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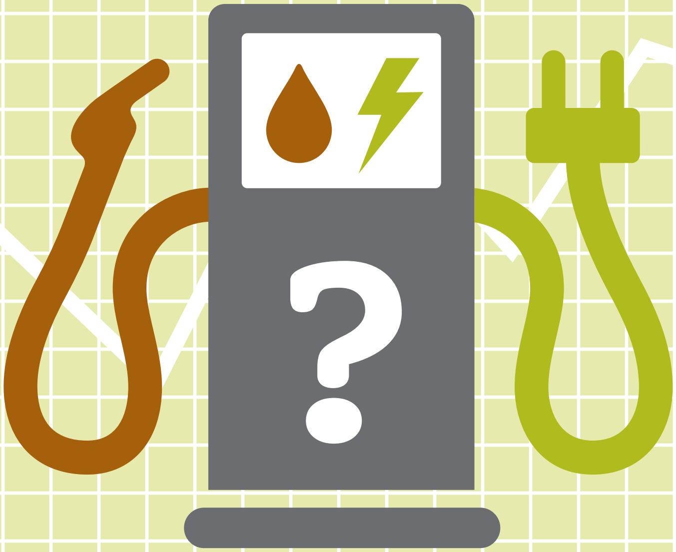
Business Case for Electric Vehicle Use in Service Vehicle Fleets



FINAL REPORT ON PROJECT EVAN (ELECTRIC VEHICLE ANALYSIS)

JUNE 2013

ABOUT POLLUTION PROBE

Pollution Probe is a national, not-for-profit, charitable organization that exists to improve the health and well-being of Canadians by advancing policy that achieves positive, tangible environmental change. Pollution Probe has a proven track record of working in successful partnership with industry and government to develop practical solutions for shared environmental challenges.

ABOUT TORONTO ATMOSPHERIC FUND

The Toronto Atmospheric Fund (TAF) has been sparking action on climate, air pollution and energy use in Toronto for more than 20 years. Internationally recognized for its innovative and effective programs, TAF has helped the City save millions on energy costs and helped citizens to live greener lives in healthier communities. TAF works with a variety of partners, including corporations, federal and provincial governments and community organizations, to leverage its investments in climate change action and to improve our City. The work profiled in this report was principally funded through TAF's FleetWise program, established to support public and private fleets to de-risk the adoption of low-carbon vehicles.

ABOUT CROSSCHASM TECHNOLOGIES

CrossChasm's products and services serve a broad range of applications within the vehicle Original Equipment Manufacturer and fleet management marketplace. CrossChasm's focus is to help vehicle manufactures build best-in-class hybrid, electric and plug-in vehicles, and to guide large-scale end users of those vehicles, such as fleet managers and fleet owners, in accurately assessing the full life cycle costs of next generation vehicle adoption.

ABOUT FLEET CHALLENGE ONTARIO

Fleet Challenge Ontario's mission is to reduce carbon and smog-causing emissions from on-road transportation fleets by helping to responsibly accelerate the acceptance of proven green fleet technologies and best management practices. Fleet Challenge Ontario helps fleet operators reduce their fuel consumption, operating costs and tailpipe emissions through the sharing of modern fleet management techniques, highlighting best practices and enabling peer comparison.

Pollution Probe gratefully acknowledges the funding support of this project by the following organizations:

- Toronto Atmospheric Fund
- Government of Ontario
- Environment Canada
- Power Workers' Union

Pollution Probe also thanks the City of Toronto and AutoShare fleets, as well as the Globe and Mail, for in-kind contributions made toward Project EVAN.

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For more information, please contact:
Natalia Moudrak, Project Manager, Pollution Probe
Phone: (416) 926-1907 ext. 248
Email: nmoudrak@pollutionprobe.org

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Executive Summary

This report presents the findings of Project EVAN (**E**lectric **V**ehicle **AN**alysis), a comparative study undertaken by Pollution Probe with the support of CrossChasm Technologies and Fleet Challenge Ontario to establish the business case and environmental justification for fleet managers in both the public and private sectors to incorporate electric vehicle technology into their procurement and vehicle replacement plans.

The study involved data-logging of three conventional gasoline-powered light-duty vehicles and three electric vehicle alternatives during the course of normal fleet service for one year, and then conducting a comprehensive life cycle analysis of the cost of ownership based on the data gathered. **In each case, the electric vehicle was determined to be the lower-cost option, with operational cost savings offsetting incremental price premiums to deliver a payback in just a few years**. Moreover, even when emissions from the generation of electricity (upstream emissions) were considered, electric vehicles produced 21 times less carbon dioxide equivalent emissions per year than their gasoline-powered alternatives.

Based on the experience gained through Project EVAN, the following steps are recommended to realize the financial and environmental benefits of electric vehicles in any fleet procurement plan:

1. **Measure** in-service vehicle use to generate data for confident total cost of ownership analysis.
2. **Plug in off peak** to maximize environmental benefits from electric vehicles.
3. **Engage drivers** early about plans and reasons for adding electric vehicles to fleets.
4. **Dedicate drivers** to specific electric vehicles to ensure maximum use and cost savings.

The implications of Project EVAN's findings for policymakers are:

- Communicating information to fleet managers and equipping them with analytical tools is essential, including in-service vehicle data-logging and tracking systems, and total cost of ownership analysis.
- The electric vehicles purchase incentive currently offered by the Government of Ontario (*Electric Vehicle Incentive Program*) should be maintained, while further investigation of the business case is conducted through ongoing analysis of electric vehicles in fleets.
- An alternative way to mitigate the incremental cost of electric vehicle technology is to enhance the residual value of the battery. For example, an electric vehicle battery may provide value, such as energy storage, once the vehicle itself is decommissioned.
- Strategic placement of charging stations can address range anxiety among fleet vehicle users; provided that the placement is informed by the vehicle use data generated though fleet measurement.

The story that emerges from Project EVAN is that, in the cases examined, the environmental objectives of the fleet owner need not run counter to the financial realities of the fleet manager's budget. Although a small sample size was used as a proxy, and therefore Project EVAN's findings may not apply in all circumstances, there are merits of undertaking similar studies across interested fleets. **Our advice is simple: Don't guess. Measure; then decide**.

Introduction

ABOUT THIS REPORT

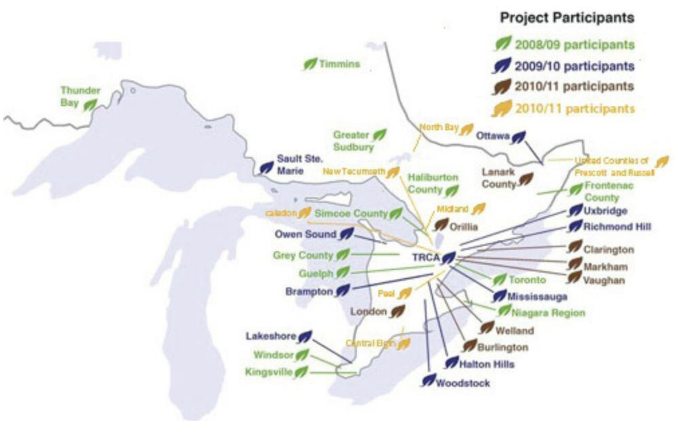
This report presents the findings of a study undertaken by Pollution Probe with the support of CrossChasm Technologies and Fleet Challenge Ontario to establish the business case and environmental justification for fleet managers in both the public and private sectors to incorporate electric vehicle technology into their procurement and vehicle replacement plans.

The study involved the data-logging of conventional gasoline-powered light-duty vehicles during the course of normal fleet service to establish a baseline for operational performance. Against this baseline, electric vehicle alternatives were tested and measured using the same procedures. The data generated was used to conduct comparative analyses of the costs and the emissions performances between conventional vehicles and electric vehicles.

CrossChasm Technologies contributed its industry-leading expertise in vehicle powertrain simulation and in-service vehicle data collection and analysis. Fleet Challenge Ontario managed the communications and interactions with fleet personnel and conducted the economic and financial analyses. Accountable to the project funders, Pollution Probe managed the overall project and interpreted the findings into the narrative that comprises this report.

WHY EVS AND WHY FLEETS?

Electric vehicle technology has the potential to significantly reduce emissions that contribute to smog, particularly in urban regions, and to climate change by displacing the demand for gasoline that powers vehicles with electrical energy. The environmental policies and sustainable development objectives of governments and private corporations, therefore, drive an interest in electric vehicle technology for fleets.



This map shows the Ontario municipal fleets that have engaged Fleet Challenge Ontario to review their operations and to provide recommendations around green vehicle procurement, as well as best practices in fleet management and environmentally-friendly operations (i.e., "E3 Green Fleet Reviews") since 2007.

However, electric vehicles are a new and expensive technology. Because electric vehicles are partly- or fully-powered by electricity, and because their mechanical design is different, the higher upfront capital costs may be offset through reduced fuel and maintenance expenses over their service life in a fleet. Because vehicles in public or commercial fleet service often log more hours and mileage than personally owned vehicles, and because fleet managers have the motivation and capacity to measure the use of the vehicles within their operations, it is expected that the return on the investment in electric vehicle technology will be more economically attractive for use in fleets.

But is it? The answer is not obvious, because the latest generation of electric vehicles from major automakers have only been available for a few years, and experience with this new technology is limited. Also, fleet owners and managers face numerous other barriers and uncertainties, such as those below:

> “Barriers to mass adoption of electric vehicles, like high price tags and limited access to recharging points, will be more easily overcome by companies and governments with bigger budgets and predictable driving routes.”
>
> – Maria Gallucci, “Auto industry pins hopes on fleets to charge electric market”, *Reuters*, September 13, 2011.

CANNIBALIZATION OF CAPITAL VEHICLE REPLACEMENT PROGRAMS

Organizations with vehicle fleets can encounter unexpected changes in their fortunes, especially in uncertain times. New priorities emerge and change during the budgeting process, and vehicle replacements are often deferred to free up capital for other urgent expenses. This can lead to an older, less reliable fleet of vehicles that ultimately costs more to maintain. To defend their budget, fleet managers must have a solid business case in place for all vehicle replacements; one that demonstrates the financial and service-level impacts of an aging fleet.

LACK OF INFORMATION

Many fleet managers in Ontario municipalities, as well as some commercial and private-sector fleet operators, employ a “revolving fund” process to determine their annual capital budget. Each year, this process involves reserving funds (often equivalent to about 20 per cent of each vehicle’s original acquisition cost) in a capital program for the replacement of “rolling stock” (i.e., the fleet of active vehicles). When a unit is due for replacement, funds that were allocated to the vehicle capital replacement program should be available, in theory. This method of forecasting replacement costs, however, does not help identify how the funds should be optimally deployed. So, when a vehicle is due for replacement, the capital program is automatically tapped and a new vehicle is procured, even if that vehicle has become unnecessary within the fleet, or the service that it provides has become redundant to the operation. All too often, fleet managers simply do not have historical usage data sufficient to make vehicle replacement choices that optimize the efficiency of their fleet operations.

Increasingly, savvy fleet managers are using advanced life cycle analysis (LCA) tools to develop optimal vehicle retention cycles and replacement rates. Real data gathered on the use of vehicles comprising a fleet can be inputted into an LCA to produce an operational use review. Once LCAs have been conducted for each vehicle type in an organization’s fleet, and by studying vehicle availability (uptime) rates by age, fleet operators can determine the optimal replacement cycle for each vehicle type and for the fleet as a whole. This level of review also ensures that each and every vehicle in the fleet that is due for replacement is serving a useful purpose relative to the organization’s stated objectives. Comprehensive analyses based on thorough data collected objectively produces a strong business case with which to develop a long-term (e.g., 5 to 10 year) capital vehicle replacement budget – and to defend it! This process is also very effective for maintaining the most efficient fleet possible and the highest levels of availability. In other words, decisions made about capital expenses should serve to minimize fueling and maintenance expenses.

The Fuel Line in the Municipal Budget – By Chris Hill (President and CEO of Electric Mobility Canada and a former manager of the Central Fleet for the City of Hamilton Public Works Department)

Year after year, City Council asks that operating budgets come forward with a 0 per cent increase. Our labour contracts all contain increases, so everything else has to go down. Diesel fuel and gasoline for the city fleet are always labelled a "pressure", and with good reason. We are big enough to secure good pricing, but motor fuel fluctuates with oil prices. We can't control it or even predict it. Looking back eight years ago, we see that a compact pickup truck cost only $26 to fill the gas tank. Today it costs $61. So, what do we do about next year's budget with that history?

City Council has given us the mandate to "green the fleet". It's good for our image. Citizens like it because they like clean air. And the hybrids sure do their part, cutting vehicle fuel use by about 20 per cent. But there are still lots of city drivers who don't care about fuel conservation, and operating division chiefs who "blame Fleet" for not controlling costs while refusing to turn in under-used fleet vehicles. That makes it tough to reduce greenhouse gas emissions, too.

Can fuel costs be "locked in"? Hedging might work, but it has risks. Only if fuel prices are known in advance can we make an accurate budget forecast. Well, it turns out that electricity prices are regulated, and decisions about price increases are known well in advance. If electricity can replace all of those fuel sites that the fleet has to maintain and operate, that would be a huge saving to the city. And those greenhouse gas emission targets just got a whole lot easier.

But electric vehicles come with a very high sticker price. We need guidance that is comprehensive – something that tells us not just what they cost, but what they will save. What is the business case that makes electric vehicles the best choice? And can they make the promise of 0 per cent a reality?

Project EVAN was designed to help fleet managers understand how to establish the business case for electric vehicles in their own fleets, by sharing the results of the research team's total cost of ownership intelligence gathered in real-world fleet testing, as well as the emissions performance observed during the investigation.

The findings of Project EVAN are not the last word on the suitability of electric vehicles in fleet operations. A small sample size was used as a proxy and, therefore, Project EVAN's findings may not apply in all circumstances. Furthermore, while the design of the research was intended to control for as many variables as was reasonable, the results cannot be reproduced, as would be the case in a proper laboratory experiment. Working in our "real world" laboratory was a messier business! It is more proper to say that the findings of Project EVAN demonstrate the importance of measuring fleet vehicles and routes that are being considered for electric vehicles, as the payback can be attractive if the technology is used in the right applications. Guesswork must be displaced with evidence. To this end, the findings tell an important story for all those concerned with optimizing fleet operations and with promoting the use of electric vehicle technology.

The relevance of this research goes beyond the community of fleet owners and managers. Fleets are often early adopters of new vehicle technology – a platform from which broader consumer acceptance can grow. In Ontario, fleet managers are responsible for managing about 5 per cent of all vehicles in the province, or more than 350,000 vehicles (see Table 1). The first hybrid-electric vehicle that most people saw on the roads was probably part of municipal or commercial fleets – and so it is with electric vehicles.

Table 1: Estimated Number of Vehicles in Service Vehicle Fleets in Ontario, 2006

Vehicle Type	Taxis	Trades	Urban delivery	Government/ Utilities	National/ Regional	Transit	Total
Sub-compact/compact cars	213	2,407	2,276	9,252	431		14,579
Mid/full-sized cars	9,095	10,928	1,498	8,301	6,066		35,888
Mini vans/small trucks	502	9,416	1,964	12,326	17,851		42,059
Full-sized vans/pickup trucks	1,111	57,156	1,717	15,978	20,236		96,198
Medium/heavy duty trucks	1,008	46,694	12,917	14,488	80,057		155,164
Buses				11,665	1,695	4,529	17,889
TOTAL	**11,929**	**126,601**	**20,372**	**72,010**	**126,336**	**4,529**	**361,777**

Estimated Number of Vehicles in Service Vehicle Fleets in Ontario, 2006
Source: Fleet Challenge Ontario

The report is organized in the following manner:

- **Chapter One** provides a detailed overview of Project EVAN;
- **Chapter Two** profiles operational performance, financial implications and driver experience with electric versus gasoline-powered vehicles in service vehicle fleets;
- **Chapter Three** outlines the steps to establish the business case for electric vehicle use in service vehicle fleets; and
- **Chapter Four** discusses the implications of the findings for policymakers in an Ontario context.

Chapter One: Project EVAN Background

The purpose of Project EVAN was to establish the business case for electric-powered vehicles using comparative vehicle performance data on electric and gasoline-powered service vehicles and driver experience feedback.

Originally, the intention was to secure electric and gasoline-powered vehicles that would be driven by the same drivers on the same routes. The drivers would be alternating between electric and gasoline-powered vehicles - the two independent variables in the experiment. Dependent variables, including unique driving patterns, daily distances travelled and vehicle loads would be controlled for the accuracy of energy consumption, vehicle emissions and other comparisons. This purposeful sampling approach, which relies on selecting information-rich cases for study in depth (i.e., those cases from which one can learn a great deal about issues of central importance to the purpose of the research), would justify the small sample size of test vehicles used in the experiment.[1]

However, at the outset of the data collection process, it became apparent that the test vehicles would not be driven by the same drivers, on the same routes, as they were not assigned to specific drivers (the only exception to this was the Transit Connect Electric vehicle, which was used by the same driver during the course of the experiment). Fleet management, the primary point of contact for Project EVAN, did not have direct control over vehicle usage and operations, which were in fact determined by the end-user departments within the fleets. Increasing the sample size of test vehicles to compensate for a less precise comparison would have been one way to address this shortcoming. However, due to resource limitations, the small sample size had to be maintained. Nevertheless, from discussions with fleet management personnel, it was apparent that the vehicle usage varied little between the different drivers, as the compact vehicles were primarily used to attend meetings and to make site visits and inspections, and the vans were used to perform light cargo deliveries.

The following vehicles[2] belonging to City of Toronto and AutoShare fleets were employed for the purposes of Project EVAN:

- **Electric-powered vehicles:** Nissan LEAF, Mitsubishi i-MiEV and Ford Transit Connect Electric
- **Gasoline-powered vehicles:** Ford Focus Wagon and two Ford E-250 Vans

Each vehicle was equipped with a data logger that wirelessly tracked and stored vehicle performance data during a period of one year from December 2011 through to December 2012 (see Appendix A, "Data Collection and Analysis Methodology").

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[1] Patton, M. (1990). Qualitative evaluation and research methods (pp. 169-186). Beverly Hills, CA: Sage.

[2] All vehicles were 2011 model years, with the exception of Ford Focus Wagon, which was a 2005 model year.

CrossChasm used its proprietary FleetCarma technology to process the data obtained through the data loggers and to derive the following information:

- Annual and average daily distance travelled, measured in kilometers (km)
- Fuel economy (distance travelled per unit of fuel), measured in average miles per imperial gallon of gasoline equivalent (MPGe), and fuel consumption, measured in litres per 100 kilometers travelled (L/100 km)
- Energy use (electricity used per unit of distance travelled), measured in kilowatt-hours per mile (kWh/mile) and kilowatt-hours per kilometer travelled (kWh/km)
- Tailpipe and upstream emissions (estimated values), reported in kilograms of carbon dioxide equivalent per year (kg CO_2e/year)

Start- and end- of-day battery state of charge (SOC) information was also tracked for electric vehicles and reported in percentage points (0 per cent = fully drained; 100 per cent = full battery charge).

Once the findings were finalized for the full year, Fleet Challenge Ontario used its life cycle analysis and total cost of ownership (TCO) models, as prepared for the Toronto Atmospheric Fund's FleetWise EV300 initiative, to conduct a financial analysis of purchasing electric versus gasoline-powered vehicles.

The cost categories considered for the TCO analysis included:

- Ownership:
    - acquisition/purchase price minus financial incentives, including government or manufacturer incentives or concessions
    - cost of capital or lease payments
    - end of cycle salvage/residual values
- Vehicle administration costs, including insurance and licensing fees
- Fuel and electricity costs
- Repair and maintenance:
    - regular repairs and preventive maintenance
    - replacement of "wear-out" items, such as brake pads and lights
    - driver productivity loss due to maintenance, measured in salary rate per hour of lost time
- Carbon cost to account for potential future monetization of carbon credits

Notably, for the fuel costs category, TCO analysis was not based on laboratory testing and/or manufacturers' fuel economy/electricity usage claims. This is because real-life fuel consumption can differ substantially from these estimates due to unique driver behaviour, weather, vocational and operational characteristics. Instead, Project EVAN relied on in-service data obtained through data loggers to make fuel cost comparisons as accurate as possible.

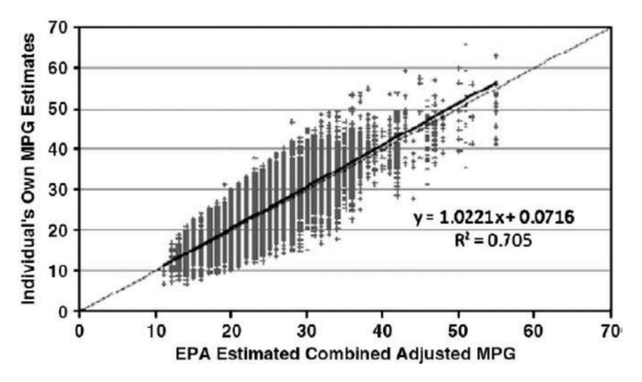
In addition to the quantitative analysis described above, a 10-question survey was designed to investigate driver satisfaction with using an electric vehicle. Eleven City of Toronto staff who drove electric vehicles completed the survey in September 2012, helping to inform the user-experience perspective of the business case (see Appendix B for the survey template and response summaries).

Both the quantitative and qualitative findings profiled above inform the business case and policy recommendations put forward in this report.

Why measure vehicle energy use at all? Why not just look up the figures in the Fuel Consumption Guide?

Fuel consumption and greenhouse gas emissions figures published by the Office of Energy Efficiency in Canada (and the US Environmental Protection Agency) are determined via standardized laboratory tests (i.e., "Federal Test Protocols"). The drive cycle on which energy consumption is measured enables a degree of comparison between vehicle models, but it is not an accurate predictor of the fuel consumption performance that a given model will achieve under any operating condition.

Dr. David Greene of Oak Ridge National Laboratories gathered fuel consumption data from 3,000 drivers based on their self-generated fuel economy estimates and compared these to the US Environmental Protection Agency ratings (posted on consumer information labels) for the models that they drove. The following data plot illustrates that the estimates submitted by drivers can vary by 33 per cent above and below the rated levels.



The analysis indicates that while the EPA fuel economy ratings appear to be unbiased estimators of the average fuel economy that consumers will experience during actual driving, posted fuel economy ratings are highly imprecise, nonetheless.

Therefore, while published fuel consumption ratings are a good starting point in the search for fuel-saving vehicle models, they are not a substitute for the direct measurement of vehicle use and life cycle analysis of costs.

David L. Greene. Uncertainty, loss aversion, and markets for energy efficiency. *Energy Economics*, Volume 33, Issue 4, July 2011, (pp. 608-616).

Chapter Two: Project EVAN Findings

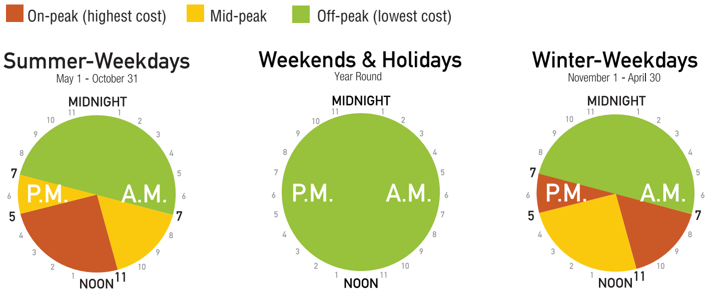
This chapter profiles Project EVAN's findings across the four main parameters of vehicle performance analysis: operating characteristics, fuel consumption and energy use, vehicle emissions and financial projections. The findings of this intimate, one-year data-tracking study are conclusive: electric vehicles are a worthy option to explore in the context of City of Toronto and Autoshare fleet management cost reductions and in the pursuit of environmental goals. The findings suggest that there are merits to undertaking similar studies across a broader range of fleets in Ontario (and Canada) to uncover the business case for electric vehicles that might similarly exist.

OPERATING CHARACTERISTICS

For service vehicle fleets, the key enabler for electric vehicle technology was assumed to be the operational synergy between the electric vehicle technology and urban duty-cycles, where the service vehicle employed often runs the same routes on a daily or weekly basis and returns to the same location nightly. This proved to be the case with the City of Toronto service vehicles, which were typically used from 7:00 a.m. to 4:30 p.m., Monday to Friday, within the City of Toronto area. Accordingly, approximately 14-hour windows were available from Monday to Friday for the overnight charging of electric vehicles, as well as 48-hour charging time windows over the weekend.

One advantage of charging electric vehicles overnight in Ontario is that lower "off-peak" electricity rates can be applied for charging between 7:00 p.m. and 7:00 a.m., Monday to Friday, or at any time on the weekends (see Figure 1).[3]

Figure 1: Time-of-Use Periods, Electricity, Ontario, 2011



The Ontario Energy Board (OEB) sets the daily and seasonal time-of-use prices and periods every May 1 and November 1.
Visit www.ontarioenergyboard.ca to see current prices.

Moreover, 14-hour charging windows for electric vehicles used in service fleets are sufficient for charging through ordinary three-prong 110-volt outlet (level one charging), negating the need for costlier charging solutions, such as the 240-volt (level two) or 500-volt direct current (level three) charging systems. Nevertheless, electric vehicles analysed for Project EVAN were charged using level two charging systems that were provided in the City of Toronto and AutoShare parking locations.

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[3] For more information on Time-of-Use electricity pricing, refer to Ontario Energy Board website:
http://www.ontarioenergyboard.ca/OEB/Consumers/Electricity/Electricity+Prices/Regulated+Price+Plan+FAQs

As shown in Table 2, the average state of charge for the electric vehicles in the test was 95 per cent at the start of the day. Through discussions with fleet managers, it became apparent that this percentage was indicative of the instances when electric vehicles were left uncharged overnight, and is not evidence of insufficient charging times to allow the battery to reach a 100 per cent charging state. Moreover, at no point over the entire duration of Project EVAN data collection did the electric vehicles analysed run out of battery. By the end of the year, their average state of charge at the end of the day was 59 per cent. **In other words, electric vehicles in the test were underutilized and could have been driven longer distances before battery exhaustion.**

Table 2: Electric Vehicle Battery, Average State of Charge (SOC), in Per Cent

Model	Average SOC (start of day)	Average SOC (end of day)
Transit Connect Electric	96	44
Nissan LEAF	92	61
Mitsubishi i-MiEV	96	71
Average Performance	**95**	**59**

0 per cent = empty battery; 100 per cent = full battery

As illustrated in Table 3, electric vehicles were driven 1.6 times less than their gasoline-powered alternatives in the fleet pool. This was especially true in the case of Mitsubishi i-MiEV vehicle, which was driven only 3,249 km over the course of the year, or 9 km per day.

Table 3: Distance Travelled[4]

Model	Total Annual Distance Travelled (km)	Average Daily Distance Travelled (km)
	Electric Vehicles	
Transit Connect Electric	11,460*	31*
Nissan LEAF	11,350	31
Mitsubishi i-MiEV	3,249	9
Average Performance	**8,686**	**23.7**
	Gasoline-Powered Vehicles	
Ford Focus - unit #004006	19,345	53
Ford E-250 Van - unit #112293	11,420	31
Ford E-250 Van - unit #112294	9,829	27
Average Performance	**13,531**	**37**

**The City of Toronto employs two Transit Connect Electric vehicles in its service vehicle fleet, with the driver alternating between them. For the purposes of Project EVAN, only one of these vehicles was equipped with a data logger. These "distance travelled" values could be multiplied by a factor of two to reflect this two-vehicle set up.*

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[4] These distances are comparable to average distances travelled across similar service vehicle fleet applications.

One explanation for these figures is that the drivers perceived the travel range of electric vehicles to be insufficient for their daily routes, leading them to choose conventional over electric vehicle options more often. However, as mentioned earlier, the electric vehicles examined were never used to their full battery potential. Working to make fleet vehicle drivers more familiar and comfortable with the new technology should help to address this issue.

FUEL CONSUMPTION AND ENERGY USE

Electric vehicles that were examined as part of Project EVAN had fuel consumption and energy use levels that were nine times lower than their gasoline-powered alternatives (see Table 4).[5] Notably, although there were clear seasonal variations in electricity use for the electric vehicles analysed, with the highest levels reached in winter months (attributed to additional demands on the vehicle for heat), electric vehicles always demonstrated superior operating efficiency compared to the gasoline-powered vehicles in the study (see Appendix C).

Table 4: Fuel Consumption and Energy Use

Model	L/100 km	kWh/km
	Electric Vehicles	
Transit Connect Electric	2.77	0.268
Nissan LEAF	2.07	0.200
Mitsubishi i-MiEV	1.63	0.158
Average Performance	**2.16**	**0.209**
	Gasoline-Powered Vehicles	
Ford Focus - unit #004006	10.6	1.025
Ford E-250 Van - unit #112293	24.8	2.399
Ford E-250 Van - unit #112294	22.8	2.206
Average Performance	**19.4**	**1.878**

Appendix D contains sample use charts (also called the vehicle's "fingerprint") based on typical days of vehicle operation, illustrating vehicle usage patterns, including driving and battery charging intervals. One can see that electric vehicles were used rather sparsely compared to their gasoline-powered alternatives. However, with such promising fuel consumption and energy use results as shown in Table 4, there ought to be higher electric vehicle use in the future in the City of Toronto and AutoShare fleets.

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[5] A factor of 0.097 was used to convert L/100 km to kWh/km (using US EPA fuel economy conversion rate of 1 gallon of gasoline being equivalent to 33.7 kWh of electricity).

VEHICLE EMISSIONS

The two most common ways to compare air emissions from electric and gasoline-powered vehicles are to consider either tailpipe or both tailpipe and upstream emissions from the generation of "fuels" used to power the vehicles - electricity or gasoline. For a fair comparison, a common metric of kilograms of carbon dioxide equivalent per year (kg CO_2e/year) was used, with emission factors estimates accounting for the unique composition of Ontario's energy mix:

- **Upstream emissions factor for gasoline:** 0.998 kg CO_2e/Litre (as per Daniel Sperling and James Spencer Cannon, *Driving Climate Change: Cutting Carbon from Transportation*, Academic Press, 2007)
- **Gasoline CO_2e:** 2.3 kg/Litre (as per Natural Resources Canada's *2011 Fuel Consumption Guide*)
- **Electricity CO_2e:** 0.187 kg/kWh (as per Environment Canada's *National Inventory Report 1990-2010: Greenhouse Gas Sources and Sinks in Canada*)

Because all electric vehicles analyzed were battery electric, they were assumed to produce zero tailpipe emissions from engine operations. When emissions from upstream generation were considered, electric vehicles were found to emit 21 times less kg CO_2e annually (see Table 5). When these values were normalized with respect to the total annual distance travelled by each vehicle (see Table 3), electric vehicles were found to emit 16.6 times less g CO_2e for every kilometer travelled. This was illustrative of how the efficiency with which energy was used within each vehicle affected emission levels. This finding suggests that significant air emissions reductions are possible from integrating electric vehicles into City of Toronto and AutoShare fleet operations.

Table 5: Annual Vehicle Emissions

Model	Tailpipe kg CO_2	Tailpipe & Upstream kg CO_2e	Tailpipe & Upstream g CO_2e/km
	Electric Vehicles		
Transit Connect Electric	0	574	50.09
Nissan LEAF	0	425	37.44
Mitsubishi i-MiEV	0	96	29.55
Average Performance	**0**	**365**	**39.03**
	Gasoline-Powered Vehicles		
Ford Focus - unit #004006	4,783	6,432	332.49
Ford E-250 Van - unit #112293	6,648	9,468	829.07
Ford E-250 Van - unit #112294	5,248	7,744	787.87
Average Performance	**5,558**	**7,881**	**649.81**

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[6] Marginal demand for electricity is met by marginal supply. In other words, the incremental demand for power when an EV plugs into the grid is met by engaging additional sources of power. In Ontario, if the nuclear base load supply, the available hydropower and other renewables sources are fully tapped, then the added demand for EV charging would be met by dispatching power generated from gas-fired or coal-fired power plants, and the associated emissions are tied to these marginal sources of supply.

FINANCIAL CONSIDERATIONS

Once all of the findings profiled above were finalized for the full year, a total cost of ownership (TCO) analysis was completed to assess the lifetime costs associated with purchasing (or leasing), operating and maintaining each of the vehicles. A 10-year life cycle was assumed for all vehicles, which is typically the optimal duration of vehicle ownership chosen by fleet managers in Ontario.[7] To ensure a fair TCO comparison, vehicles were then divided into two categories, with electric vehicles being compared to a baseline case of their gasoline-powered alternative, across all cost categories:

- **Cars:** Ford Focus, Nissan LEAF and Mitsubishi i-MiEV
- **Cargo vans:** Ford E-250 Van and Transit Connect Electric

The following acquisition costs were used in the TCO mode (see Table 6):

Table 6: Vehicle Acquisition Costs

Model	Vehicle Price (excluding HST)	Government of Ontario Incentives	Net Purchasing Cost
	Electric Vehicles		
Transit Connect Electric	$62,250	$8,500	$53,750
Nissan LEAF	$38,395	$8,500	$29,895
Mitsubishi i-MiEV	$32,998	$8,230	$24,768
	Gasoline-Powered Vehicles		
Ford Focus Wagon	$22,529	$0	$22,529
Ford E-250 Van	$33,092	$0	$33,092

A cost of capital/lease finance rate of 5 per cent with no down payment and end-of-life residual value of 11 per cent were assumed for all vehicles. An annual vehicle administration cost, which includes such expenses as vehicle insurance and licensing, was assumed to be $792 for all vehicles.

For the cars, the total annual distance of 19,345 km per year was applied for TCO calculations, as this was the highest value actually observed in this vehicle category (see Table 2, Ford Focus Wagon data). For cargo vans, the total annual distance of 22,920 km per year was applied for TCO calculations, as this would have been the highest value observed in this vehicle category, which is an estimate of the sum of distances logged for the two Transit Connect Electrics.[8] The fuel consumption and energy use rates used in the calculations are provided in Table 4.

In terms of calculating energy consumption costs, a rate of $1.20/L for gasoline was assumed for fuel cost calculations. The following Time-of-Use (TOU) rates were used for electricity cost calculations, reflective of the 2011 Ontario Energy Board pricing:

- **On-Peak Rate:** 0.099 $/KWh
- **Mid-Peak Rate:** 0.081$/KWh
- **Off-Peak Rate:** 0.051$/KWh

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[7] According to Fleet Challenge Ontario's database of over 50,000 vehicles.

[8] Only one of the two Transit Connect EVs was data-logged, but both were observed to be used similarly over the year, in terms of distance and service.

The assumption was made that electric vehicles charged overnight, so off-peak rates were applied. As illustrated above, the rate paid to the local utility company for a kilowatt-hour of electricity in Ontario varies according to the time of day (i.e., TOU rates). The lowest "off-peak" rates are charged between 7:00 p.m. and 7:00 a.m. during the weekdays, and throughout weekends. This is because the demand for electricity is usually lower during these times (i.e., "off peak" time), and so less power generation needs to be brought on-line. Thus, the payback periods can be optimized if electric vehicle charging occurs during the off-peak periods. However, this may not align well with typical fleet operations during the weekdays, as those observed in Project EVAN, where vehicles returned from their daily runs at around 4:30 p.m., just prior to the onset of the most expensive "on peak" electricity rates (from 5:00 p.m. to 7:00 p.m.). Fleet managers could ensure that a means to delay plugging in fleet electric vehicles until off-peak periods. Either evening personnel can take on the task of charging electric vehicles or an automatic timer system could be installed (some electric vehicles can also be programmed to delay charging).

The maintenance costs for kilometers driven, including expenses associated with the charging system, engine/electric motor systems, HVAC system, lighting system, oil changes and lube, steering and suspension, brakes, tires and transmission, were captured in the TCO calculations. A driver productivity loss of $60/hour was also applied to account for the times when the vehicles were undergoing maintenance work.

For all of the aforementioned TCO model components, a 3 per cent annual rate of inflation was assumed. A 5 per cent discount rate was applied for net present value calculations.

For environmental impact calculations, a rate of $2/metric tonne of carbon was assumed to estimate the future impacts of carbon pricing policies.

In terms of environmental impacts of electric vehicle battery disposal, research is currently underway to understand the potential reuse of electric vehicle batteries for power-grid applications.[9] The financial impact of electric vehicle battery disposal was not included in the TCO model calculations, as there is much uncertainty about the commercial viability of this technology as it develops over the next 10 years, which approaches the end of the vehicle life cycle period assumed for Project EVAN. In the future, it is plausible that electric vehicle batteries may bring additional financial value to fleet managers during vehicle disposal, if these batteries can be sold for an "after-life" use across power-grid applications.

For both categories of vehicles (cars and cargo vans), electric vehicles in the sample were found to be less costly to own and to operate. In the cars category, the operational savings from electric vehicles offset the additional incremental cost of purchasing, compared to the gasoline-powered alternative, after the first 2.5 and 0.7 years for the Nissan LEAF and Mitsubishi i-MiEV, respectively (see Table 7).

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[9] For further information, refer to ABB and General Motors research on the potential role that electric vehicle batteries may play to support renewable energy integration with power grids at a household level: http://www.abb.ca/cawp/seitp202/8cb38a9d23816174c1257ab500497848.aspx

Table 7: Total Cost of Ownership: Ford Focus, Nissan LEAF and Mitsubishi i-MiEV

Annual Cost (in 2012 CAD)	Ford Focus	Nissan LEAF	Mitsubishi i-MiEV
Ownership	$3,322	$4,129	$3,567
Maintenance	$2,420	$1,802	$1,802
Gasoline	$2,655		
Electricity		$686	$594
Driver productivity loss	$642	$319	$319
Carbon	$10.18	$1.77	$1.40
Total	**$9,049**	**$6,938**	**$6,283**
Net Purchasing Cost		$29,895	$24,768
Incremental Purchasing Cost		$7,366	$2,239
Operational Savings		$2,919	$3,011
Net Present Value versus Baseline (Ford Focus)		$17,128	$22,425
Payback (Years)		**2.5**	**0.7**

In the cargo vans category, the operational savings from the Transit Connect Electric offset the incremental cost of purchasing, compared to the Ford E-250, after the first 2.5 years (see Table 8).

Table 8: Total Cost of Ownership: Ford E-250 Van and Transit Connect Electric

Annual Cost (in 2012 CAD)	Ford E-250 Van	Transit Connect Electric
Ownership	$4,479	$6,742
Maintenance	$3,893	$2,183
Gasoline	$7,062	
Electricity		$941
Driver productivity loss	$731	$409
Carbon	$27.07	$2.82
Total	**$16,192**	**$10,278**
Net Purchasing Cost	$33,092	$53,750
Incremental Purchasing Cost		$20,658
Operational Savings		$8,178
Net Present Value versus Baseline (Ford Focus)		$47,962
Payback (Years)		**2.5**

Figure 2 and Figure 3 below portray the TCO data presented above, clearly illustrating the total cost of ownership advantages of electric vehicles compared to their gasoline-powered alternatives, for cars and cargo vans, respectively.

Figure 2: Total Cost of Ownership: Ford Focus versus Nissan LEAF and Mitsubishi i-MiEV

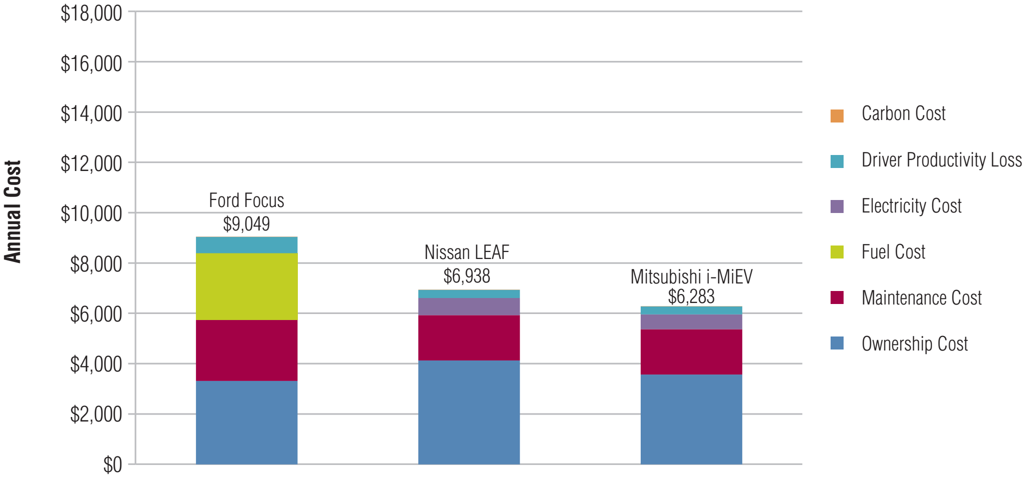
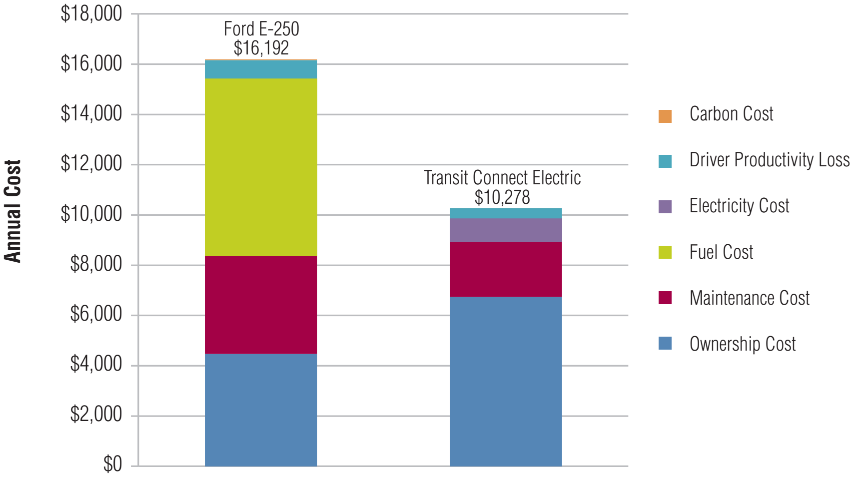


Figure 3: Total Cost of Ownership: Ford E-250 and Transit Connect Electric



One of the critical factors that enables better paybacks on electric vehicles is lower operational cost due to much lower energy expenses (annual spending on electricity) than that of their gasoline-powered alternatives (annual spending on gasoline). From a budgeting perspective, electricity prices are relatively stable compared to the uncertainty of fluctuating gasoline prices, so operating expenses for electric vehicles ought to be easier to predict.

USER EXPERIENCE FEEDBACK

In addition to the quantitative analysis profiled above, Project EVAN considered various aspects of the driver experience with electric vehicles. To this end, 11 City of Toronto staff provided feedback through a survey that ranked various aspects of their experience with driving electric vehicles using a scale of 1 to 5. A ranking of 1 meant that the experience was "excellent"; 2, "very good"; 3, "average"; 4, "below average"; and 5, "poor". City of Toronto staff were also invited to provide additional feedback, in the form of open-ended commentary.

In general, the City of Toronto's staff experience with electric vehicles was positive, with most of the respondents rating it as "excellent" or "very good" (see Table 9).

Table 9: Driver Experience with Electric Vehicles: Survey Results Summary

Aspect of Driving an Electric Vehicle	Most Frequent Ranking	Average Ranking	Number of Responses
Driving Experience	**1**	**2.1**	**11**
Reliability	1	2.1	11
Range	**4**	**2.9**	**11**
Ease of Use	1	1.9	11
Effectiveness as a Fleet Vehicle	2	2.4	10
Easy to Charge	1	2.3	11
Integration with the job function	2	2.4	11
Difficulty of switching from a conventional vehicle	2	2.7	10
Overall Rating	**2**	**2.4**	**11**

The detailed results of the survey are provided in Appendix B. Additional comments received from City of Toronto staff consisted of positive feedback in general and less enthusiastic feedback about electric vehicle range:

"An excellent vehicle for site visits. Starting each day with a full 'fuel tank' is a great plus. Ideal for a car that is left at work at the end of the day."

"Its smaller size enhances electric vehicle parking opportunities downtown."

"Good for attending meetings anywhere in the city. Range does not allow for more than five hours of field work. Toronto traffic (gridlock) can result in lots of idling and significant reduction in operating range."

"Highway use seems to be hard on the battery mileage."

"Range could be better, however, often the case is that there is limited charging opportunity at destinations."

"More electric charging areas needed."

The next chapter reflects both the quantitative and qualitative findings presented above and outlines the "ideal case" scenario for electric vehicle use in service vehicle fleets.

Chapter Three: Establishing the Business Case for Electric Vehicle Use in Service Vehicle Fleets

The findings presented in the previous section demonstrate a compelling case for adding electric vehicles to an organization's fleet of service vehicles, provided that the electric vehicles are used in the right applications. Notwithstanding the relatively small sample size in the survey, which was composed of six City of Toronto and AutoShare fleet vehicles, the utilization data gathered was very comprehensive and the analysis is robust. Therefore, the economic case and environmental justification for fleet procurement of electric vehicles can be made with confidence if the following steps are followed.

Step 1: Measure

Whether by data logging or by other means, a reasonably complete picture of the use of vehicles in a given fleet should be developed. An understanding of both the routes serviced by the vehicles and the drivers that use the vehicles will round out this picture. As evident from the driver surveys, concerns about driving range limitations of electric vehicles combined with drivers' tendency to overestimate the distances that they actually drive limits how often drivers choose an electric vehicle for their day-to-day needs. This, in turn, undermines the economic benefits of electric vehicle use (i.e., the more they are used, the faster they pay back, based on fuel savings). Once the patterns and parameters that characterize the use of the vehicles in the fleet are understood, an informed choice can be made of which electric vehicle to purchase and the regular service to which it should be applied. If chosen correctly, then the investment in electric vehicle technology should return a net economic gain through reduced operational expenses.

Step 2: Plug-In Off-Peak

Electricity demand is highly variable throughout the day, as well as during the year. To meet the varying electricity demand, a mix of base, intermediate and peaking load power-generating plants is used, which rely on different energy sources. In Ontario, base power-generating plants rely primarily on nuclear and hydro sources, whereas the intermediate and peak loads are supplied by coal, natural gas, oil and hydroelectric generators with storage.[10] Thus, emissions reductions associated with electric vehicles will vary depending on the energy source used for electricity generation at the time that the vehicles are charged. Charging electric vehicles during off-peak hours, or between 7:00 p.m. and 7:00 a.m. during the weekdays and throughout weekends, maximizes their environmental benefits by ensuring that the lowest-emitting sources of electricity are powering electric vehicles.

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[10] Amal A. M. Farhat and V. Ismet Ugursal. Greenhouse gas emission intensity factors for marginal electricity generation in Canada. *International Journal of Energy Research*, Volume 34, Issue 15, 201, December 2010 (pp. 1309 – 1327).

Step 3: Engage Drivers Early

As the Project EVAN driver experience survey findings indicate, some fleet drivers are more enthusiastic about electric vehicle technology than others. This is not a fault of the drivers – electric vehicles operate differently than conventional vehicles, and the experience of driving one can be disorienting to those new to the technology. Therefore, it is important to engage drivers early in the process. Communicating the operational, environmental and economic benefits that electric vehicles can bring to the fleet – and even sharing the findings contained in this report – can help to build the conditions for confidence in and the adoption of this new technology.

Step 4: Dedicated Drivers

Once it becomes clear which routes are optimal for electric vehicle use and which drivers are the most likely to be the optimal users of electric vehicles, consider pairing them up for optimal results. Early wins are important with new technology, and dedicating the right drivers to new electric vehicles can help generate an impressive pattern of cost savings and an early payback. Dedicated drivers will use electric vehicles more, which also makes the electric vehicle more visible to the public, fostering familiarity with the technology and general acceptance.

Avoiding a misfit of technology with fleet application is as important as levering the conditions for success. The above steps will help in both regards.

Chapter Four: Implications of Findings for Policymakers

Project EVAN generated robust analyses and findings that were based on the real-time data-logging of fleet vehicles in actual day-to-day service in Toronto. The findings indicate the potential scale of economic benefits and emissions reductions associated with electric vehicle use. These gains are considered to be marginal to moderate, and are thus sensitive to government policy.

Pollution Probe believes in the benefits of replicating this approach across a wider range of service vehicle fleets to illuminate the opportunities that may exist for electric vehicle adoption in this niche sector in Ontario. The following recommendations largely convey this conviction:

1. Electric vehicle use generates measureable benefits in fleet applications, but not in all cases or applications. Therefore, strategies to communicate information to fleet managers and to equip them with analytical tools are essential, including in-service vehicle data-logging and tracking, and total cost of ownership analysis. With the right information and tools, fleet managers can establish the business case for electric vehicles in their unique situations and accurately estimate the environmental gains.

2. Electric vehicles are high-priced, partly due to the cost of their advanced battery technology. The Total Cost of Ownership analysis conducted in Project EVAN shows the sensitivity of the payback period to the purchase price of the electric vehicle. Policies that mitigate the costs of the capital outlay will contribute positively to a business case that supports electric vehicle procurement in fleets. Therefore, Pollution Probe believes that the electric vehicles purchase incentive currently offered by the Government of Ontario (*Electric Vehicle Incentive Program*) should be maintained, while further investigation of the business case is conducted through ongoing analysis of electric vehicles in fleets.

3. An alternative way to mitigate the incremental cost of electric vehicle technology is to enhance the residual value of the battery. A feasibility study into the value that the retired electric vehicle battery represents to a third party may reveal an effective value proposition. For example, municipality-owned utilities may see value in accumulating used batteries from municipal fleets for smart grid energy storage systems.

4. Concerns about electric vehicle range continue to be an inhibitor to the optimal use of this unfamiliar technology. The strategic placement of charging stations to address range anxiety among fleet vehicle users can help, provided that the placement is informed by the vehicle use data generated through fleet measurement.

Conclusion

Project EVAN demonstrates the importance of establishing a business case for electric vehicle procurement in public and private sector fleets. If applied to the right type of service, electric vehicles can generate substantial cost reductions in fleet operations. But to capture operational savings through electric vehicle use, a discipline of vehicle use measurement and analysis is needed. Fortunately, the tools of measurement and analysis are available to fleet managers, as Project EVAN demonstrates. Project EVAN logged vehicle data for an entire year! Discovering the sweet spot for electric vehicles in your particular fleet can be established with reasonable accuracy in a matter of months or less.

The story that emerges from Project EVAN is that the environmental objectives of the fleet owner need not run counter to the financial realities of the fleet manager's budget. In this sense, the phrase "greening the fleet" actually appears to be a double-entendre, since electric vehicle use can benefit both the financial and the environmental bottom lines.

Our advice is simple: Don't guess. Measure; then decide.

Appendix A: Data Collection and Analysis Methodology

ACRONYMS

CAN	Controller Area Network (automotive industry standard communication protocol)
DLC	Data Link Connector (the diagnostic port generally located below the steering wheel)
DRU	Data Recorder Unit (ISAAC Instruments' data logging hardware)
OBD	On Board Diagnostics (SAE-mandated diagnostic interface)
OEM	Original Equipment Manufacturer (refers to vehicle manufacturer e.g. GM, Toyota)
SAE	Society of Automotive Engineers (standards organization)

SOURCE DATA

The current methodology utilizes the CAN data stream available via the OBD DLC. Available data includes both runtime and diagnostic signals. Automotive OEMs often broadcast important signals on the CAN bus connected to this port to facilitate troubleshooting by their mechanics. SAE mandates that a small subset of essential signals is made available on this port.

DAQ HARDWARE

Three data collection solutions have been used, with two still in active use (C5 and CarChip). ISAAC Instruments offers a data recorder unit (DRU) which can log two CAN buses simultaneously. Additionally, the hardware is modular with peripheral ports allowing it to attach analog sensors, connect to GPS, and communicate wirelessly with a base station via GSM. The large wiring harness and additional peripherals do present a challenge for neatly integrating the logger into a vehicle, when concealment for aesthetic reasons is required.

Davis Instruments offers a simple data logger that can be configured to log some of the SAE OBD signals on conventional vehicles that support them. Its low logging frequency makes it suitable for long-term data monitoring of relatively stable signals, but loses some accuracy when monitoring transient behaviour. The logger unit plugs directly into the OBD port, and its low physical profile means that there is no additional installation work to keep it out of the way.

CrossChasm Technologies has developed an in-house data logging solution called the C5. This device is also capable of logging two CAN channels simultaneous. It expands the available dataset by allowing capture of both OBD PID queries and runtime signals. Slightly larger than a CarChip, it also plugs directly into the OBD port.

LOGGING

The loggers remain plugged into the vehicle at all times, collecting data whenever a vehicle is in operation (driving or charging). Each signal is sampled periodically at a fixed timestep. The minimum logging frequency depends on the resolution required by the variable in question.

For the conventional vehicles the following signals were logged:

- Time
- Vehicle speed
- Engine speed
- Mass Air Flow
- Intake Air Temperature

The signals logged on the electric vehicles varied by vehicle. In all cases, the following values (or equivalent) were logged:

- Time
- Vehicle speed
- Battery power (or equivalent, such as voltage and current), for both driving and charging
- Battery State of Charge (SOC)

A number of other signals were captured, including HVAC and motor signals; however, the signals above were the minimum set required for the objectives of this project.

DATA TRANSMISSION

ISAAC (EDGE) – average of 5 kb/sec observed, limit in practice is 10 kb/sec.

ISAAC data is uploaded automatically (currently configured to attempt uploading whenever vehicle is off) through a GSM modem that connects to Rogers EDGE network. Data transmission rate averages 5 kb/sec, with an observed peak of around 10 kb/sec.

CarChip data must be uploaded through a FleetCarma program installed on the client's computer.

C5 data must be uploaded through a web interface on the FleetCarma website.

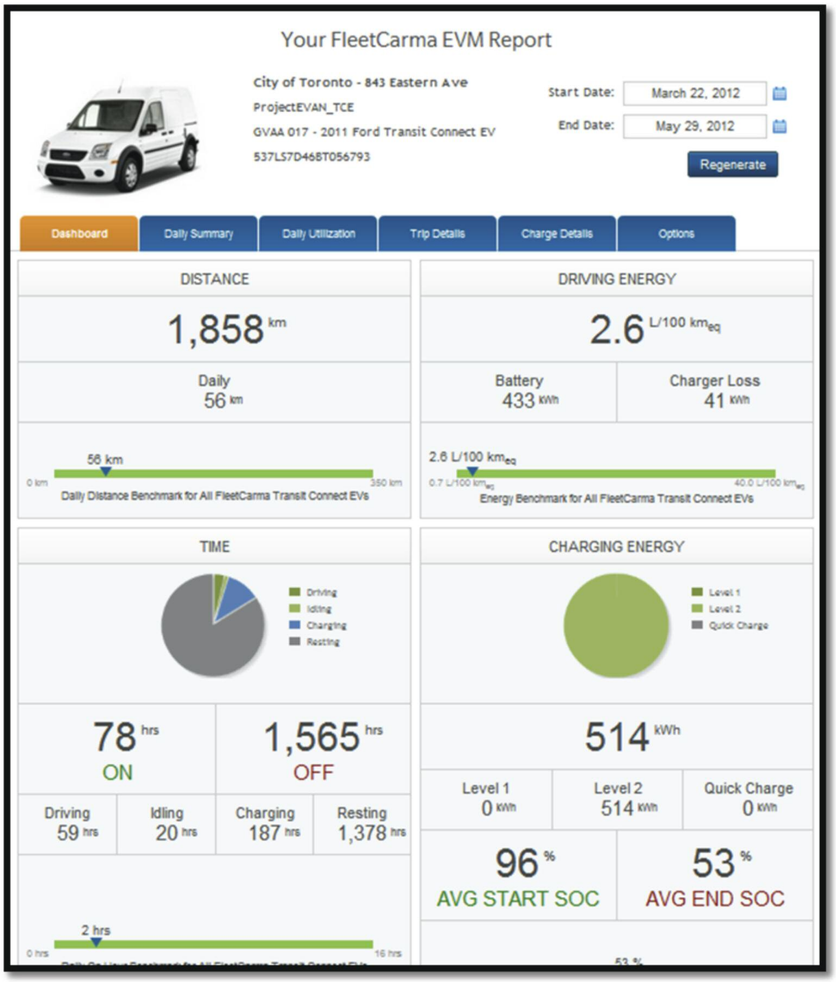
DATA LOGGER SWAPPING SCHEDULE/PROCESS

Fleet Challenge Ontario staff regularly attended the City of Toronto Fleet Services maintenance garage at Sheppard Ave., Toronto in order to exchange the Car Chip data loggers that were installed on the ICE vehicles. These site visits took place at most every eight weeks. With support from Toronto Fleet Services fleet staff, new Car Chips were "swapped" with the previously installed devices.

While the Car Chips are capable of storing many weeks of vehicle data, a sufficient margin was allowed between the "swaps" to avoid the potential of data overload and consequential errors. After making the swaps, Fleet Challenge Ontario staff uploaded the data to CrossChasm Technologies' servers for analysis.

DATA SIGNALS & PROCESSING

Upon upload of data to CrossChasm Technologies' servers, the raw data was decoded and converted into summary data. In the case of C5 data, this was completed by automated scripts that generated FleetCarma EVM (Electric Vehicle Monitoring) reports. A screenshot of the dashboard is shown below.



Your FleetCarma EVM Report

City of Toronto - 843 Eastern Ave
ProjectEVAN_TCE
GVAA 017 - 2011 Ford Transit Connect EV
537LS7D46BT056793

Start Date: March 22, 2012
End Date: May 29, 2012

DISTANCE
1,858 km
Daily 56 km

DRIVING ENERGY
2.6 L/100 km_{eq}
Battery 433 kWh
Charger Loss 41 kWh

TIME
78 hrs ON
1,565 hrs OFF
Driving 59 hrs
Idling 20 hrs
Charging 187 hrs
Resting 1,378 hrs

CHARGING ENERGY
514 kWh
Level 1 0 kWh
Level 2 514 kWh
Quick Charge 0 kWh
96 % AVG START SOC
53 % AVG END SOC

In the case of CarChip data, the data was uploaded using the FleetCarma client and again analyzed using automated scripts that generated FleetCarma TCO reports. While the intent was not to perform a TCO report, these reports generated the majority of the sought metrics.

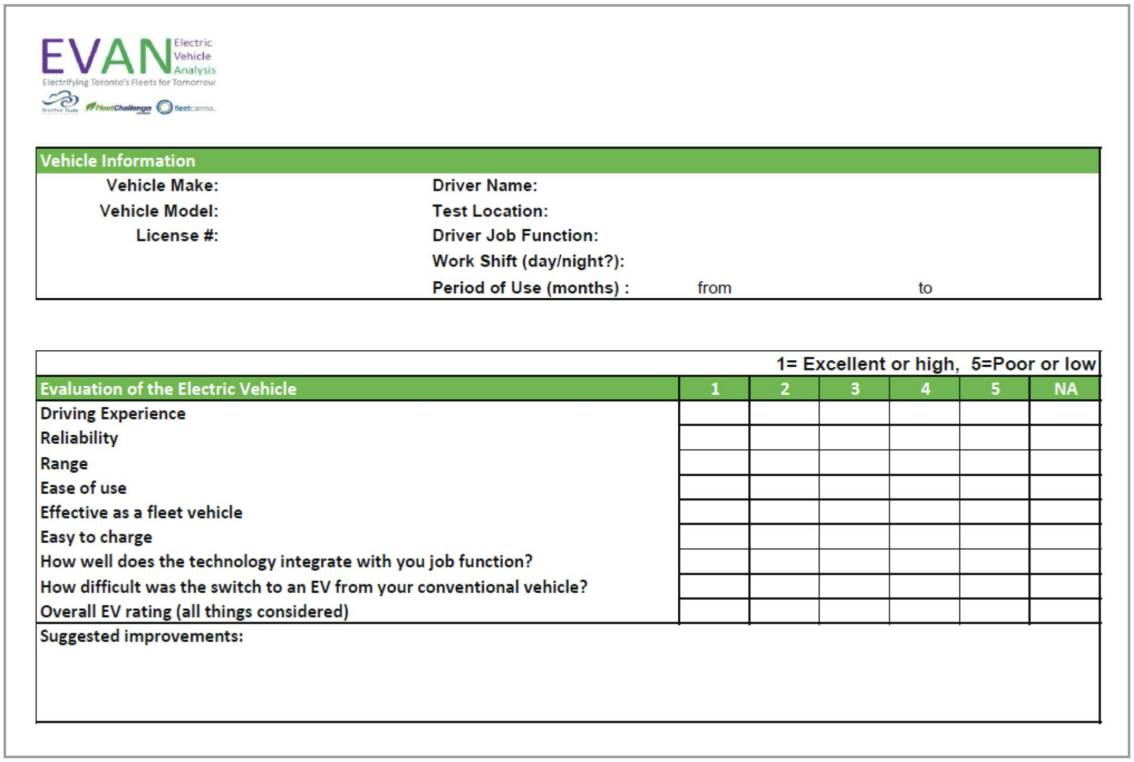
In the case of ISAAC data, the data had to be extracted to a Matlab .mat file and then custom scripts for the individual files and uploads needed to be created to convert the raw data into the summary metrics listed.

DATA SECURITY

All of the data described above is stored in CrossChasm Technologies' secure FleetCarma databases. The system is accessed through secure logins that include password hashing with salt.

Appendix B: Project EVAN Driver Experience Survey Template and Response Summaries

PROJECT EVAN DRIVER EXPERIENCE SURVEY TEMPLATE:



EVAN Electric Vehicle Analysis
Electrifying Toronto's Fleets for Tomorrow
fleetChallenge fleetcarma.

Vehicle Information

Vehicle Make:
Vehicle Model:
License #:
Driver Name:
Test Location:
Driver Job Function:
Work Shift (day/night?):
Period of Use (months) : from to

1= Excellent or high, 5=Poor or low

Evaluation of the Electric Vehicle	1	2	3	4	5	NA
Driving Experience						
Reliability						
Range						
Ease of use						
Effective as a fleet vehicle						
Easy to charge						
How well does the technology integrate with you job function?						
How difficult was the switch to an EV from your conventional vehicle?						
Overall EV rating (all things considered)						

Suggested improvements:

PROJECT EVAN DRIVER EXPERIENCE SURVEY RESPONSE SUMMARIES:

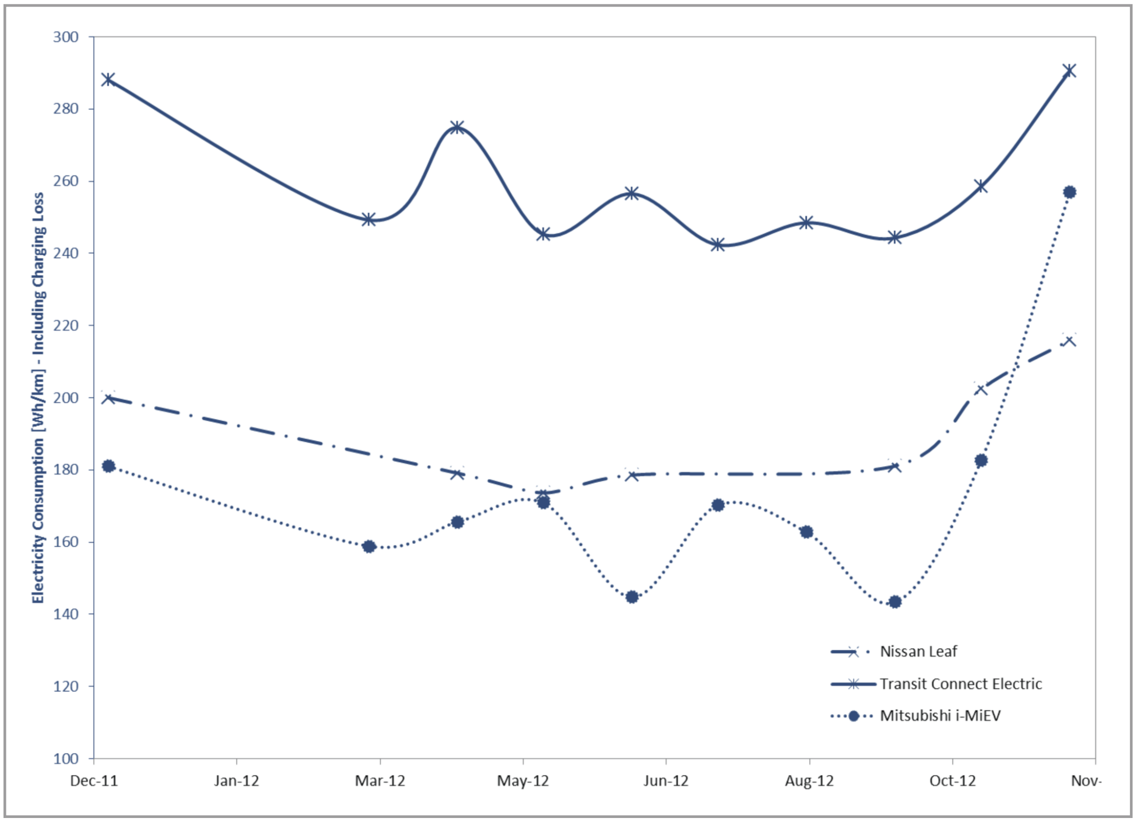
Eleven City of Toronto staff, who drove the electric vehicles examined during Project EVAN, completed the survey in September 2012, helping inform the user-experience perspective of the business case. Below are their responses to the survey featured above:

- More than half of respondents (7/11) rated their **driving experience** to be excellent to very good, with the remainder split between average (2/11) to below average (2/11).
- More than half of respondents (7/11) rated **reliability** to be excellent to very good, with the remainder divided between average (2/11), below average (1/11) and poor (1/11).
- More than half of respondents (7/11) had some concerns about **range**, rating this as average to poor. Other respondents felt that the electric vehicle range was good (2/11) or excellent (2/11).
- The majority of respondents (8/11) rated their electric vehicles **ease of use** as excellent or very good, with the remainder split between average (1/11) and below average (2/11).

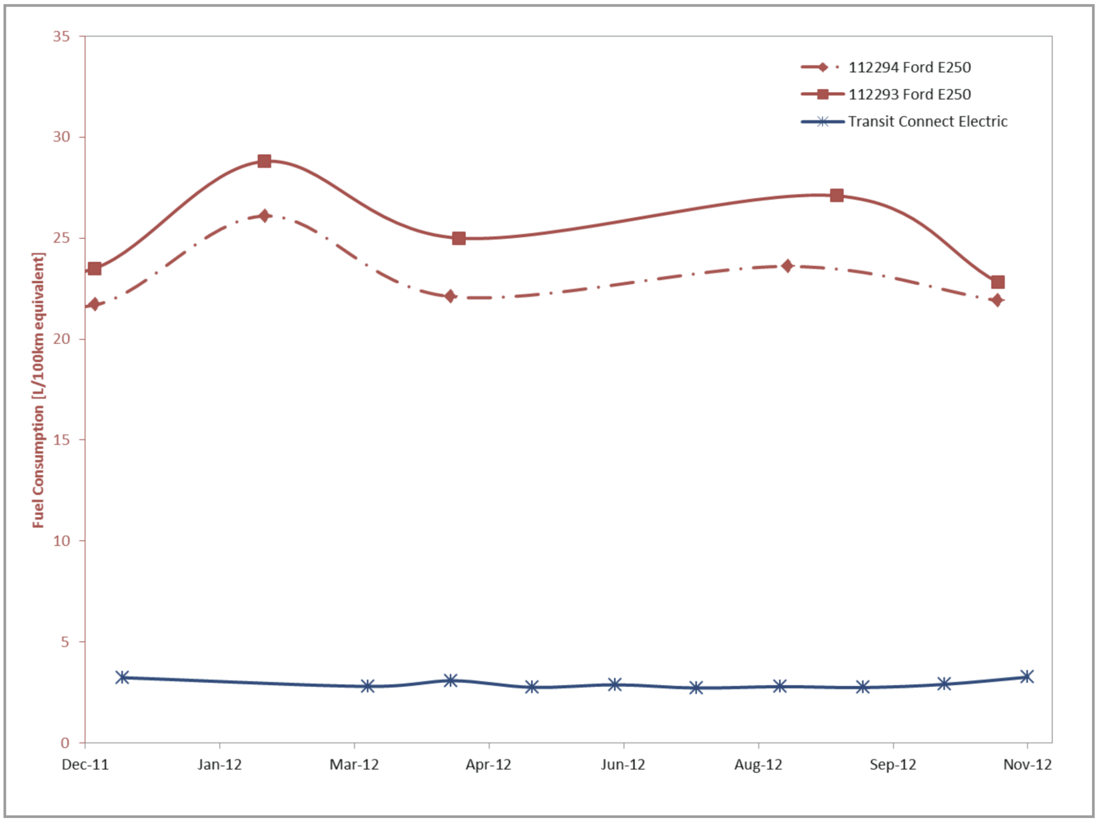
- More than half of respondents (6/10) rated their electric vehicles as excellent or very good for **service vehicle use**. Other respondents rated electric vehicles effectiveness as service vehicles average (2/10) and below average (2/10)/
- The majority of respondents found the electric vehicles **easy to charge** (7/11), however other respondents rated this average (2/11) and poor (2/11).
- The majority of respondents felt that electric vehicles **integrated well with their job function** (8/11), however others found this average (1/11), below average (1/11) and poor (1/11).
- More than half of respondents found that it was **easy to switch** from conventional to electric vehicles (6/10), however others found this average (1/10) and poor (3/10).
- More than half of respondents rated electric vehicles **overall** as very good to excellent (7/11); other rated their experience as average (2/11) and below average (2/11).

Appendix C: Project EVAN Electricity and Fuel Consumption – Seasonal Trends

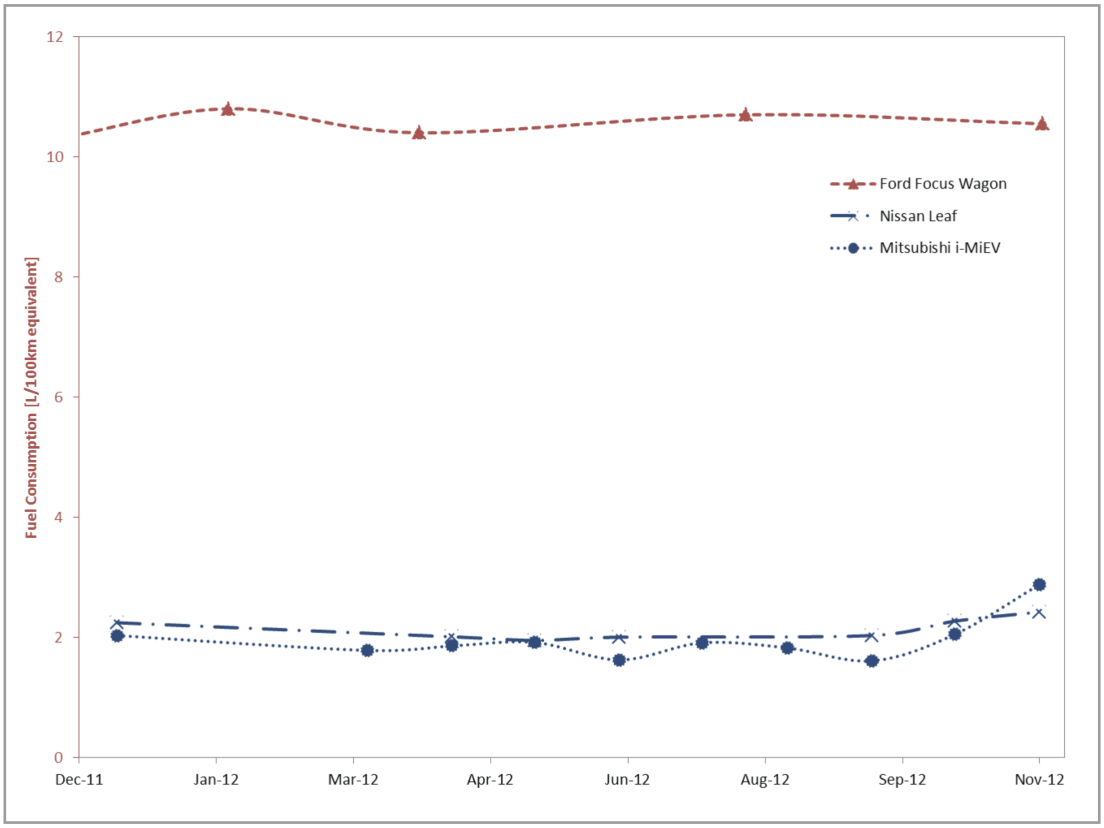
Nissan LEAF, Mitsubishi i-MiEV and Transit Connect Electric – Electricity Consumption



Cargo vans: Ford E-250 Van and Transit Connect Electric – Fuel Consumption

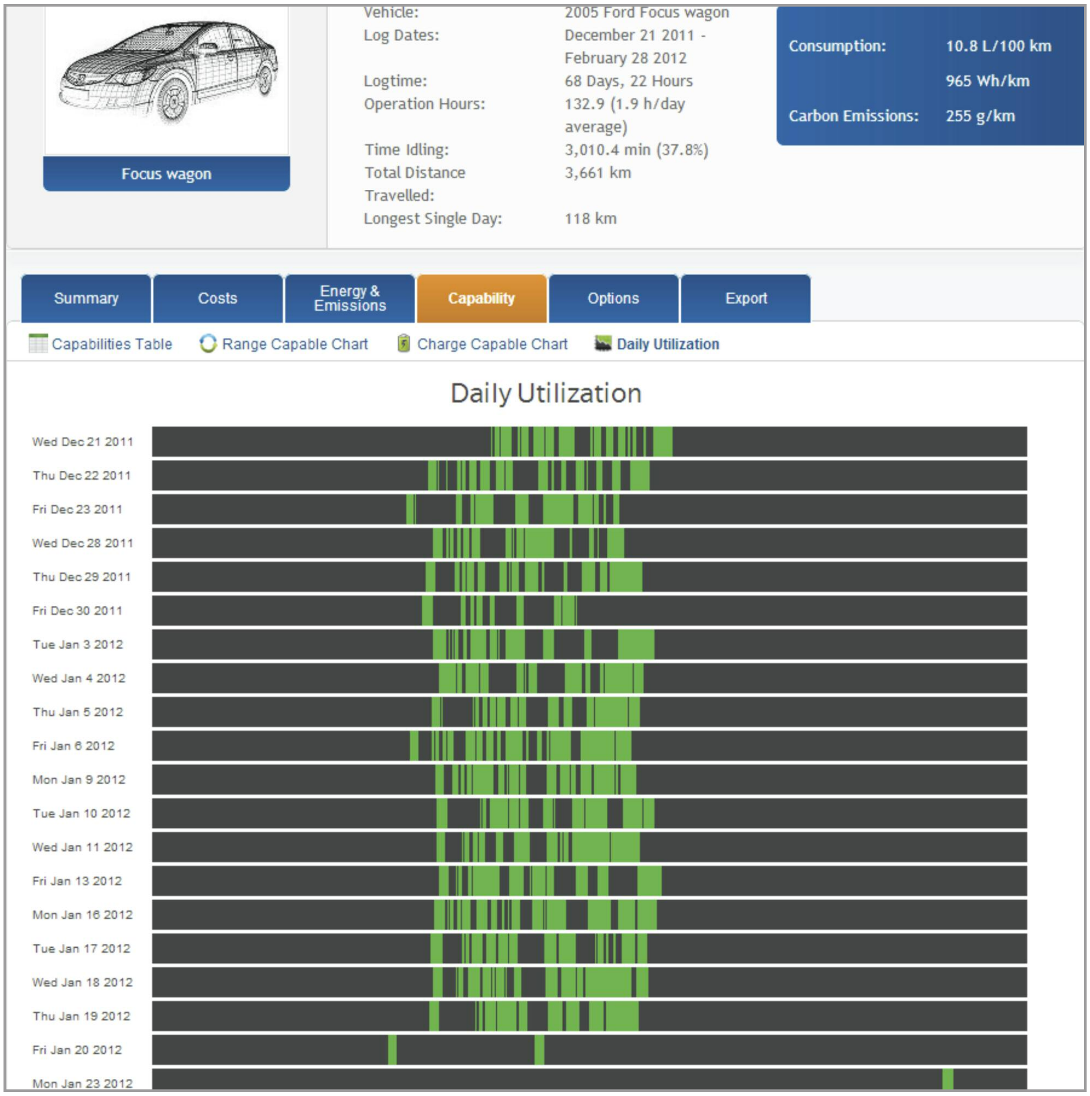


Cars: Ford Focus, Nissan LEAF and Mitsubishi i-MiEV – Fuel Consumption



Appendix D: Project EVAN Daily Vehicle Use – Select Fingerprints

Ford Focus Wagon

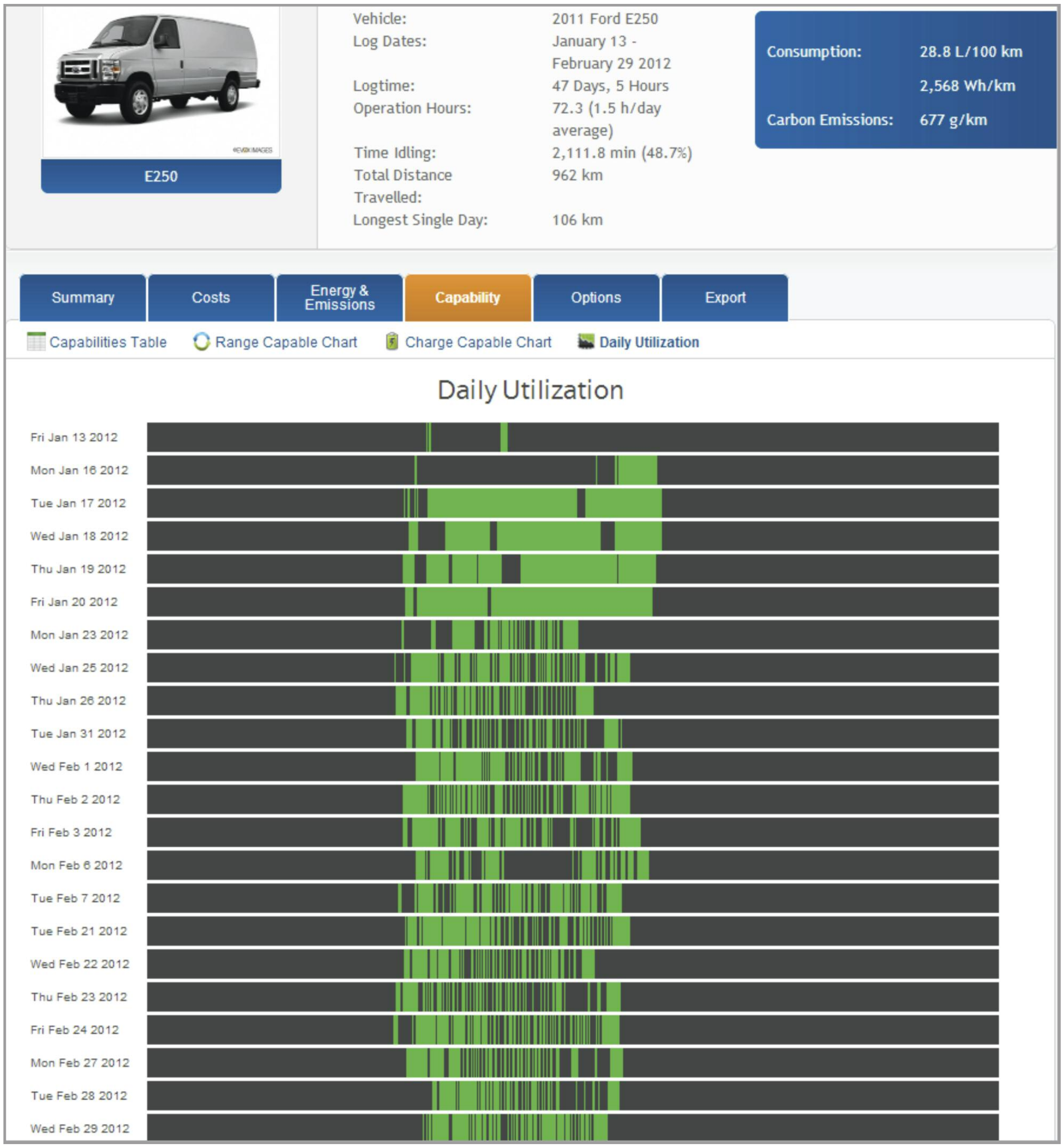


Vehicle:	2005 Ford Focus wagon
Log Dates:	December 21 2011 - February 28 2012
Logtime:	68 Days, 22 Hours
Operation Hours:	132.9 (1.9 h/day average)
Time Idling:	3,010.4 min (37.8%)
Total Distance Travelled:	3,661 km
Longest Single Day:	118 km

Consumption:	10.8 L/100 km
	965 Wh/km
Carbon Emissions:	255 g/km

Daily Utilization

Ford E-250 Van - unit #112293

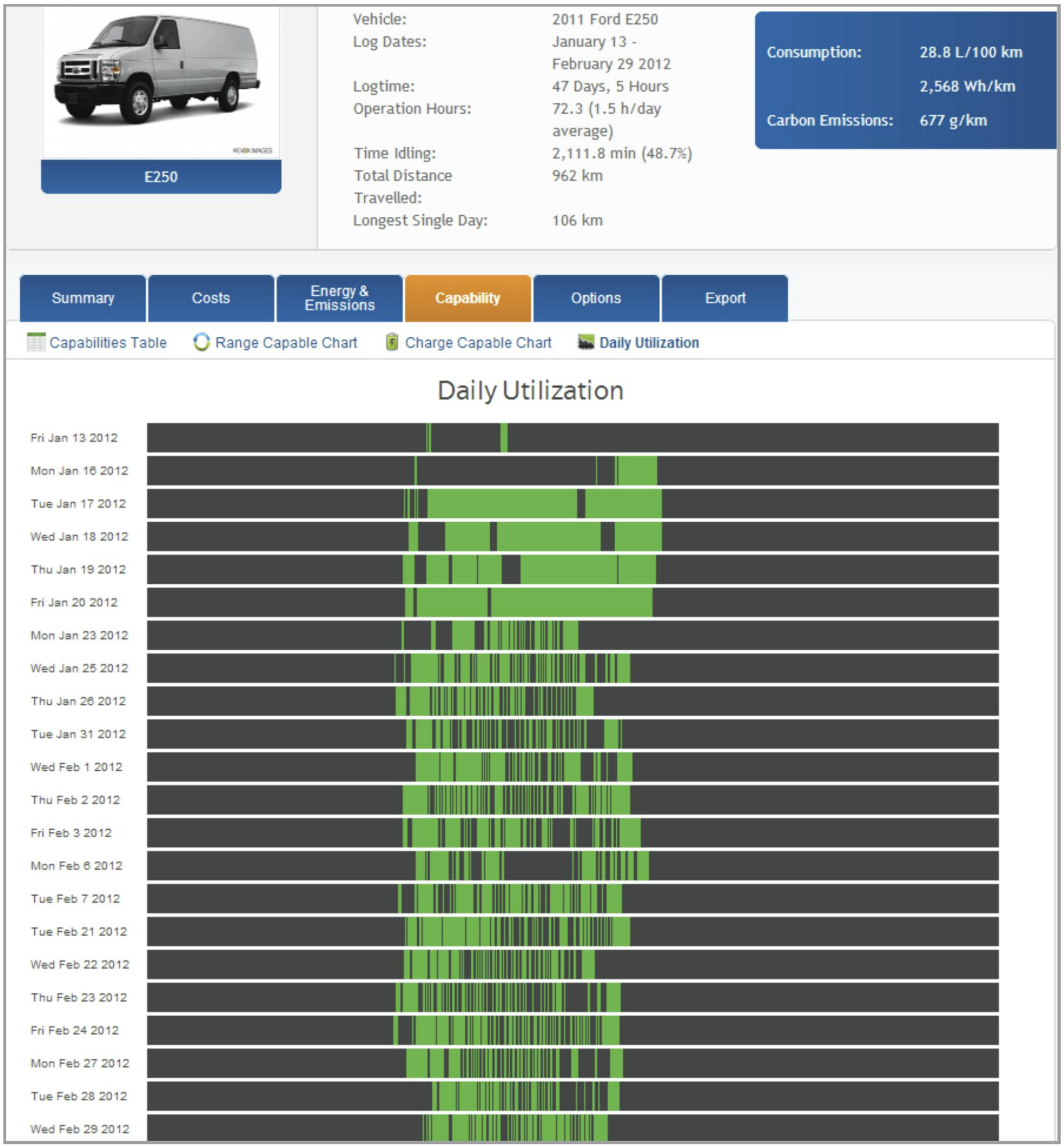


Vehicle: 2011 Ford E250
Log Dates: January 13 - February 29 2012
Logtime: 47 Days, 5 Hours
Operation Hours: 72.3 (1.5 h/day average)
Time Idling: 2,111.8 min (48.7%)
Total Distance Travelled: 962 km
Longest Single Day: 106 km

Consumption: 28.8 L/100 km
2,568 Wh/km
Carbon Emissions: 677 g/km

Daily Utilization

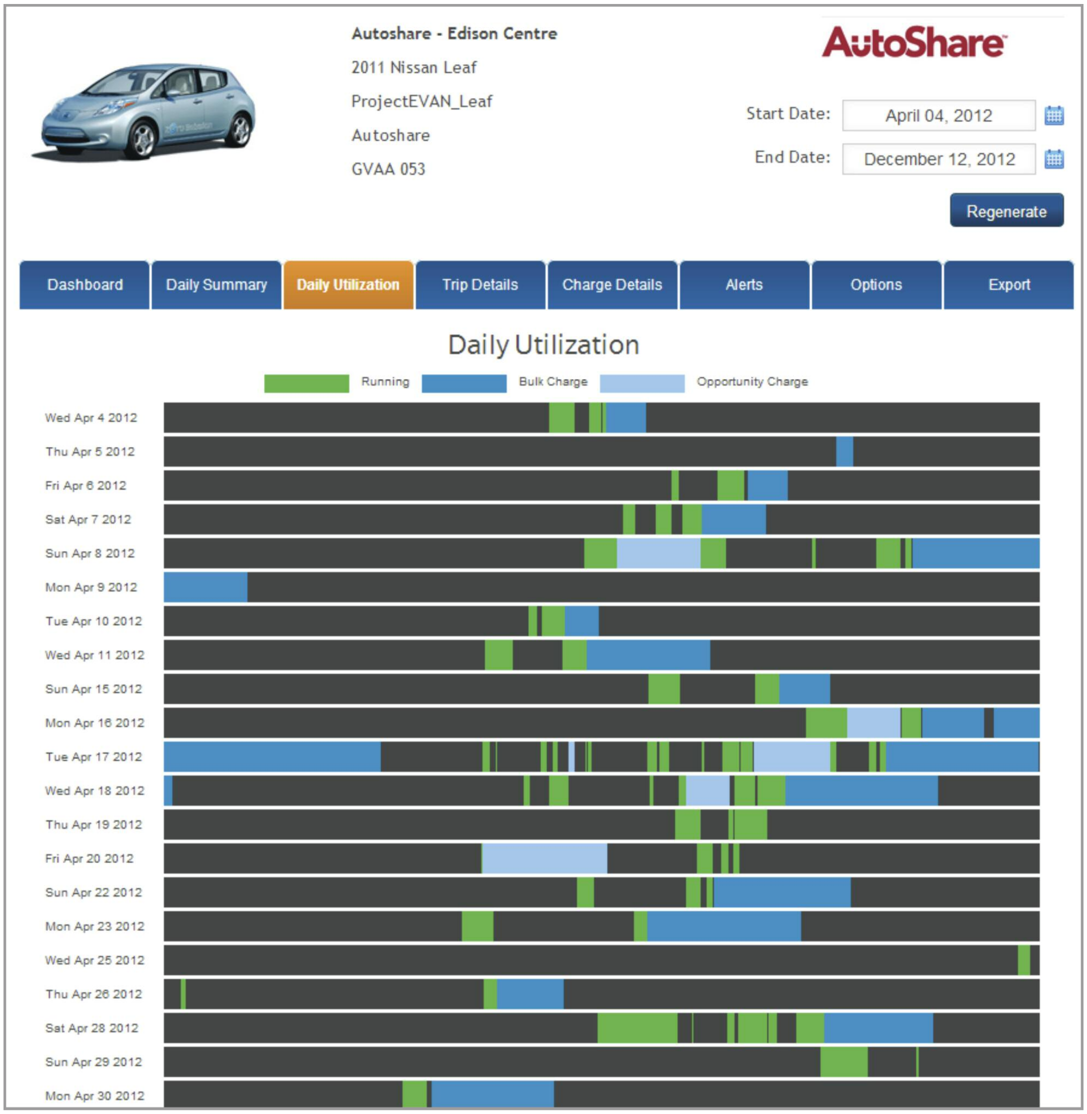
Ford E-250 Van - unit #112294



Vehicle:	2011 Ford E250
Log Dates:	January 13 - February 29 2012
Logtime:	47 Days, 5 Hours
Operation Hours:	72.3 (1.5 h/day average)
Time Idling:	2,111.8 min (48.7%)
Total Distance Travelled:	962 km
Longest Single Day:	106 km

Consumption:	28.8 L/100 km
	2,568 Wh/km
Carbon Emissions:	677 g/km

Nissan LEAF

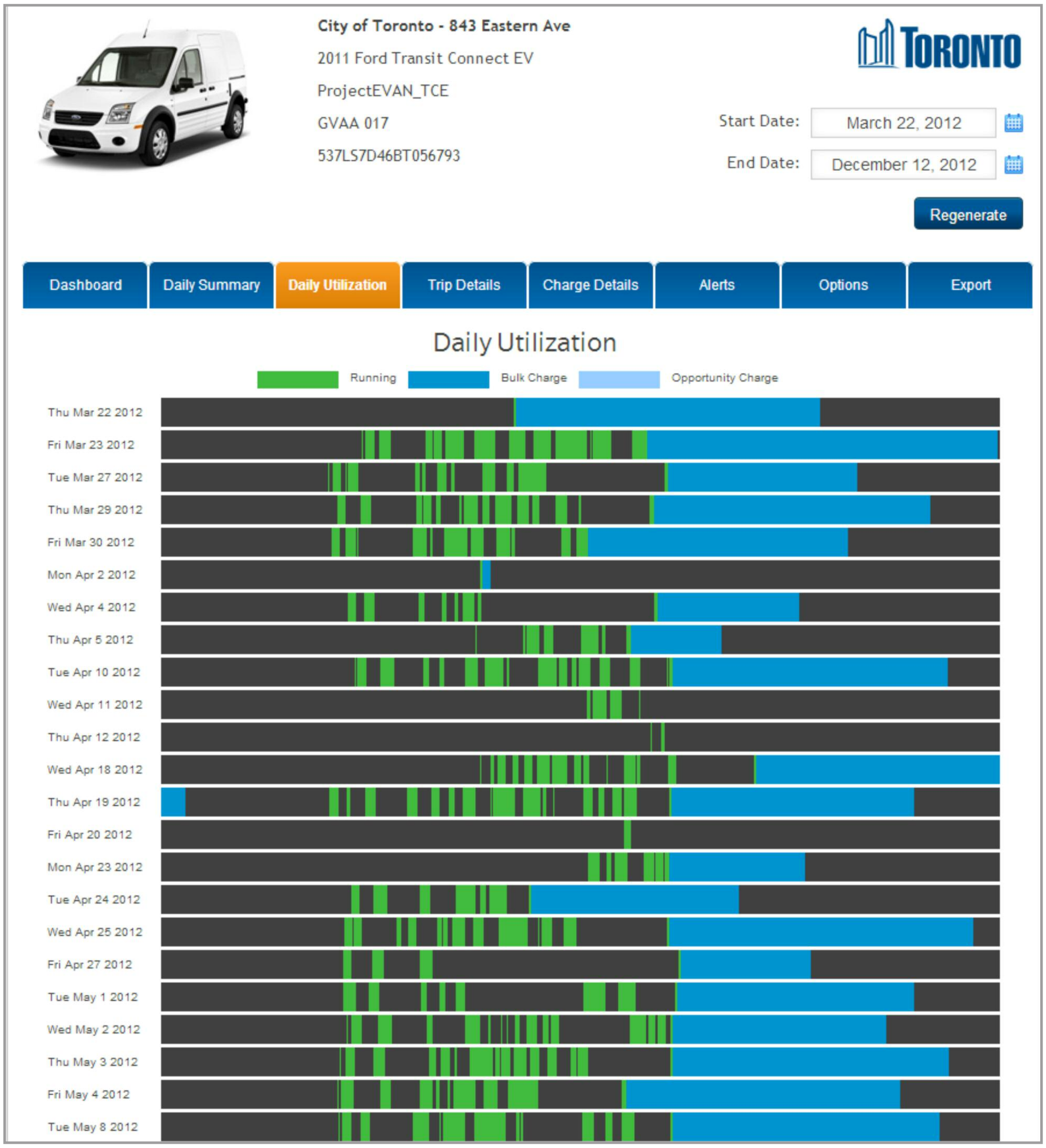


Autoshare - Edison Centre
2011 Nissan Leaf
ProjectEVAN_Leaf
Autoshare
GVAA 053

Start Date: April 04, 2012
End Date: December 12, 2012

Appendix D: Project EVAN Daily Vehicle Use – Select Fingerprints

Transit Connect Electric

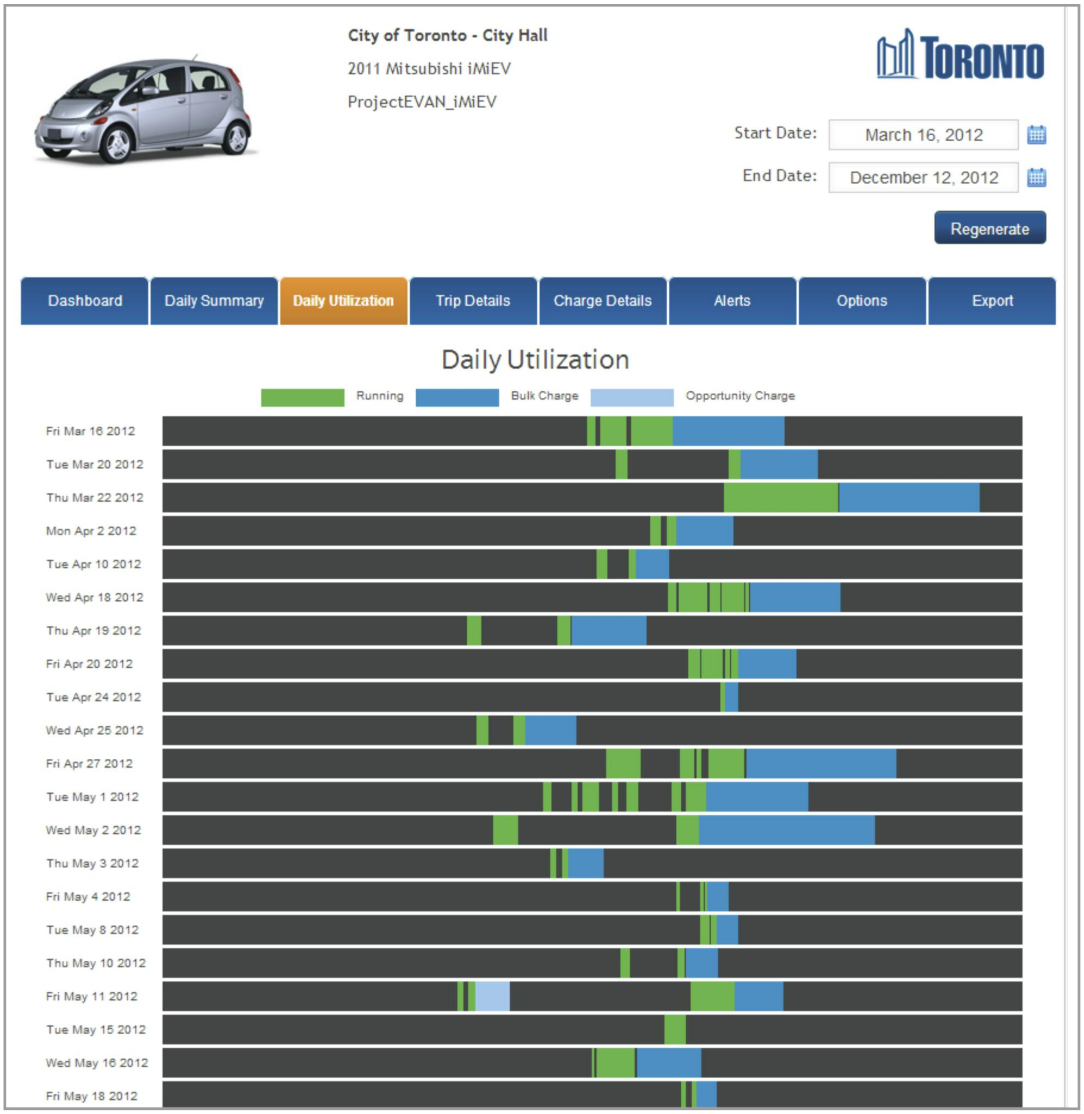


City of Toronto - 843 Eastern Ave
2011 Ford Transit Connect EV
ProjectEVAN_TCE
GVAA 017
537LS7D46BT056793

Start Date: March 22, 2012
End Date: December 12, 2012

Appendix D: Project EVAN Daily Vehicle Use – Select Fingerprints

Mitsubishi i-MiEV



City of Toronto - City Hall
2011 Mitsubishi iMiEV
ProjectEVAN_iMiEV

Start Date: March 16, 2012
End Date: December 12, 2012

POLLUTION PROBE
CLEAN AIR. CLEAN WATER.

208-150 Ferrand Drive, Toronto, Ontario M3C 3E5

T 416-926-1907
F 416-926-1601
Toll Free 1-877-926-1907
E pprobe@pollutionprobe.org

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