs since 2007

On the Horizon

- Meeting/surpassing Phase 2 GHG targets
- Reduction in idling emissions to meet goals
- Phasing out gas powered fleet

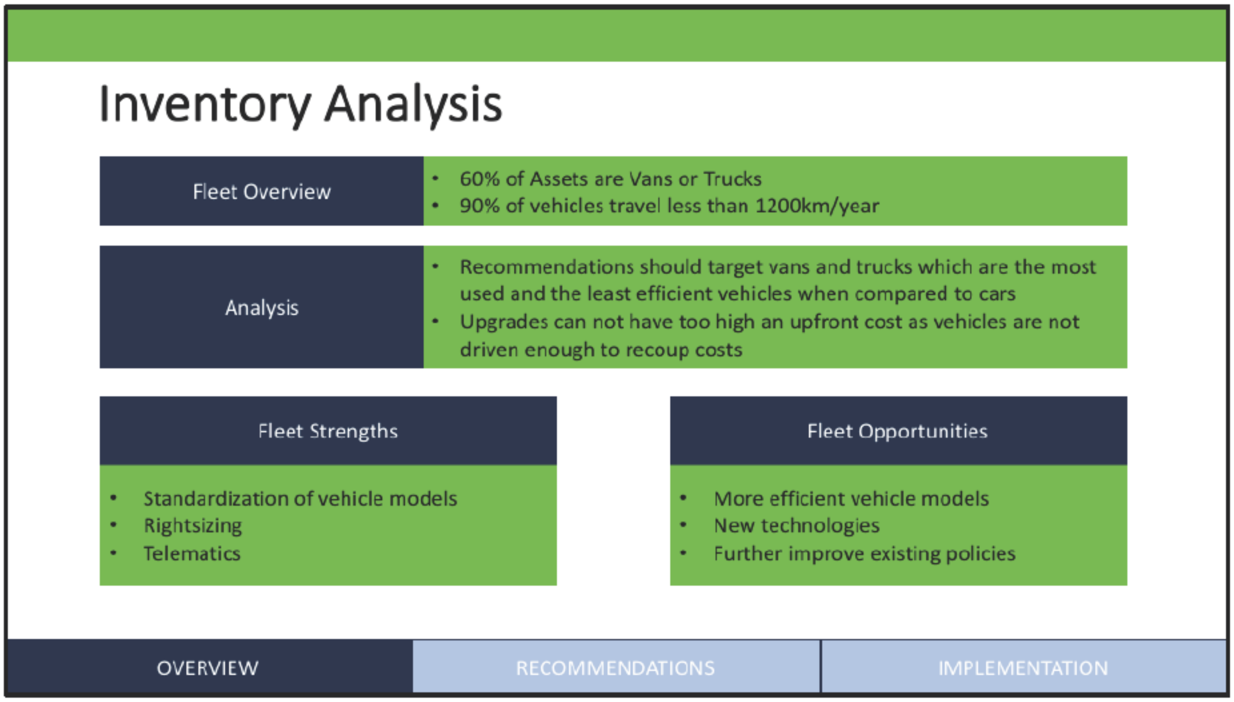
OVERVIEW | RECOMMENDATIONS | IMPLEMENTATION

S nce former UBC Pres dent Stephen Toope announced the schoo 's aggress ve C mate Act on P an targets of 2010, many steps have been taken to ncrease the eff c ency of the campus veh c e f eet S nce the announcement, GHG em ss ons are down an est mated 44% on 2007 f gures 11% further than targeted A so s nce the 2010 announcement, 125 f eet veh c es have been rep aced w th more eff c ent counterpa ts
UBC s the on y un vers ty campus w th E3 (energy, env ronment, exce ence) status, earned through meet ng the h gh standards of E3s f eet rev ew and f eet rat ng process
UBC s on ts way to becom ng a wor d eader n veh c e f eet operat ona eff c ency and s act ve y surpass ng target goa s
However, w th d m n sh ng marg na GHG em ss on reduct ons (13%, 8%, 6% reduct on changes for 2014, 2015, 2016 f gures respect ve y), t appears un ke y UBC can ach eve ts Phase 2 goa s of a 67% decrease on 2007 GHG em ss on f gures n the next 3 years (by 2020) w thout mp ement ng exp oratory p ot tact cs Fu ther, n order to e m nate 100% of GHGs UBC must sh ft ts focus to a comp ete overhau of ts f eet over the next 30 years
Targets
Em ss on Goa s (us ng 2007 em ss ons of 833 tCO2e as base ne)
- 33% by 2015 (target = 558 tCO2e) ✓
- 67% by 2020 (target = 275 tCO2e)
- 100% by 2050

F eet goa s by 2016
- 20% of the f eet e ectr c ✓
- 80% of the f eet rep aced ✓
- Average age of f eet < n ne years ✓

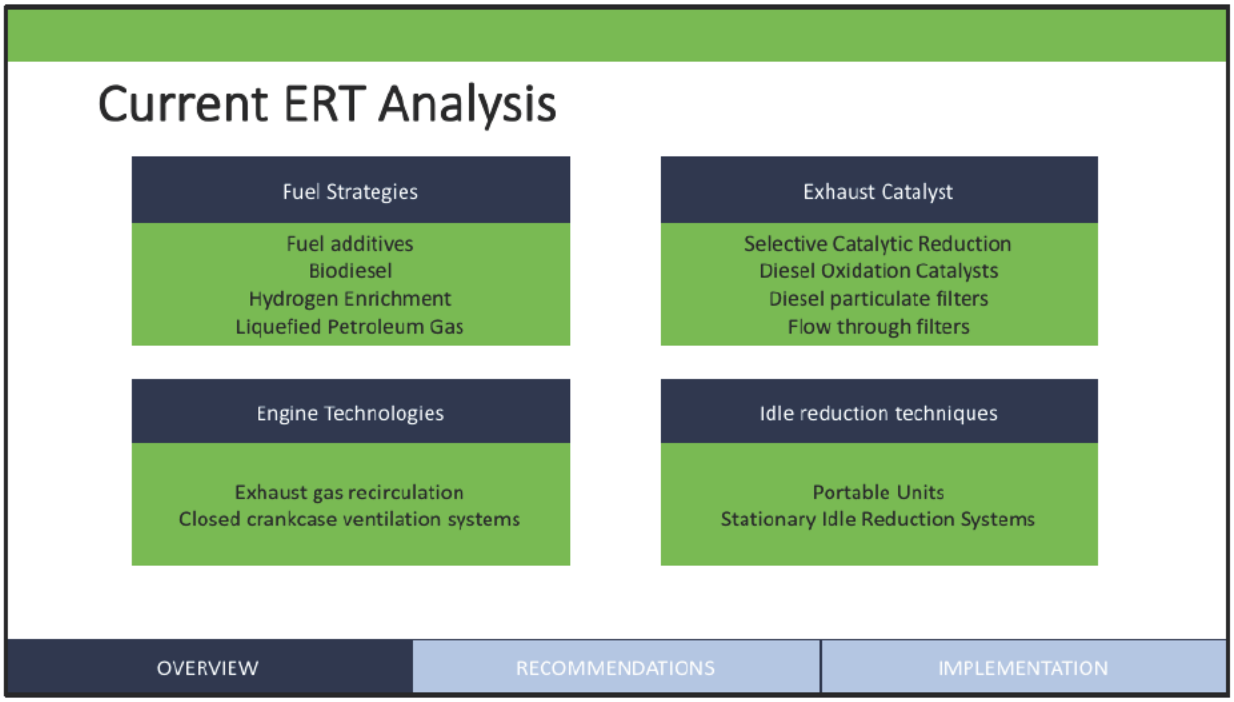
d ng (Us ng 38 tCO2e per annum as base ne)
- 25% reduct on by 2014
- 50% reduct on by 2015
- 75% reduct on by 2020
- 100% reduct on by 2025

t s nterest ng to note that 690 tonnes of GHG em ss ons were recorded n 2012 n the same year, the d ng base ne est mate was 43 tonnes of GHG em ss ons
43t/690t = **6.2% of total GHG emissions were a result of idling in 2012.**



After an ana ys s of UBC F eet’s nventory we not ced a coup e of key p eces of data that gu ded our ana ys s The f rst be ng that the c ear ma or ty of assets are arge veh c es ke vans or trucks These veh c es tend to be ess fue eff c ent then cars, and have ess e ectr c a ternat ves ava ab e Another th ng to note about the nventory s that over 90% of assets trave ess than 1200 Km’s a month We are not go ng to recommend someth ng that has a very arge upfront cost because these veh c es aren’t dr ven enough to recoup that cost, even f the cost of operat on s dramat ca y reduced

We not ced a few po ces that we rea y ke and we aren’t go ng to change To sta t, we want to keep a standard mode for each veh c e category Th s reduces the cost of repa rs and ma ntenance because the mechan cs on y need to have parts for those few mode s UBC a so has a r ghts z ng po cy wh ch s a so someth ng that makes the f eet more eff c ent t’s mportant to have the r ght veh c e for the ob so you don’t have too many veh c es that you don’t need or use a arge veh c e when a sma er, more fue eff c ent veh c e wou d suff ce Te emat cs are a techno ogy that UBC shou d cont nue to nvest n They a ow data co ect on to further mprove ex st ng po ces and gu de new ones



W th regards to eva uat ng new techno og es, we factored n a poss b e and popu ar ERT techno og es current y be ng used n the ndustry The tab e dep cts a current ERT techno og es as h gh ghted n the Transpo tat on Research Record Journa by academ cs Dr Mohamadreza Farzaneh, Gokhan Mem sog u, and K avash K anfar As seen above, there are 4 ma n techno ogy categor es Hav ng extens ve y ana yzed our pr mary and seconda y research data, we have focused our efforts and chosen two ma n categor es wh ch wou d he p ach eve our goa s These are Exhaust Cata ysts and d e Reduct on techno og es We be eve both these categor es are a strateg c f t for the company and sat sfy our dec s on cr ter a, wh ch s fundamenta y rooted n ach ev ng our target of creat ng a s gn f cant y more eff c ent and cost effect ve f eet of veh c es, wh e s mu taneous y dramat ca y reduc ng f eet veh c e greenhouse gas em ss ons

The reason why we have not chosen eng ne techno og es and fue strateg es are two fo d; the setup costs are h gh as the techno ogy tse f s d ff cu t to nsta as t requ res e ther “rebu d ng”, “repower ng” or “rep ac ng” n add t on, there s not enough data to suggest that these two techno ogy categor es are effect ve n reduc ng GHG em ss ons For nstance, EGR’s may ncrease PM, HC and CO em ss ons and b od ese can ncrease NOx em ss ons accord ng to the Transportat on Research Record Journa

W th regards to the two categor es we have chosen, both c ear y sat sfy our dec s on cr ter a The data nd cates that there are s gn f cant fue sav ngs, a measurab e mpact of the reduct on of GHG em ss ons and both techno og es are easy to mp ement n a current and future veh c es Our pr or ty was that there wou d be a short payback per od and that the techno ogy can be eas y retrof tted Thus we recommend mp ement ng the ant d ng techno ogy of D rect F red Heater n 85% of the d ese veh c es by 2020 and E ectr ca y Ass sted D ese Part cu ate F ters n 85% of the d ese cars by 2030 (assum ng techno ogy becomes ava ab e)

Car Share Analysis

UBC Parking as a Customer

- Car2go
- Modo
- Zipcar
- Evo

UBC Parking as a User

- Non-Existent

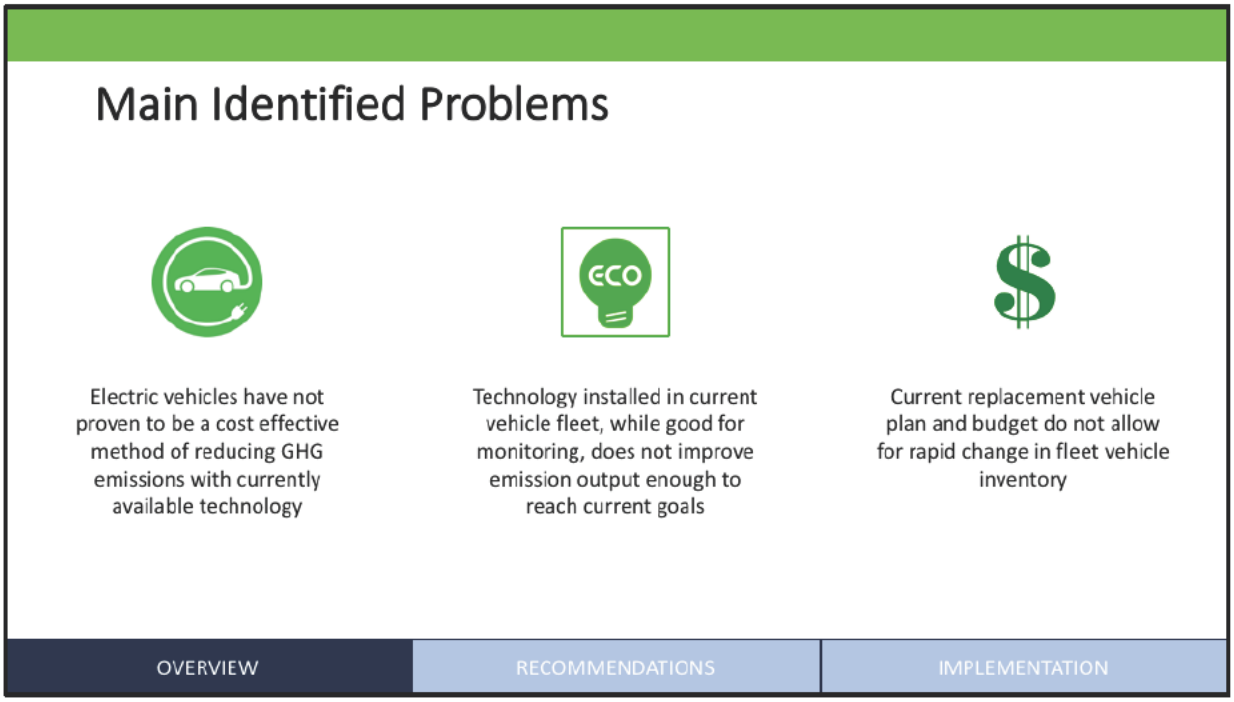
Although helpful with GHG emission reductions, not cost efficient when considering entire fleet.

Barriers include slow adoption and hesitation amongst departments regarding ownership of vehicles.

Addresses people-moving vehicles only. Fails to take into account larger, heavy duty vehicles.

OVERVIEW | RECOMMENDATIONS | IMPLEMENTATION

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, e ectr c veh c es – un ess fu y ut zed – represent a cost negat ve approach to reduc ng GHG em ss ons as part of an organ zat on's green f eet p an Wh e t may appear to be the trendy opt on current y, many other Green F eet p ans have found that the purchase or eas ng of e ectr c veh c es has not mproved the r GHG em ss ons effect ve y re at ve to the necessary costs of nfrastructure and the veh c es themse ves:

City of Toronto Consolidated Green Fleet Plan 2014 2018: "Most of the p ug n hybr d e ectr c veh c es (PHEV) and battery e ectr c veh c es (BEV) that have been added at Centra y Managed F eet wou d requ re h gher ut zat on than they have had, n order to reach the r potent a for reduc ng fue consumpt on and ower ng the tota cost of veh c e ownersh p n rea wor d cond t ons, part cu ar y n a c mate w th extreme temperatures, adequate range n BEVs s an mped ment to h gh ut zat on that needs to be managed"

City of Seattle Green Fleet Plan 2014: " n order to expand our EV f eet, we need to strateg ca y estab sh a comprehens ve charg ng nfrastructure network Some of the current cha enges to do ng so nc ude fund ng the n t a cap ta nsta at on cost, ack of e ectr ca capac ty n bu d ngs and estab sh ng the ro es and respons b t es of p ann ng, acqu s t on, ownersh p and ma ntenance between FAS, Fac ty Operat ons, C ty departments and Cap ta Deve opment"

Current Technology
Current y, the vast ma or ty of UBC Bu d ng Operat on's f eet on y use te emat c report ng and mon tor ng Hybr d veh c es have d e stop techno ogy and a veh c es have Geomat cs nsta ed for mon tor ng purposes Wh e th s array of techno ogy s certa n y he pfu n dent fy ng ssue areas we be eve these a one w not a ow UBC Bu d ng Operat ons to reach the r 2020 em ss on reduct on targets

Overarching Strategy

Using a cost-neutral decision making process, adopt fuel saving technologies in the short term, and transition the fleet to electrically run vehicles when financially viable.

OVERVIEW | RECOMMENDATIONS | IMPLEMENTATION

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

e egasus 5 0 epo , s a es a " d g was es 35,6 L of fue eac yea fo fo y ee o s of GHG em ss o s" T e efo e, s mpe a ve o educe d g by mod fy g d ve be av o a d e fo c g a d g po cy Howeve , ese so u o s wo k bes w e po c es a d be av o based app oac es ave e co ec a d g ec o ogy o comp eme

D ve s e d o keep e ve c es de oe e keep e ea g o o def os e w ds e ds, keep e e g e wa m, fo d ve comfo a d o p ov de e ec ca powe o uck mou ed equ pme Ou c e a UBC, as s a ed a "Was e Ma ageme , Ha d La dscape a d Sof La dscape ave a umbe of spec a zed u s a d e efo e yp ca y fa ou s de of ou s a da d za o p og am Due o pay oad equ eme s w e wo k pe fo med, ese a e some of e eas fue eff c e u s" T e efo e s mpe a ve o a ge ese ve c es o ac eve ou em ss o a ge s

T e easo w y we be eve po cy s o e oug s because eve oug s a es a d ve s a e o a owed o be d e mo e a 3 co secu ve m u es a 60 m u e e va , e fac s a eve mo e a 0 seco ds of d g bu s mo e fue a s a g up o s u g dow e e g e acco d g o a e a u e ev ew co duc ed a pape pub s ed e Jou a of E e gy Co ve s o a d Ma ageme add o , e d g po c es p ace a UBC ave seve a d g excep o s a c ude d g fo safe ope a o (def os g w ds e d), a ow g equ pme o be wa med up a d mo o ve c es a ave equ pme equ g powe f om e e g e T e efo e ce a ve c es a e equ ed o d e due o e a u e of e ob a d s e efo e co bu es o GHG em ss o s T us, a d g ec o ogy a ge s s def c e cy

s a so es ma ed a ea g e cab by d g e ve c e was es ove 85% of e e gy e d ese fue d g cos s 3 2 es of fue pe ou acco d g o e ede a o of Ca ad a Mu c pa es epo o E v o ee s Hg g ed a epo by e Ce a ee Adv so y Comm ee, C y of Ham o , a d g ec o ogy ca cu fue use by mo e a 80% compa ed o d g a d save wea a d ea o e e g e a d e efo e as e po e a o dec ease ma e a ce cos s

ofesso A a Mck o s book "G ee Log s cs mp ov g e E v o me a Sus a ab y of Log s cs" s a es a yb d ve c es a d a d g ec o og es a e e eva o g du y ve c es a d va s "due o e g p opo o of ope a o s ca ed ou s op s a e v o me s a d mu d op de ve y ou ds" He a so s a es a ese ec o og es w becom g c eas g y popu a e ea fu u e a d w be co po a ed w f ee ma ageme sys ems

Se o expe s e f e d, D S a c a, H H Mas uk , M A Ka am, M R zwa u a a , M M Ras ed, H K Ras edu w o ave pub s ed e pape e Jou a of E e gy Co ve s o a d Ma ageme , ave s ow a "e e gy co sump o w R ec o og es s muc owe a ose w ou d g ec o og es, a d eve e eas -eff c e op o s ex b ed a a mos e a y educ o fue usage" T us, desp e e e fo ceme of a d g po c es UBC, we be eve a e ec o ogy s c uc a fo e po cy o be effec ve o add ess e ssue of GHG em ss o s o 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

n the meta ana ys s paper n the Journa of Energy Convers on, a current R techno og es have been cons dered, eva uated and d scussed The tab e above shows the current and popu ar ant d ng techno og es ava ab e commerc a y n the market For a pract ca purposes, on y a few of the techno og es have been presented based on mmed ate requ rements of the c ent and dec s on cr ter a f t The techno og es present a so prov de a rough dea of a the d fferent var et es of techno ogy ava ab e n the ant d ng techno ogy catego y For nstance, many of the other R techno og es have a neg g b e mpact of GHG em ss ons and fue sav ngs For a more deta ed tab e w th a R techno og es sted, p ease refer to Append x X

Aux ary Power Un ts Sma eng nes that prov des power to heat and coo the veh c e
D rect F red Heater Supp es heat from a combust on f ame to a heat exchanger
Automat c Shutdown/Startup systems Starts or stops the eng ne based on def ned parameters
Fue Ce s Uses a Proton Exchange Membrane Fue Ce s (PEMFCs) or a So d Ox de Fue Ce (SOFC) to supp y energy to the veh c e
E ectr c Shorepower So ut ons Prov des p ug n e ectr c power
Energy Recovery Systems Supp y e ectr c power for heat ng

From the tab e above t s c ear that D rect F red Heaters (DFH) use the east amount of fue compared to other R techno og es n add t on, True Aux ary Power Un ts (APU) and D rect F red Heaters are the two techno og es that best f t our dec s on cr ter a Automat c Shutdown/Startup Systems, for nstance, are hard to f nd commerc a y, e ectr c Shorepower so ut ons have h gh nsta at on costs and Energy Recovery Systems do not prov de enough warmth for dr ver comfort
t s a so mportant to note that So ar Powered APU's and hybr d so ut ons were cons dered but there was not enough data for these emerg ng techno og es to recommend them to our c ent We be eve that the r sk s too h gh a though these techno og es c a m to prov de substant a benef ts When more tests are conducted and as these techno og es become more ma nstream, these techno og es can then be recons dered
Based on the tab e above, we further ana yzed and compared True APU's and DFH's to see wh ch one s more effect ve w th regards to ach ev ng our target set by our c ent We ooked at Fue sav ngs, Reduct on of GHG em ss ons, Ease of mp ementat on and an add t ona cr ter a, compat b ty w th future veh cu e types/techno ogy

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 ournal 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.

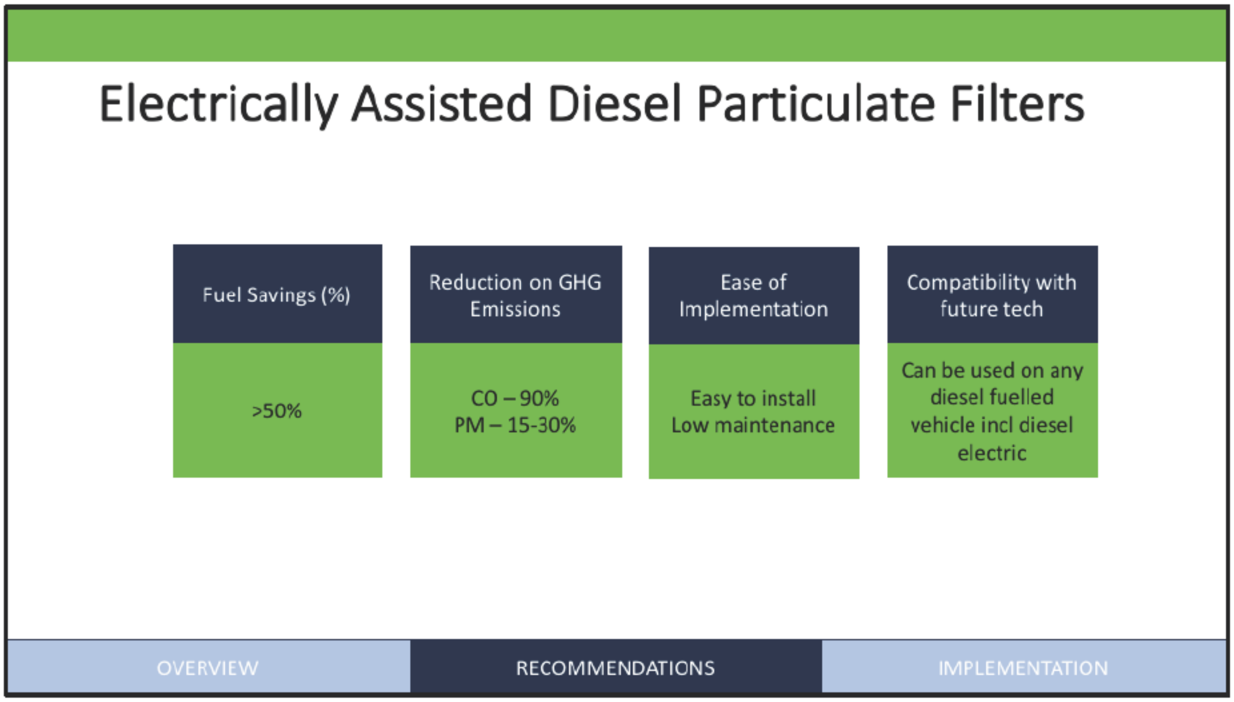
Different types of DFH s cost different amounts. We recommended DFH s that are powered from the vehicle s battery and diesel fuel which cost $1,600 although considering budget constraints, one powered solely from the vehicle s battery should suffice as well. DFH s that are powered solely through the 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.



Ou eam a so ooked a ex aus ca a ys ec o ogy o e p ac eve ou a ge of educ g GHG em ss o s D ese a cu a e e s a e e of ec o ogy a 's w de y W e e cu e ec o ogy s effec ve educ g GHG em ss o s, equ es ex a fue o pe fo m a ege e a o cyc e by c ea g ea e efo e bu g mo e fue esu g owe ove a fue eco omy Ou eam us dec ded o ves esea c g a e a e ec o og es ways a add ess s p ob em We fou d a Ge e a Mo o s as bee c ea g a af e ea me sys em a co po a es e ec c y a e a fue o a se e empe a u e e d ese pa cu a e f e T s ec o ogy as bee a ed by T uck T e d as " e ex ge e a o of D ese a cu a e e Tec o ogy" T e e a e s g f ca be ef s a cou d be ea zed f om s ec o ogy suc as ue sav gs a d educ o GHG em ss o s s a so ex eme y easy o mp eme as wou d come w e e g e fac o y s a ed o e of ed T e a es s of e EAD sys em was co duc ed us g a fou cy de 9L CDT a /GM e g e T s mea s a s ec o ogy cou d be used o V-6 a d V-8 e g es us e of g a va e y of GM ve c es, f om e C ev o e Spa k o Esca ade SUVs

Tes s by Ge e a Mo o s e Oak dge Na o a Labo a o y ave s ow a e E ec ca y Ass s ed D ese a cu a e e (EAD) ec o ogy esu s a 50% educ o fue pe a y compa ed o co ve o a D s a d o e fue -based ege e a o ec ques Mos mpo a y, e ege e a o me s educed by 60% w e EAD w c s pa cu a y be ef c a fo ve c es a a e s op a d s a c y e v o me s as e e a e f eque ac ve ege e a o e va s w c educe e fue eco omy T e es s evea ed a ege e a o ook 4 o 6 m u es a d e m a ed 80-90% of e apped soo w c esu s g ea e em ss o educ o a ad o a D s

W e exac cos s a e u k ow fo s ec o ogy, we used seve a ma ke p ace webs es suc as eBay o come up w a es ma o w ow muc a o ma D cos s Ou esea c s owed a e cos s wou d a ge f om $400 o $3000 depe d g o e ve c e We be eve s wou d g ve us a oug dea as o ow muc EAD 's wou d cos was a c pa ed a GM wou d mp eme s ec o ogy e 20 7 mode s bu as bee de ayed T e efo e, ou eam as dec ded o e of 85% of d ese ve c es w s ec o ogy (p ov ded s ava ab e) by 2030 Neve e ess, e ec o ogy s expec ed o come fu y s a ed e ve c e Acco d g o e E v o ee Repo by e ede a o of Ca ad a Mu c pa es, o ma d ese pa cu a e f e s "ca emove up o 90 pe ce of ca bo mo ox de a d yd oca bo s, educe pa cu a e ma e by be wee 5 a d 30 pe ce , a d educe o se" T us, a EAD cou d do s a d add o e fue eco omy a d c ease sav gs

mp eme g s ec o ogy s easy as ca be used o a y d ese fue ed ve c e, ow su p u o u a ow su p u d ese a d s compa b e w b od ese Mo e mpo a y, e EAD des g ca be adap ed fo use w fu u e d ese ec o og es suc as au oma c s a /s op ec o ogy a d be e of ed d ese e ec c ca s ca eo e ca y be used C ev o e S e a 500 yb d p ckup ucks, a d ese powe ed e ec c yb d suc as e C ev o e Vo , d ese e ec c yb d suc as e C ev o e C uz o d ese e ec c powe ed C ev o e Co o ado

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

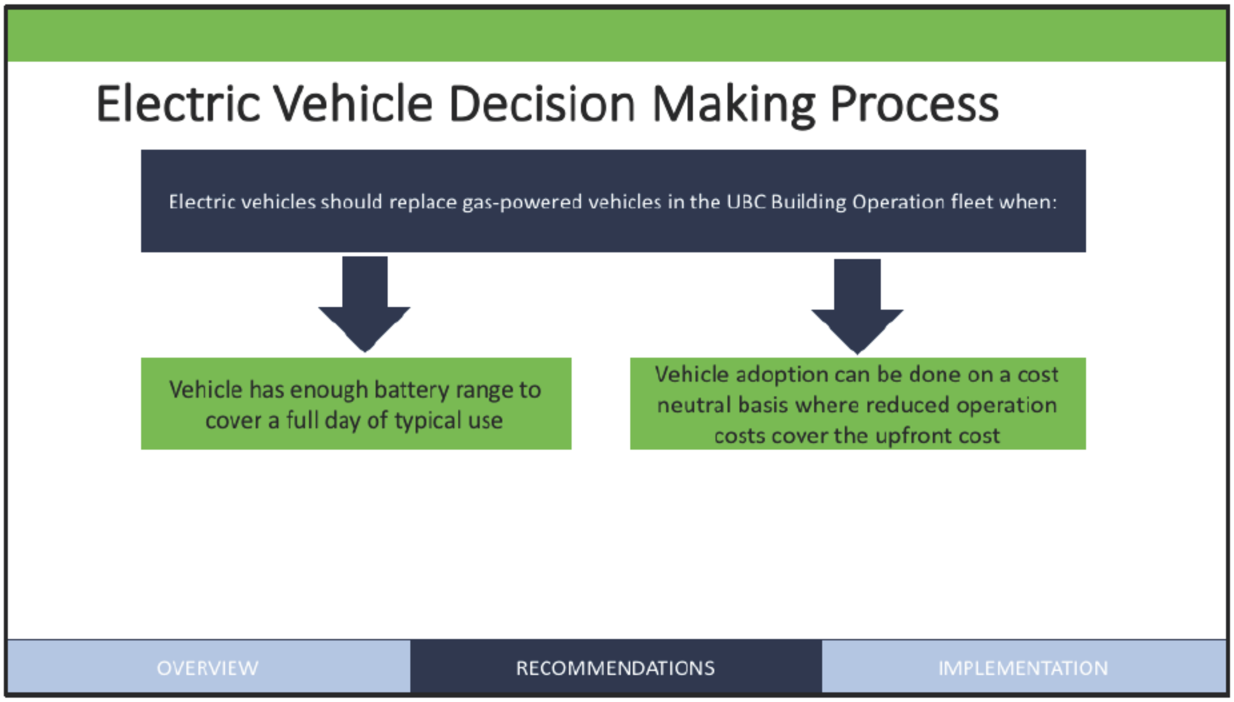
OVERVIEW | RECOMMENDATIONS | IMPLEMENTATION

The second part of our recommendat on nvo ves the stream n ng of UBCs current f eet through strateg c rep acements As part of our three fo d recommendat on, we found that th s opt on acts as an effect ve and eff c ent sho t term so ut on of opt m z ng the f eet n terms of fue economy

We found that keep ng a standard f eet based on veh c e type was an effect ve way to rema n as cost eff c ent as poss b e through the s mp f cat on of ma ntenance and operat ons Through our ana ys s of the standard zed f eet rang ng from vans, trucks, and compact veh c es, we dent f ed areas UBC s exce ng n as we as others w th potent a room for mprovement Overa , UBC Bu d ng Operat ons are effect ve y eva uat ng future veh c e rep acements by cons der ng mportant factors such as fue consumpt on and GHG rat ngs Through further ana ys s of rank ngs on the Natura Resources Canada Fue Consumpt on Gu de, however, there are some ex st ng mode s that cou d potent a y rep ace current veh c es w th n the f eet Spec f ca y, we wanted to ook further nto our rep acement opt ons for current nventory of Ford Trans ts, Toyota Tacoma's, and Tundra's W th mprovement n van and med um s zed p ckup truck nventory, there s great potent a to reduce GHG em ss ons through the stream n ng of the standard zed f eet

To determ ne whether these recommendat ons were v ab e opt ons, we cons dered the fo ow ng dec s on cr ter a: Est mated annua fue cost, est mated CO_2 em ss ons, a ternat ve fue opt ons, and rank ngs amongst the Natura Resources Consumpt on Gu de These cr ter on were based on the standard zat on requ rements as we as the dec d ng factors of purchas ng mode s outs de of the current se ector out ned n the Pegasus report Our f nd ngs ed us to 3 potent a opt ons for rep acement veh c es

When cons der ng the a ternat ve opt on for vans, we found that the N ssan NV200 exceeded the Ford Trans t n three out of four areas A though the est mated cost does not d rect y re ate to UBCs case as the un vers ty purchases fue n bu k, t st shows that overa fue costs are ower for the N ssan van than the Ford Add t ona y, w th the ower GHG em ss ons and h gher NRC rank ng shows great prom se for fue eff c ency The case for p ckup trucks s s m ar as the Chevro et Co orado and GMC Canyon, both equa y fue eff c ent, ead n the rank ngs compared to the f eet's current veh c e cho ces A though these a ternat ves may not yet be us ng CNG, the overa use of GHGs st rema ns ower than current operat ons

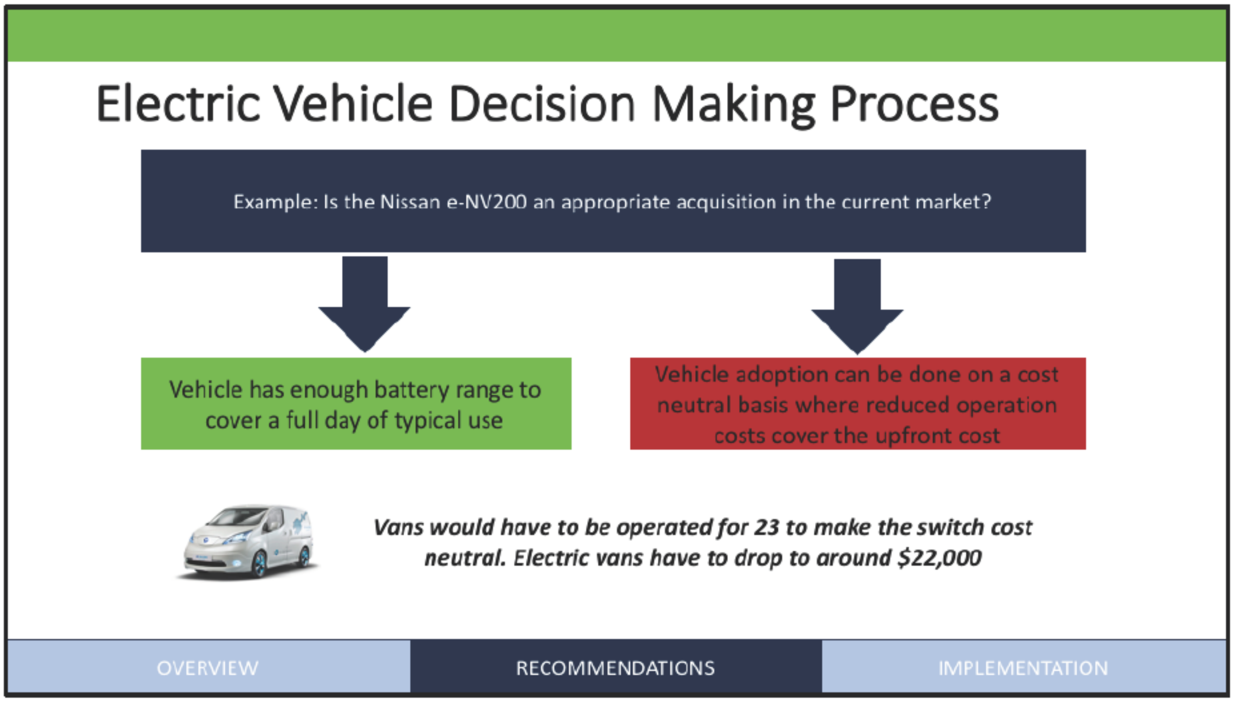


The 2050 goa for the Pegasus pro ect s for CO2 em ss ons to be 100% e m nated The on y way for that to happen s to adopt a 100% e ectr c f eet Keep ng n m nd the des re to standard ze the make of veh c e for each category of veh c e, e ectr c veh c es w be adopted when they pass a test for v ab ty

The range of the e ectr c veh c e's battery has to be arge enough to ast what the da y requ rement of the veh c e s A EV battery usua y takes mu t p e hours to charge so f a battery can't ast a day, there w e ther be a need for mu t p e veh c es to be rotated, or an nterrupt on n work

Current y E ectr c Veh c es cost substant a y more than a regu ar veh c e, but cost substant a y ess to operate When the cost to operate an e ectr c veh c e over ts fet me s the same as a gas veh c e, those e ectr c veh c es shou d be adopted

For veh c es ke garbage trucks, the advantage of ower costs of operat on s more prom nent because garbage trucks need more fue to operate However, t w ke y take onger before techno ogy advances to the po nt where a fu y e ectr c veh c e w th capab e range s ava ab e For sma er veh c es ke the Ford Trans t Connect, e ectr c veh c e techno ogy s a ready ava ab e n certa n countr es However, ana yz ng the use of these veh c es revea that the ower cost of operat on doesn't offset the h gher n t a cost qu te yet



We are go ng to use a new p ece of EV techno ogy, the N ssan e NV200, that s ava ab e n Europe and As a as an examp e The e NV200 s a sma e ectr c van that cou d rep ace the Ford Trans t trucks that current y occupy around one f fth of the current UBC f eet

The f rst part of our process s to determ ne f the veh c e has enough battery range to ast over an average work day The N ssan e NV200 has a range of 170kms on one battery charge After an ana ys s on the use of Ford Trans t vans we determ ned that on average a van trave s 3700 Km per year and the furthest trave ng vans cover around 13000km a year Assum ng that there sn't too much var at on n the amount that a truck s used on a day to day bas s, that means the N ssan e NV200 has more than enough battery range to ast over an average day

Now next to the second part of the process, the cost ca cu at on We found that there are no veh c es that wou d benef t on a cost bas s from the sw tch to e ectr c veh c es UBC s mp y does not dr ve the r vans enough to make the ower cost of operat on wo th the expens ve cost at the out ay We found that the average van wou d have to be used for 23 years to make the nvestment cost neutra , or e ectr c vans need to drop n pr ce to $20,000 to make th s upgrade make f nanc a sense Thus, the N ssan e NV200 does not pass our dec s on process and we recommend wa t ng for cheaper e ectr c veh c es to come ava ab e

UBC Building Operations

Current Financial State and Environmental Impact

Financial State

Annual Budget	$1,800,000
Maintenance Costs	$285,000
Estimated Fuel Costs	$350,000
Estimated Lease Costs	$900,000
Remaining Budget for Staff, Aux. Expenses	$265,000

Environmental State

Estimated GHG Emissions/Year by UBC Building Ops

713 Tonnes

GHG Emissions/Dollar Spent (vehicle direct)

0.93 Pounds/Dollar

Average Litre/100km of current emitting vehicles

24.0

OVERVIEW | RECOMMENDATIONS | IMPLEMENTATION

n order to assess the cost effect veness and env ronmenta mp cat ons of our recommended so ut ons t s f rst mportant to understand the assumpt ons ay ng beneath our ana ys s of UBC F eet Management's current state For our ca cu at ons we used current f eet numbers for a veh c es w th a p anned rep acement after 2015/2016 and we used rep acement veh c e numbers for a veh c es w th a p anned rep acement dur ng the 2015/2016 per od or ear er Our assumpt on was that these rep acements d d n fact happen

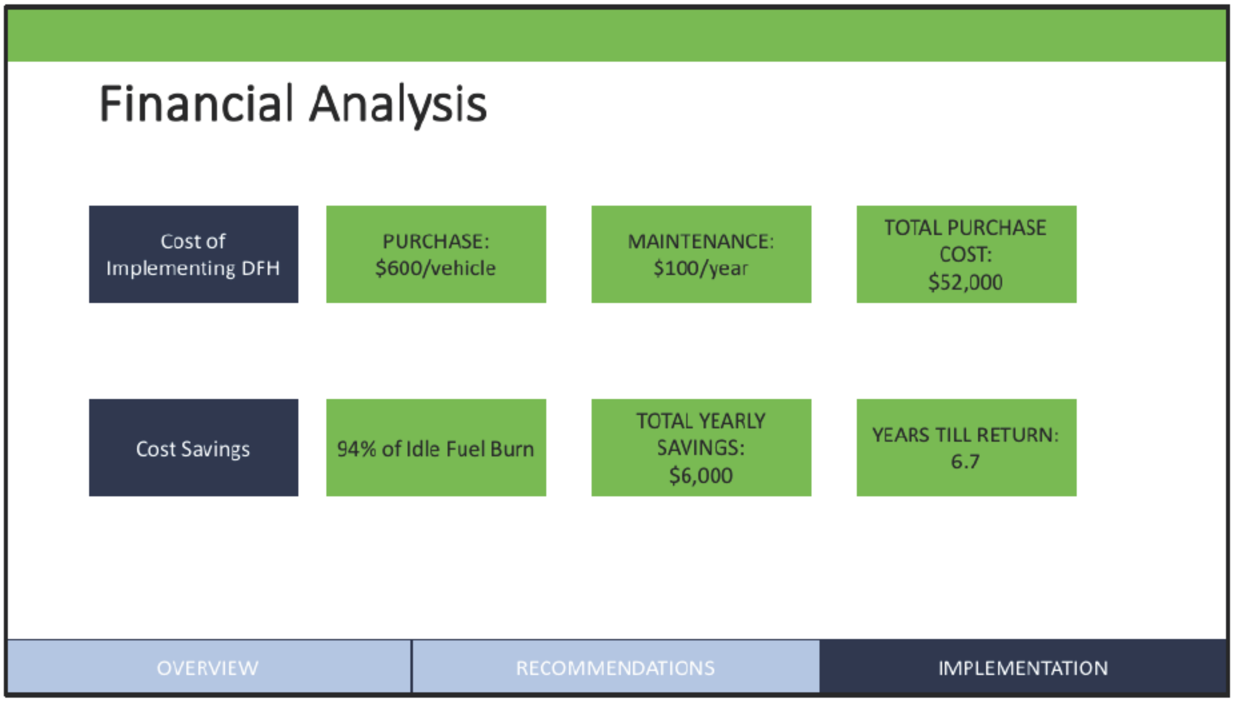
Financial State

Annual Budget: The fleet manager described the annual budget for UBC Fleet Management dur ng quest on per od.
Maintenance Costs: S nce there were no ma ntenance cost numbers prov ded for rep acement veh c es, we used the o d veh c e ma ntenance costs as a p aceho der Natura y, we wou d assume that th s number w , n rea ty, be ower – but not s gn f cant y ower where t w make a d fference n our ana ys s
Fuel Costs: Our Fue Cost Est mat on was done by pr c ng the ex st ng L tres Consumed' annua y for each veh c e at $1 29, the current cost of gas n Vancouver
Lease Costs: The Lease Cost was ca cu ated by tak ng a ex st ng eases, determ n ng the r month y cost, and trans t on ng th s to a year y amount

Th s eaves rough y $265,000 n the annua budget wh ch we assume s used for staff ng and aux ary expenses

Environmental State

Tota GHG Em ss ons annua y were ca cu ated us ng a 20 pounds of C02/ tre of gas and/or d ese n rea ty, gas em ts s ght y ess than 20 pounds per tre on average, wh e d ese burns s ghter more than 20 pounds per tre on average Overa , we be eve our 20 pound assessment s fa r, and f anyth ng s s ght y on the h gh s de When ca cu at ng our em ss ons/do ar spent we *did* nc ude smart cars and ow em ss on veh c es However, when determ n ng the average tre/100km used n the f eet we d d not We be eve th s g ves us a better understand ng of how c ean techno ogy can he p those veh c es n our ana ys s



n order to reach a return on cap ta expend tures when purchas ng DFH techno ogy, the techno ogy shou d on y be nsta ed on the h ghest ut zat on veh c es We have dent f ed 73 veh c es n the f eet that are h gh em tters of em ss ons and that use a s gn f cant amount of fue throughout the year A st of these veh c es s supp ed n the append ces

We est mate that these veh c es d e for approx mate y 15% of the t me that they are n use

Year y ma ntenance costs for 73 veh c es nsta ed w th DFH techno ogy costs $7,300

The overa cost sav ngs from ower fue usage equates to approx mate y $13,000/year

W th 6 7 years t return on mp ementat on we be eve th s techno ogy s a v ab e so ut on that prov des cost neutra expend tures wh e de ver ng mproved GHG em ss on reduct on over the suggested (6 10) fet me of UBC F eet Management veh c es

Due to the unknown nature of EADPF techno ogy we have not comp eted f nanc a ana ys s of mp ementat on as we v ew th s as a m d ong term so ut on We acknow edge that the EADPF techno ogy wou d need to be nsta ed n on y h gh ut zat on veh c es n order to prove a cost neutra so ut on

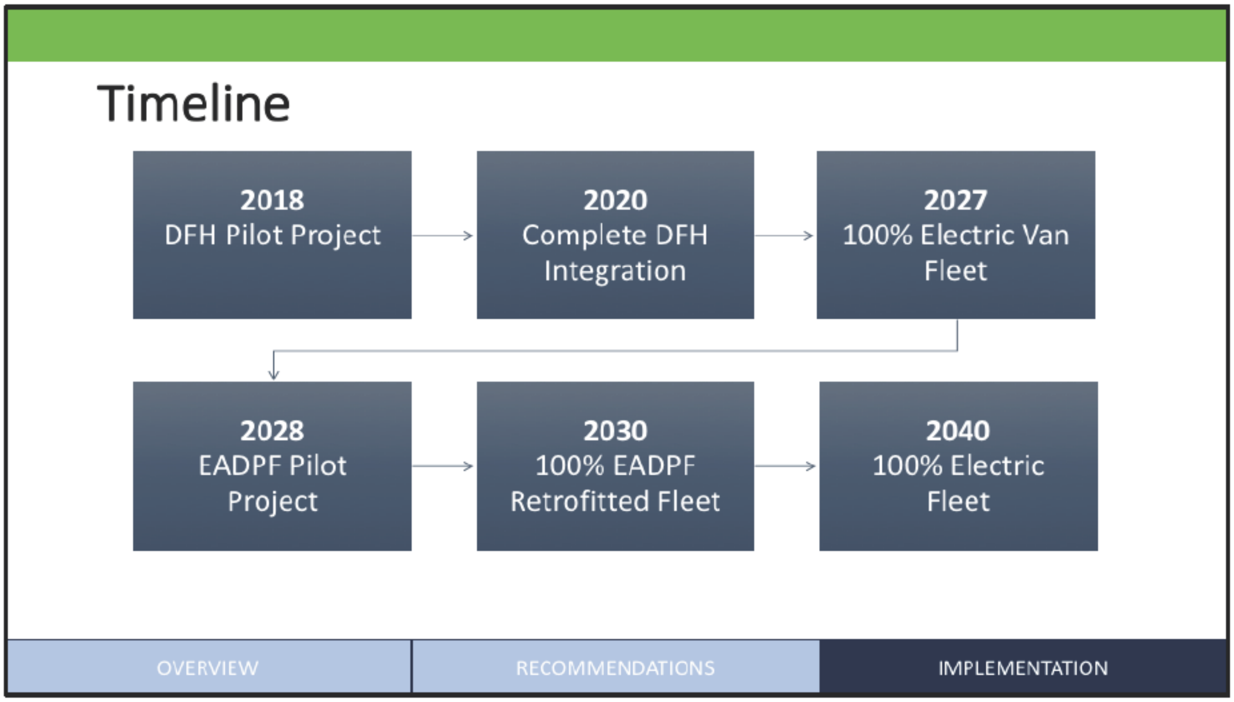
Environmental Analysis

Fuel Savings (%)	Reduction on GHG Emission	New L/100km
14.1%	70,000 pounds/year	20.43

OVERVIEW | RECOMMENDATIONS | IMPLEMENTATION

The ntroduct on of DFH techno ogy can de ver s gn f cant resu ts n both the short term and ong term By nsta ng DFH nto the 73 veh c es dent f ed we are ab e to see pos t ve GHG em ss on re ated resu ts after ust the f rst year

For the 73 veh c es w th DFH nsta ed, they w see a 14 1% decrease n the amount of fue used over the course of a year Th s amounts to 70,000 pounds/year, or a 5% reduct on n overa GHG em ss ons put out each year by UBC F eet Management When compared to a 0 2% of the overa budget we fee th s s a s gn f cant return on nvestment



S nce the aggress ve C mate Act on P an targets of 2010, UBC has cons stent y met the audac ous goa s set for tse f Bu d ng Operat ons n part cu ar has cons stent y str ved for the utmost n eff c ency wh e ts m n m z ng env ronmenta mpact Over the next 30+ years, we be eve UBC shou d set the bar even h gher for tse f, and broaden ts strateg c v s on to nvo ve more spec f c goa s and f gures We be eve the fo ow ng t me ne can he p ach eve exact y that

2018: DFH Pilot Project

Before undertak ng exper menta techno ogy adopt on comp ete y, we recommend UBC conduct a sma p ot pro ect on no more than 3 nd v dua veh c es and track the r progress over a 3 month per od Because UBC has not yet used D rect F re Heater techno ogy, t s adv sab e to test the pro ect on a sma sca e before fu sca e mp ementat on

2020: full DFH Installation

After gather ng nformat on of the DFH p ot pro ect through Geotab techno ogy, UBC wou d have the f gures necessary to determ ne f fu sca e mp ementat on of DFH techno ogy s feas b e and ts potent a effect veness

2027: 100% Electric Van Fleet

Because vans account for more than 25% of UBC's campus veh c e f eet, because of the r homogeneousness, and because of the r extens ve use on campus, we recommend comp ete e ectr c van mp ementat on sooner than other veh c es n the f eet

2028: EADPF Pilot Project

E ectr ca y Ass sted D ese Part cu ate F ters (EADPF) are aga n, an exper menta techno ogy UBC has yet to ncorporate nto ts operat ons f eet Because of th s, we recommend a sma sca e retrof t of 2 5 veh c es pr or to commenc ng fu sca e mp ementat on, n order to gather more nformat on and cons der the f nanc a feas b ty of the move w th nformat on gathered from p ot veh c es

2030: 100% EADPF Retrofitted Fleet

W th co ected data, UBC w be ab e to make an nformed dec s on on mov ng forward w th retrof tt ng the ent re f eet w th EADPF techno ogy

2040: 100% Electric Fleet

Our ana ys s po nts to 100% e ectr c veh c es n the UBC operat ons f eet by 2040 – 10 years ahead of schedu e

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 s the r sk that veh c es and dr vers are a ready fu y opt m zed and the techno ogy we are recommend ng w not have any pos t ve mpact on gas costs A though there a ready s techno ogy and po c es n p ace, there s a ways room for mprovement Our m t gat on to th s r sk s to test these techno og es n a sma number of veh c es f rst before expand ng to the rest of the f eet

The second r sk s that UBC w reduce UBC F eet Serv ce's budget Th s has a ow sever ty because UBC f eet has such an essent a mandate and t's not rea y someth ng UBC can ve w thout To m t gate th s r sk UBC F eet Serv ces shou d cont nue to become more eff c ent on a cost and em ss ons bas s and commun cate these successes

The next r sk s that E ectr c Veh c e Techno og es do not advance and/or become cheaper Th s r sk has a ow probab ty because the demand for arge e ectr c veh c es s so h gh n add t on, most est mates show that there w be a arge reduct on n pr ces for e ectr c veh c es over the next few decades

The ast r sk s that more facu t es dec de that they are better off on the r own and take care of the r own veh c e serv ces, reduc ng the effect veness of any UBC F eet Serv ces n t at ves To m t gate th s r sk UBC F eet Serv ces shou d commun cate the r successes and show departments the va ue they create by opt m z ng costs and reduc ng em ss ons

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

Deve op ng re evant metr cs s cruc a when mp ement ng a new strategy We be eve we have dent f ed four metr cs that w he p UBC F eet Management understand the effect that our recommended suggest ons have n both the short term and ong term:

Fuel Efficiency

There are many metr cs that can he p te us whether we are becom ng fue eff c ent, but we prefer to cont nue us ng the standard L/100km metr c that s a ready be ng measured by UBC F eet Management to track success here Current y veh c es that em t em ss ons n the f eet use 24 tres per 100 k ometres Our goa for th s metr c s to see a decrease n both the short term and ong term A decrease n the amount of gas/d ese used per k ometre means both ower costs for gas n the future and a so ower em ss on output

Cost Efficiency

UBC F eet Management needs to ensure that the purchases they are mak ng resu t n cost sav ngs n the ong run wh e reach ng cost neutra n the short run The best way to do th s wou d be to track cost sav ngs veh c e by veh c e When techno ogy has been nsta ed n a veh c e, how much ess does that veh c e cost the f eet over the next 5 10 years n ma ntenance and fue Th s number shou d be compared to the n t a cap ta expend ture to ensure that money s be ng spent w se y

Efficient Purchasing

Th s t es n w th cost eff c ency Wh e we want to make sure we are gett ng a return on our purchases, we a so want to ensure that these purchases are ead ng us to over em ss on reduct on goa s The best way to mon tor th s s to track our overa em ss on reduct ons throughout the ent re f eet and compare th s w th the cost of upgrad ng the f eet Current y UBC F eet Management em ts 0 93 pound of GHG em ss ons per do ar spent on d rect costs to the f eet (ma ntenance, fue , eas ng) We be eve that reduc ng th s number s an exce ent way to understand whether money s be ng spent eff c ent y and effect ve y on f eet upgrades

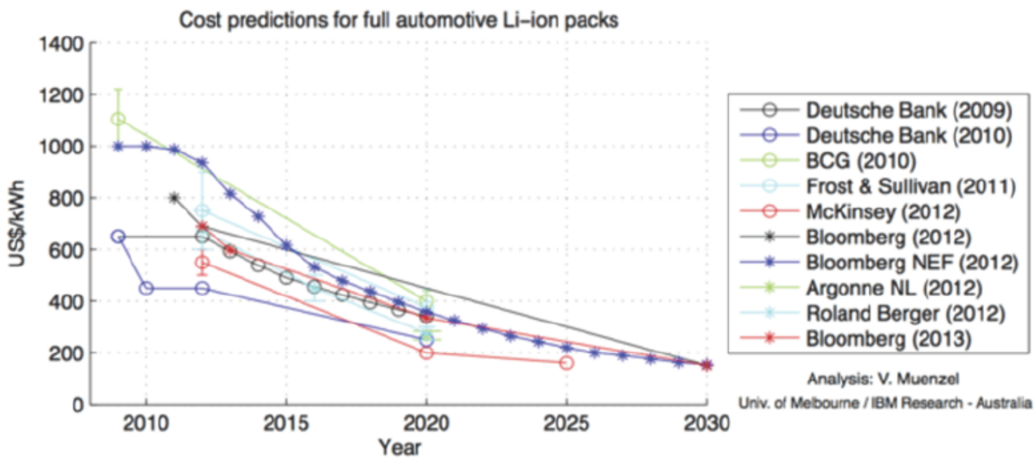
GHG Emissions

One of the under y ng goa s of the Pegasus pro ect s to reduce em ss ons by the stated goa s Therefore, cont nu ng to mon tor em ss ons on mon tored veh c es year by year s cruc a to rea z ng our goa s By cont nu ng to mon tor th s we w better understand whether the mp emented techno ogy we suggest s mak ng a d fference n rea ty

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

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 conditoner'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]

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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).

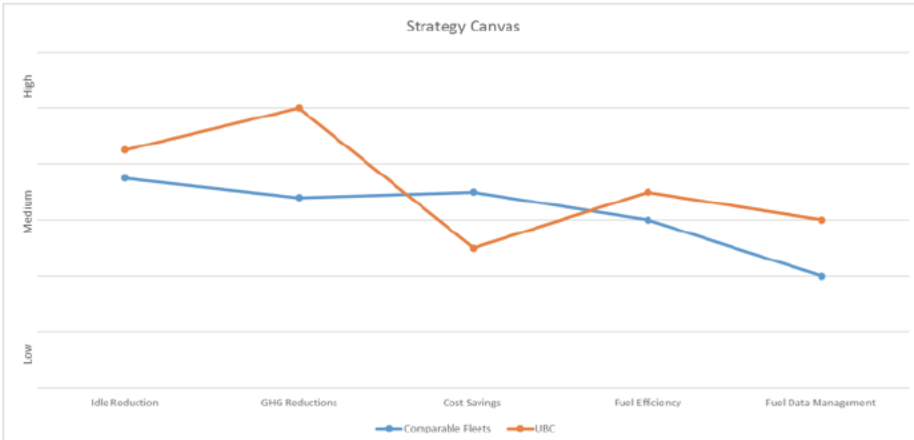
APPENDIX

SWOT

Strengths	**Weaknesses**
• Standardization of vehicle models • Rightsizing • Telematics • Driver Training Policies • 20% electric	• 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

APPENDIX

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 T34CNP TACOMA	144.17
2013 TYSF1T 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