FLEETWISE EV300

Findings Report on EV Usage in Sixteen GTA Fleets

TORONTO ATMOSPHERIC FUND

TORONTO
ATMOSPHERIC
FUND

FLEETWISE EV300

Findings Report on EV Usage in Sixteen GTA Fleets

June 2015

Toronto Atmospheric Fund invests in urban solutions to reduce greenhouse gas emissions and air pollution. We are always ready to listen to your ideas about how to shrink the City of Toronto's carbon footprint. For more information, please visit our website at **TAF.ca**

Acknowledgments

The EV300 Program was a highly collaborative effort that depended on the support and cooperation of many different public and private sector organizations. This included 16 GTA-area fleet partners, five vehicle partners, five electric utility partners and eight program and technology partners.

Technology and services provided by **FleetCarma, a division of CrossChasm Technologies**, warrant specific recognition. Its data loggers, modeling tools and analytics provided the empirical data to help guide fleet operator vehicle selection, provided the basis of their 2013 EV300 findings report and now enable TAF to use the results to make the environmental and business cases for converting fleets from combustion-engine to electric vehicles.

Key program management services were provided by **Fleet Challenge Ontario**, brought on due to their expertise in green fleet planning and adoption of new technologies. Program managers were former Bell Canada national fleet manager Allan King and former GM Canada staffer John Lyon.

TAF also acknowledges the contributions and support of the **City of Toronto Electric Vehicle Working Group.**

Financial support for the EV300 Program was provided by **Hydro One**, the **Ontario Ministry of Transportation** and **Natural Resources Canada**.

This report has been prepared by **Brian Banks** based on technical project findings technical project findings from CrossChasm Technologies.

Contents

1.0 Introduction

Moving people and goods by vehicle accounts for 38% of Toronto's greenhouse gas emissions and is a major source of smog-producing pollutants. As an element of its mandate, the Toronto Atmospheric Fund (TAF) has been working since 2007 with operators of public and private fleets to encourage and support adoption of low/no-emission electric vehicles.

In February 2010, TAF launched the EV300 Program, a comprehensive, incentivized program to help public and private organizations shift portions of their fleets to plug-in hybrids and all-electric vehicles.

The EV300 Program included partnerships with vehicle makers and technology providers, providing fleet operators with the benefits of discounted vehicle procurement, needs assessment, customization advice, performance testing and operational training.

The program set an initial goal of adding 300 electric vehicles to these fleets by 2012.

2.0 Overview

EV300 objectives

- Replace 300 fleet vehicles in the Greater Toronto Area with electric vehicles by 2012.

- Create a critical level of local fleet demand for plug-in hybrid and all-electric vehicles and supporting EV infrastructure to help kick-start the sector and reduce barriers to greater EV use in the GTA.

- Streamline and support fleet operators who are "greening" their fleets, by helping them choose and acquire appropriate vehicles, providing driver training and performance tracking.

- Make the business and environmental cases for EV adoption by removing 300 combustion-fueled fleet vehicles from GTA roads and measuring reductions in greenhouse gas emissions, other pollutants, and savings on fuel/fleet expenses.

- Acquire and share knowledge about real-world, electric vehicle fleet and driver performance to help all EV300 partners—carmakers, technology and service providers, fleet operators and the TAF—better understand EV applicability and benefits, anticipate hurdles and obstacles to use, and tailor future programs/policies on EV adoption.

EV300 key outcomes

- Baseline monitoring of 31 conventional internal combustion fleet vehicles.
- Simulated new vehicle performance.
- Supported development of a new fleet managers' purchasing decision-making tool, FleetCarma
- Analyzed performance of 52 electric vehicles in 16 fleets across the GTA
- Created a full technical and findings report.

Methodology

The EV300 pilot project method was rooted in TAF's focus on fleets. Fleets are ideal candidates for early adoption of electric vehicles and an ideal testing ground due to their need to acquire and deploy a variety of different vehicle types and patterns of use that usually involve frequent short trips.

The pilot unfolded in two phases. In the first, as organizations joined the EV300 Program, data loggers from technology partner FleetCarma were used to record the duty cycles of a baseline sample of their current fleet vehicles. With this data, FleetCarma then ran simulations to determine the potential fuel cost savings and emissions reductions these organizations could achieve by replacing their current vehicles with the "best fit" EVs in the project.

In the second phase, which began once the fleet partners had acquired and deployed a sufficient number of new EVs (approximately 60 at that time), data loggers were again used, this time to measure these new vehicles' real-world performance.

FleetCarma analyzed the data collected and published the results, along with its conclusions and recommendations, in an EV300 report in November 2013.

Findings

Simulation results

According to FleetCarma, substituting a "best-fit" EV for the 31 gasoline vehicles that undertook baseline monitoring in the EV300 Program's simulation phase, would reduce the group's total annual fuel costs by $62,978.

Projected fuel savings varied greatly by individual vehicles—from as high as $8,524 to a low as $424—depending on the model, duty cycles and operating conditions.

Fuel costs for the simulated all-electric vehicles averaged $2.05/100 km, 87.7% less than the baseline vehicles. For the simulated plug-in hybrids, the average fuel cost was $6.62/100 km, 60.3% less than the vehicles they had replaced.

From a greenhouse gas standpoint, replacing all 31 vehicles in the EV300 Program with their simulated EV counterpart would save 149 tonnes of $C0_2$ each year.

Real world EV performance

After replacing internal combustion-powered vehicles with plug-in hybrid and all-electric vehicles, fleet partners reported saving thousands of dollars in annual operating costs and full payback on extra upfront costs from within six months to four years.

Many factors affect (and can be optimized for) vehicle use, distances travelled and overall performance. These include: temperature, driver behaviour, fleet charging practices and vehicle applications.

For the total 52 vehicles monitored in the EV300 Program, average GHG emissions from electric vehicles were 3.11 kg $C0_2$/100 km for battery electric vehicles and 15.56 kg $C0_2$/100 km for plug-in hybrid vehicles. Compared to the baseline vehicles, this represents an average 92% reduction in greenhouse gas emissions for battery electric vehicles, and a 60% reduction in greenhouse gas emissions for plug-in hybrid vehicles.

Business case

The results demonstrate a compelling business case. Average fuel costs for battery electric vehicles were 87.9% lower ($2.02/100 km) than the average baseline vehicles' fuel costs of $16.67/100 km. Plug-in hybrids' average fuel costs were $13.12/100 km, which is 21.3% cheaper than the baseline conventional vehicles' fuel costs.

Fleet partners estimated cost savings per vehicle between $2,000 and $14,000 per year.

As EV usage increases, the business case for EVs becomes stronger. Higher usage results in decreased payback periods. Therefore, ensuring prioritized EV use within fleets is a critical factor for EV success. Itis common, for example, to earn back the incremental cost of an electric vehicle compared to a conventional vehicle through fuel cost savings in the first year.

Implications of findings for best practices

- Matching EVs to duty cycle requirements optimizes savings.

- Since each plug-in vehicle offers unique benefits, fleet managers that leverage EV modeling technology driven by their own duty cycle data can better match each vehicle option to their fleet needs and to optimize costs and environmental benefits.

- There is an opportunity to use fleet EVs more often.

- Fleets with plug-in vehicles have not been using them as much as they could be used. Increasing electric vehicle utilization reduces payback periods so that fleets see corporate savings sooner.

- There are strategies to mitigate the range of implications of EVs in cold weather.

- Although data showed that EVs lose electric driving range when temperatures get cold, the data also showed that this impact can be substantially mitigated by using seat warmers, pre-conditioning vehicles while still on plug, and driving efficiently.

- GHG savings from EV fleet integration are substantial.

- This impact can be expanded upon through increased utilization of electric vehicles, and an increased portion of electric utilization for plug-in hybrid vehicles.

3.0 Program Design

Project development, purpose, scope

EV300 was created to help public and private fleet operators across the GTA to shift portions of their fleets to plug-in hybrids and battery electric vehicles. It built upon the work of the then four-year-old FleetWise program, whose objectives included:

- Positioning Toronto and the GTA as a leading adopter of electric vehicle technologies to combat climate change and smog and create new economic opportunities in the process.
- Collecting and sharing information on the costs, performance, benefits and best-practice use of electric vehicles to help fleet managers make better-informed decisions about electric vehicles.

Many public and private fleets are actively working to reduce the air polluting emissions from their fleets by "right sizing" vehicles, more efficient trip planning, and integrating alternative fuel vehicles. Electric vehicles can reduce emissions by 80% or more compared to a conventional internal combustion engine, making them an excellent choice for greening fleets.

EV300 was designed to help this process by including partnerships with vehicle makers and technology providers. The goal was making the integration of electric vehicles a more streamlined process by providing fleet operators with the benefits of discounted vehicle procurement, needs assessment, customization advice, performance testing and operational training. It set an initial goal of adding 300 electric vehicles to these fleets by 2012.

Fleet partners

The EV300 Program's 16 GTA-area fleet partners were all leaders by example. They made the commitment to procure and introduce new vehicles into their fleets, allowed those fleets to serve as project testing grounds, and reaped the rewards of the experience.

- Autoshare
- City of Hamilton
- City of Mississauga
- City of Toronto
- Greater Toronto Airports Authority
- Harbourfront Centre
- Metrolinx
- Ontario Ministry of Transportation
- Ontario Power Generation
- Toronto and Region Conservation Authority
- Toronto District School Board
- Town of Caledon
- Town of Markham
- Town of Oakville
- Town of Richmond Hill
- University of Toronto

Vehicle partners (vehicles)

The EV300 launch coincided with a number of major original equipment/automotive manufacturers bringing their first plug-in hybrid and/or battery electric vehicles into commercial production. Participation by the following companies ensured fleet partners would have an ample range of vehicle choices to match the needs and demands of their fleets.

- Ford/Azure Dynamics (Transit Connect EV)
- General Motors of Canada (Volt)
- Mitsubishi (iMiEV)
- Nissan Canada (Leaf)
- Toyota Canada (Prius)

Utility, program and technology partners

Successful EV adoption and implementation under the EV300 Program went beyond the vehicles themselves. The partners listed here helped with EV and charging infrastructure procurement and installation, driver training, in-service performance reporting and environmental and business case analysis; underlying generation, transmission and distribution of renewable energy to participants; and EV300 funding, promotion and support.

Utility partners

- Bullfrog Power
- Hydro One
- Ontario Power Generation
- Toronto Hydro
- Veridian

Program and technology partners

- Capgemini
- CrossChasm Technologies/FleetCarma
- Durham Strategic Energy Alliance
- Electric Mobility Canada
- Fleet Challenge Ontario
- Natural Resources Canada
- Ontario Ministry of Transportation
- Windfall Ecology Centre

Project timeframes

2010 EV300 Program announcement; program roll out; partner recruitment

February 2010 Toronto Atmospheric Fund announced EV300 Program. Several public fleets, including the City of Toronto, Toronto Hydro and the Ontario Ministry of Transportation, were introduced as partners at the outset.

July 2010 Recruitment for private fleet partners accelerated as new Ontario government subsidies for green-vehicle purchases took effect.

December 2010 Nissan, Mitsubishi and Ford/Azure Dynamic were all confirmed vehicle partners.

2011 Active pilot period begins; roster of vehicle partners and available vehicles finalized; more fleet partners added; fleet analysis, EV simulation modeling and EV procurement begins.

May 2011 GM Canada is the final vehicle partner added to the EV300 Program.

Ongoing 2011 The first step all fleet partners undergo is a three-week sampling of their current fleet usage and performance. With this data, technology partner FleetCarma runs simulations to determine the "best fit" EVs in the program for the fleet partner to acquire and deploy.

2012 Second phase of pilot period begins; more fleet partners added and vehicles procured; real-world EV fleet performance measured and analyzed.

Ongoing 2012 FleetCarma installs data loggers in newly deployed fleet partner EVs to measure and analyze real-world EV performance. Data collected includes distance and usage patterns, energy consumption, charging behaviour, and temperature effects on performance.

November 2013 ChossChasm/FleetCarma published EV300 Final Report.

May 2015 TAF publishes FleetWise EV300 Findings Report.

4.0 Pilot Project

Methodology

Phase One – Electric vehicle modeling and simulation

This first phase of the EV300 data gathering was conducted by installing a small data logger into fleet vehicles. These vehicles were driven for a period of approximately three weeks to collect a sufficient amount of data on their duty cycle, including any routine variation in the requirements of the fleet application. This information was used to create a baseline vehicle to benchmark against the comparable electric vehicles as substitutes.

Next FleetCarma ran simulations for the five EVs against the same duty cycle. This analysis not only predicted the fuel and electricity consumption of plug-in vehicles but the range and charge capability of electric vehicles completing those duty cycles. As part of this process, the total cost of ownership for the baseline vehicles were compared to the duty-cycle-specific costs of owning and operating, comparing EVs doing the same jobs.

The results of these simulations were then given back to the fleet managers in the FleetCarma tool, to help guide their decision-making around which vehicles to replace with EVs and which EVs would be the best fit. Access to this data and insight was a key factor that attracted fleet managers to enter the EV300 Program. In the words of one participant: "Using the FleetCarma system to collect data from our existing fleet helped us model the capabilities of EVs in our applications and to build the business case with our management team." A sample of the information that fleet managers receive is provided below, or visit www.fleetcarma.com for more information.

Figure One: A sample of the FleetCarma tool

	Range Capable	Charge Capable	Energy	Emissions	Annual Cost	FleetCarma Score	Details	Compare
2010 Nissan Sentra SE-R	-	-	9.4 L/100 km$_{eq}$	301 g/km	-	-	-	-
2012 Mitsubishi iMiEV	✓	✓	88% ↓	94% ↓	$4,586	93	▼	☑
2012 Nissan Leaf	✓	✓	82% ↓	91% ↓	$5,060	88	▼	☑
2012 Chevrolet Volt	✓	✓	77% ↓	84% ↓	$6,265	78	▼	☑
2012 Toyota Prius-Plugin	✓	✓	69% ↓	72% ↓	$5,996	75	▼	☑
2011 Ford Transit Connect EV	◔	✓	76% ↓	88% ↓	$8,642	45	▼	☑

Phase Two – In-service performance monitoring

The second phase involved in-service performance monitoring of newly introduced electric and plug-in hybrid vehicles with another type of data logger. It collected real-world information on the vehicle's mileage and utilization, fuel and power consumption, charging information, and driver behaviour over a period of up to a year.

The choice to work with fleets

Fleets are a natural choice for the early adoption of electric vehicles because:

- They are leaders of new technologies, demonstration vehicles, and pilot programs. A fleet's structure allows for greater implementation of a new technology as a large number of vehicles can be purchased and used.

- They are leaders in delivering sustainability performance for their organizations. The efficiency of vehicles within a fleet and the consequential reductions in greenhouse gas emissions is an environmental benefit that an organization can rely on to support their sustainability programs. That benefit can be used to achieve internal targets for emissions reductions or used as a highlight the work is doing in this regard to external stakeholders, citizens, and customers.

- They contain many different vehicles used for a variety of applications. This suits the integration of electric vehicles into fleets as electric vehicles can first be implemented in duty cycles, which are ideal for a plug-in vehicle. This targeted, early implementation allows for greater initial success while fleet operators, drivers, and the organizations adapt to the new technology.

- They provide an ideal testing ground due to their control over driving patterns and operation. Fleets often keep track of driving cycles and have up-to-date information on when, how, and specifically how much each vehicle is used.

- They have some control over the implementation of the infrastructure beneficial to electric vehicle adoption. Fleets can ensure that drive cycles have charging points at various locations the vehicle may be travelling to, and can also ensure regular hours for the vehicle to charge.

- They have a business interest in integrating alternative technologies, and specifically electric vehicles into their fleet due to the increasing cost of gasoline. Fueling a vehicle requires a considerable portion of the fleet's budget, and while incremental decreases in fuel consumption are helpful, replacing vehicles with electric vehicles has a much more significant decrease in operational costs.

- They are very conscious of maintenance costs. Electric vehicles require less maintenance than the internal combustion engine vehicles which, combined with fuel savings, help to reduce payback periods on the premium paid for plug-in vehicle technology.

Electric vehicles and fleet considerations

In the EV300 Program, fleet partners were presented with five vehicle options—two plug-in hybrid electric vehicles and three battery electric vehicles. All five were included and evaluated in the pilot project's first-stage electronic vehicle simulations.

Plug-in hybrid electric vehicles

Chevrolet Volt. A 4-passenger vehicle with a 16 kWh battery with 10.4 kWh of usable capacity. Advertised battery range: 40 to 80 kilometres, depending on conditions. Advertised fuel consumption: 3.0 L/100 km. The Volt qualified for an $8,231 tax credit from Ontario Ministry of Transportation during the project period.

Toyota Prius Plug-in. A 5-seater hatchback with a 4.4 kWh lithium ion battery. Rated electric range: 18 kilometres. Advertised fuel consumption: 2.5 L/100km. The Prius Plug-in qualified for a $5,000 tax incentive in the project period.

Battery electric vehicles

Nissan Leaf. A 5-passenger, 100%-electric vehicle with a 24 kWh battery pack. Advertised range: 160 kilometres, varies with temperature and driving conditions. The Leaf qualified for an $8,500 tax credit at the time of the project.

Ford Transit Connect Electric. An all-electric van produced jointly by Ford and battery maker Azure Dynamics. Battery: 28 kWh lithium ion. Advertised/tested range: 130 kilometres (manufacturer); 90 kilometres (U.S. Environmental Protection Agency). The Transit Connect qualified for a $8,500 tax credit during the project.

Mitsubishi i-MiEV. A 4-passenger, all-electric vehicle, powered by a 16 kWh lithium ion battery pack. Rated range: 100 kilometres. The i-MiEV qualified for an $8,321 tax credit at the time of the project.

Figure Two: A comparison of vehicles in the EV300 Program

Vehicle	Chevrolet Volt	Toyota Prius	Nissan Leaf	Ford Transit Connect Electric	Mitsubishi i-MiEV
Vehicle Type	PHEV	PHEV	BEV	BEV	BEV
Passenger Capacity	4	5	5	2 (cargo van)	4
Battery Capacity (kWh)	10.4	4.4	24	28	16
Battery Range (km)	40-80	18	160	90	100
Available Incentives	$8,231	$5,000	$8,500	$8,500	$8,321

Fleet considerations

Fleet operators must weigh different considerations when evaluating, deploying and managing plug-in hybrid electric vehicles compared to battery electric vehicles.

Range anxiety

The first consideration for fleet operators, at least when it comes to all-electric vehicles, is range anxiety. This is a well-documented experience felt by drivers when they aren't sure their vehicle has the range capacity to complete a planned route or trip. If not addressed through driver education, training, proper scheduling and route planning, range anxiety can cause drivers to have negative feelings towards electric vehicles, believing them to be undependable.

The impact doesn't stop at drivers' feelings. Their fears translate into serious underuse of all-electric vehicles' capacity, which not only undermines their contribution to the fleet's work, but reduces potential maximum fuel savings and cuts down on potential reductions in GHG emissions. If severe enough, fallout from range anxiety can put the entire economic justification for conversion to EVs in jeopardy.

Fortunately, there are effective strategies to reduce range issues and instill driver confidence:

Driver training. Fleet operators can ease range anxiety by ensuring their drivers have thorough training in their vehicles' range capacities, the availability of charging infrastructure, and ways to use the vehicle to extend battery life (not speeding; modest use of heating and air conditioning systems that can drain the battery, etc.).

Starting state of charge. Studies repeatedly show that if fleet operators and drivers ensure that their all-electric vehicles start the day with a battery that's closer to fully charged, they'll travel farther and experience less range anxiety on that day's rounds. This relationship holds true in the EV300's real-world fleet results (below).

Route planning and navigation. Operators can also lessen drivers' range anxiety by equipping them with reliable navigation tools and technology, to lessen the risk of unexpected extra travel. Similarly, routes that are well planned in terms of access to service infrastructure or proximity to home base can alleviate driver concerns.

Managing payback periods

A second consideration for fleet operators is managing payback periods.

In the case of all-electric vehicles, one of the unique challenges in this regard is to find applications where the vehicles will have enough daily driving to take advantage of low operating costs —thereby reducing payback periods—without running the risk of having the vehicles stranded on the side of the road. The goal, achieved mainly through scheduling, is to find the "sweet spot" of utilization that minimizes downtime and electricity charges and maximizes daily driving time to take advantage of low operating costs.

When it comes to plug-in hybrids, there are no significant constraints on unlimited use. However, managing payback periods and optimizing scheduling are still important, whether fleet managers adopt hybrid vehicles with the goal of saving money or reducing environmental impact. That's because achieving those goals is only possible if fleet operators deploy their vehicles in ways that maximize the amount of electric driving as a proportion of total vehicle use.

Current fleet performance

As fleet operators evaluate potential vehicle replacement, their current fleet performance becomes a very important consideration. In the EV300 Program, data-logger studies of the 31 baseline vehicles told fleet partners the following:

- The baseline fleet's average daily distance travelled—54.4 kilometres—was within the advertised ranges of the all-electric vehicles as well as the all-electric range of the Chevrolet Volt.The average original fleet vehicle in the EV300 Program spent 19.5% of its time idling. If such idling is unavoidable, then this represents a tremendous opportunity for fuel savings with electrification. However, as an issue, excessive idling should first be addressed with clear operator policies, driver training and adherence to idling bylaws rather than vehicle replacement.

- The “best fit” vehicles simulations projected an 88% improvement in fuel consumption for battery electric vehicles, while plug-in hybrids would achieve a 57% gain.

Real-world EV performance

At the end of the day, simulated forecasts are just that—simulations. Phase two of the EV300 pilot project marked the next step, measuring real world EV performance as fleet partners started adding new vehicles to their fleets.

The testing analyzed six months’ worth of vehicle data logs and operators’ reports for 52 vehicles, including all five electric vehicle models in the EV300 study. It was enough to assess not only how the vehicles performed in the field doing a full range of tasks in all kinds of weather, but also how the fleet operators and drivers did in terms of planning for and adapting to the new vehicles (deployment policies, usage patterns, charging behaviour, etc).

Vehicle use

Vehicle use is measured in two ways: the length of an average trip and average daily distance travelled.

Figure Three: A comparison of vehicle use

Vehicle	Average Trip Distance (km)	Average Daily Distance (km)
Nissan Leaf	21	32.1
Mitsubishi i-MiEV	32	27
Ford Transit Connect Electric	9.8	33.8
Chevrolet Volt	31.5	80.8
Plug-in-Prius	47.4	188.8

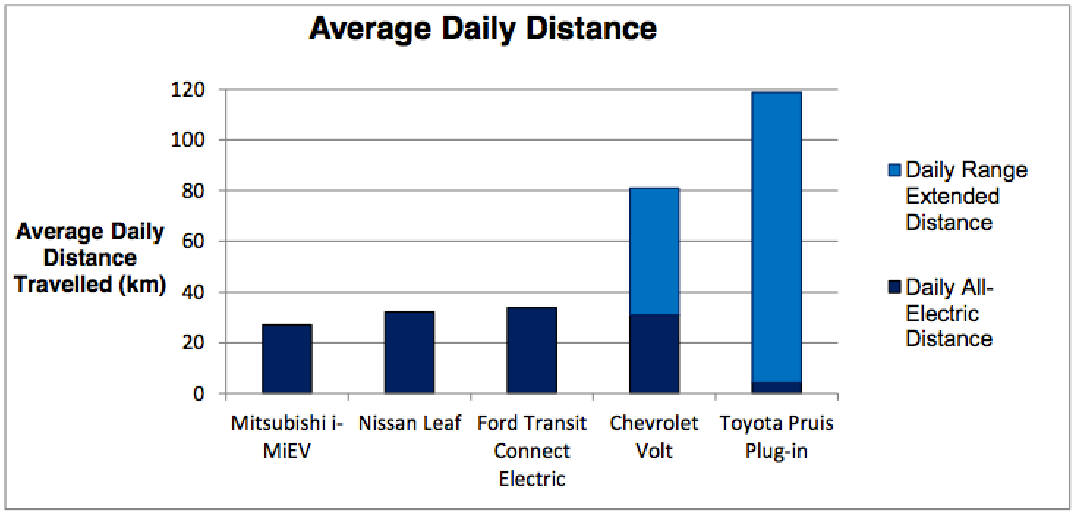
Daily distance travelled is an indicator of overall performance. In this case, it ranges from 27 km to almost 190 km.

The fact that for many fleet vehicles, trip distances are much shorter than their overall daily distance, suggests these vehicles take many short trips throughout the day.

From a charging perspective, fleet managers can use this pattern to take the time between trips to charge the vehicles. Such a fleet may rely on multiple charging sites throughout the daily duty cycle or publicly available infrastructure to do so. This “opportunity” charging can help to increase the electric distance vehicles travel in later trips.

Of the five vehicles, the model with the highest average total driving distance (188.8 km/day) is the Toyota Prius Plug-In. However, the picture changes when they are ranked strictly by electric utilization. As the average daily distance breakdown in the next chart/section shows, the Prius Plug-In has by far the lowest electric usage—even in comparison to the Chevrolet Volt, which, like the Prius, has a back-up gasoline-based power supply that extends its range well beyond the battery's original charge.

Figure 4: Average daily distance travelled by electric vehicles within the EV300 program



All-electric utilization

Mitsubishi i-MiEV. The i-MiEV in the study was driven 15 kilometres a day on average, with about half the trips ranging from 10 km/day to 30 km/day. In some cases, however, usage reached 90 km/day—still within the advertised range of the vehicle, indicating a great deal of potential remains.

Ford Transit Connect Electric. A quarter of the time the Transit Connects averaged 10 kilometres each day, with two-thirds under 30 km/day. This suggests they could be utilized much more each day.

Nissan Leaf. By a small margin, the most common daily distance was 10 km/day; however, the average daily distance for all Leaf vehicles was 32 kilometres, reflecting usage up to and over 100 km/day in some cases.

Plug-in hybrids (battery-powered use only)

Chevrolet Volt. Portion of distance travelled on electric power each day: approximately 30%. Often, the overall electric utilization was high enough to exceed the electric-only range of the vehicle. This suggests that on those days these vehicles were able to benefit from opportunities to charge throughout the day to achieve a greater electric range.

Toyota Prius Plug-In. Portion of distance travelled on electric power each day: only 3%. Almost all electric-only trip distances are short, in the 10 km to 20 km range. While these vehicles present a significant opportunity for fuel savings within the EV300 Program compared to ICE vehicles, it can only be realized by increasing the amount of electric driving as a proportion of total utilization.

Factors affecting electric utilization

Temperature

Temperature affects battery performance in all-electric vehicles and plug-in hybrids alike. However, because hybrids have a gasoline-powered back-up should their batteries run low, it's less of a concern for hybrid drivers.

Cold temperatures, in particular, can affect the efficiency of the battery, and auxiliary loads used to heat or cool the cabin consume energy from the vehicle's battery pack that could reduce its driving range.

Data gathering in the EV300 Program showed that colder temperatures (those below 15C) have a greater impact on range than warmer temperatures (those above 25C). The optimal temperatures for maximizing electric vehicle range appeared to be between 15-25C.

Variability in range for electric vehicles is often due to heating and air conditioning to keep the cabin at a comfortable temperature. This draws auxiliary power usage. In the EV300 data, we found that auxiliary power usage is a significant component in the loss of available range at high or low temperatures, more so at the latter. However, a closer examination of the data also revealed that there was a large amount of variation in the estimated driving range at any given temperature point in the graph.

These results suggest that while auxiliary load is a major factor differentiating a vehicle's sensitivity to temperature, it is not the only factor. Others such as changes in altitude, poor weather or driving conditions, and passengers or weight load combine to account for the wide variation in the ranges achievable by this vehicle.

Fleet managers can aim to reduce the need for additional auxiliary loads through several strategies. Storing the vehicle in a garage or pre-conditioning the vehicle while still charging are effective ways for the cabin to start at a comfortable temperature. During operation, drivers can employ seat and steering wheel warmers in addition to using some of the heating system for a more comfortable driving experience.

Driver behaviour

Studies of driver behaviour demonstrated that aggressive driving (such as hard braking and accelerating) increased fuel consumption in plug-in hybrids or reduced range in full EVs.

Fleet charging procedures

Charging behaviour may not be an obvious challenge but it is an important factor when trying to maximize electric vehicle use.

For the all-electric vehicles in the EV300 Program, the starting state of charge (SOC) is on average 88% of the battery's available capacity and the average ending SOC is 64%. Leaving 64% of the battery's power in the tank means the electric vehicle's capacity is being underutilized.

Greater utilization can be attained by charging the battery more at night as well as between trips throughout the day, and taking longer trips that would deplete the battery and displace more usage, presumably, of gasoline-powered vehicles.

Plug-In hybrids are different. They have an average of 55% starting SOC, declining to 28% ending SOC. However, the starting state of charge is much lower than the battery electric vehicles, particularly in the case of Toyota Prius Plug-in models. This indicates that the area for improvement with plug-in hybrid vehicles within these fleets is to improve the amount of charging that occurs overnight.

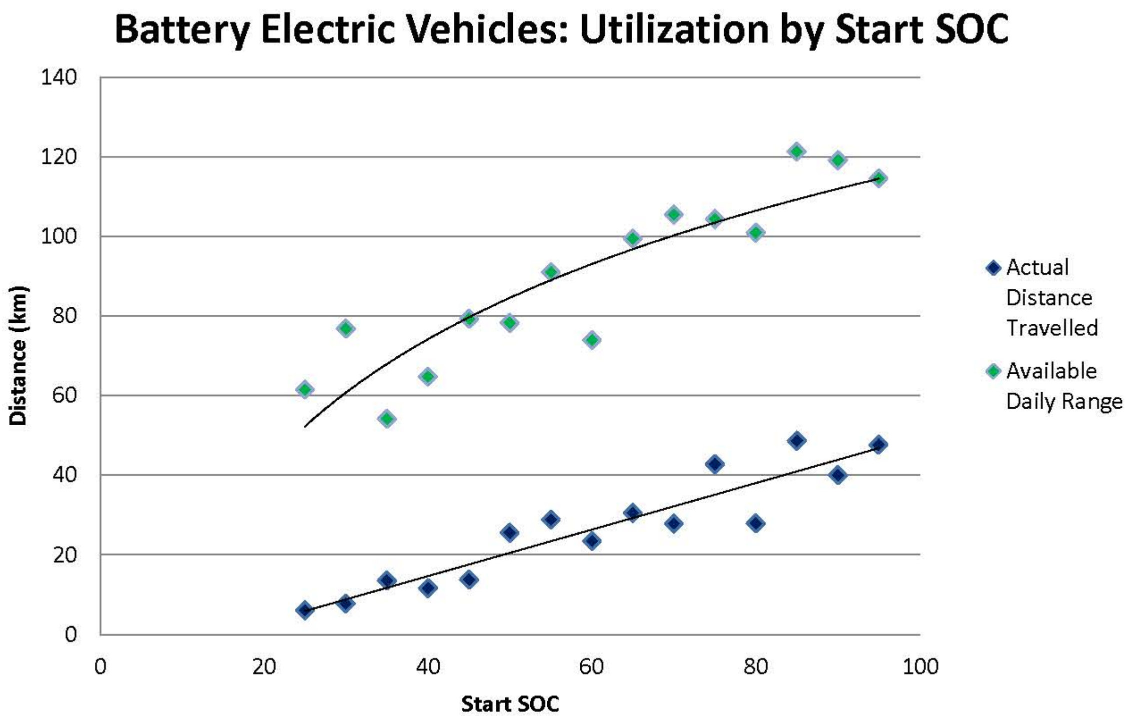
Fleet managers can increase the amount of charging by allowing more access points to chargers at vehicle destinations. Fleet managers can also adopt 'Plug-in' policies which require the driver to plug in the vehicle whenever possible. These strategies can aid in seeing greater electric utilization from plug-in hybrid vehicles.

This data suggests that fleets with plug-in hybrids may not be charging the vehicle enough. As it not necessary to charge a plug-in hybrid to continue operating the vehicle it is a facet of ownership that may become overlooked.

Starting state of charge (SOC)

For battery EVs, SOC has a strong, positive effect on the distance travelled throughout the day.

Figure Five: Daily utilization of battery-electric vehicles relative to their start of day SOC



With plug-in hybrid vehicles, however, there is no significant relationship between the battery SOC at the beginning of the day, and the distance the vehicle travels. This is likely because the vehicle operator is less aware of any diminished all-electric range, and can use the vehicle as much as required.

Charging impact on grid

Electric vehicles within fleets benefit from regular operational hours and dedicated facilities where infrastructure can be installed. However, fleets also face concerns around reimbursement of charging expenses when the vehicle travels away from fleet infrastructure or is taken home at night.

Charging off-peak is important for fleet vehicles. Ontario's time of use rates present an opportunity for fleets to find additional savings, as they shift their energy usage from on-peak daytime hours to off-peak overnight charging.

The fleet vehicles within the EV300 Program conducted 64% of their charging off-peak. Even so, there still appeared to be an 'early ramp' of charging during on-peak times at the end of the work day rather than delaying the charge period to begin at off-peak times.

Fleet managers wishing to improve their charging can schedule charging events to occur later in the evening and install programmable devices to control the vehicle's charging controls or the charge equipment itself.

Greenhouse gas emissions impacts

The project's two-phase vehicle study format yielded two complementary data sets that both show big reductions in greenhouse gas (GHG) emissions when fleet operators convert to electric vehicles.

Baseline vehicle simulated GHG emissions savings

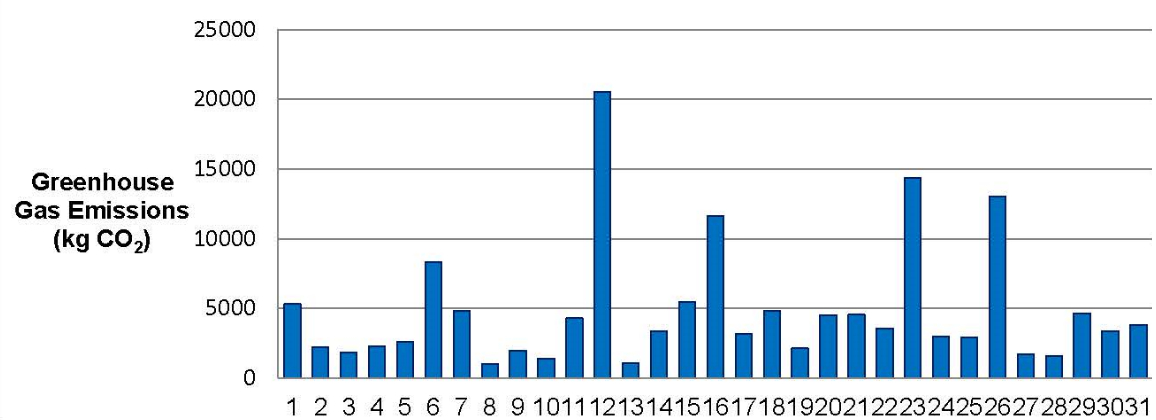
In the EV300's early stages, data loggers were used to record the duty cycles, fuel use and emissions performance of 31 traditional gasoline-powered vehicles in partners' fleets.

Using the data collected, FleetCarma simulated the performance of the five electric vehicles in the EV300 Program in the same duty cycle. As noted earlier, this methodology was used to determine which EVs offered the "best fit" with a particular fleet's needs, thereby helping fleet partners with vehicle selection. Equally important, however, is the ability to compare the fleet's baseline GHG emissions and the substantial estimated GHG emissions reductions that switching to those "best fit" EVs achieves.

Baseline internal-combustion emissions varied from 10.9 kg CO2/100 km to 106.3 kg CO2/100 km. On average, fleets were emitting 39.1 kg CO2/100 km. These totals included both tailpipe emissions and upstream fuel emissions associated with the extraction, refinement and transportation of the fuel before it is used. The electric vehicle results were from 4 to 20 times better, with estimated emissions ranging from approximately 2.0 kg CO2/100 km to nearly 12 kg CO2/100 km. The lowest figures are the battery-electric EVs, whose only GHG emissions come from upstream electricity production. Plug-in hybrids, depending how often their gasoline engines are used, have both upstream fuel production and tailpipe emissions.

Annual projected GHG emission savings per vehicle were as high as 20,540 kg of CO2 and as low as 1,043 kg of CO2. If all the monitored vehicles in the EV300 program were replaced with their "best fit" EV counterpart, the program could save up to 149,201 kg of CO2 each year.

Figure Six: GHG emissions savings from 31 electric vehicles relative to the baseline vehicles



Real-world GHG emissions savings

When data loggers were attached to new EVs in the partner fleets in EV300's second phase, they provided a real-world measure of GHG emissions savings and a direct means of comparison with the results from the baseline fleet vehicles.

Across the entire program, average GHG emissions from electric vehicles were 3.11 kg CO2/100 km for battery electric vehicles and 15.56 kg CO2/100 km for plug-in hybrid vehicles. Compared to the baseline vehicles, this represents an average of a 92% reduction in greenhouse gas emissions for battery electric vehicles, and a 60% reduction in greenhouse gas emissions for plug-in hybrid vehicles.

Data logged through late 2012 from the first 31 electric and plug-in hybrid vehicles in the project found CO2 reductions in the EV300 Program at 13,148 kg CO2 annually. Findings from FleetCarma show that those reductions could be even higher with further work on scheduling, driver behaviour and vehicle use. FleetCarma also found that fleets were using their plug-in hybrids more than necessary and that lower-emission battery electrics weren't yet being used to their full potential, largely due inexperience, poor optimization and drivers' lack of awareness.

Business case for EVs

Saving money

The two phases in the EV300 pilot project study were unanimous: electric vehicles are significant cost savers. Cost differentials are quickly recouped and the business case is rock solid.

Depending on the electric vehicle chosen and the application, FleetCarma's simulation analysis found that fleets can expect to see annual fuel savings from $424 to $8,524 per vehicle.

If the 31 vehicles monitored in the simulation phase were to be replaced with the "best fit," simulated electric vehicle counterpart, the fleets within the program could realize a cumulative fuel savings of $62,978 each year.

In a sample real-world, direct-vehicle comparison, fleet operators who swapped an internal combustion cargo van for a Ford/Asure Dynamics Fleet Connect battery electric, saw $7,150 in annual fuel savings. That would be a $50,050 savings over a projected seven-year vehicle service life.

In two other electric car-and-service-van-versus-internal-combustion-engine comparisons, operators enjoyed 83% and 90% energy savings, 93% and 96% reduction in greenhouse gas emissions, and 87% and 92% reduction in operating costs.

Overall, the baseline fleet of conventional vehicles replaced in the program has an average operational cost of $16.67/100 km. The plug-in hybrids that replaced them enjoyed savings of 60.3%, while the battery electric vehicles saved even more, at 87.7%.

Plug-in hybrids – a special case

For plug-in hybrid vehicles, a much larger range existed between the most and least expensive to operate. This variation exists because of the multiple vehicle modes in which a plug-in hybrid can operate. Trips taken that are powered solely from the battery are considerably less expense than those that are mixed, or the trips where the battery has been depleted and the vehicle travels in hybrid mode.

Fleets can reduce operational costs by maximizing both the distance plug-in hybrid vehicles travel, as well as the portion of that distance that is powered by the battery. Fleets can maximize this distance by planning for adequate charging for their vehicles and making use of opportunity charging throughout the day.

Time to recoup payback will vary significantly for each fleet partner. But ensuring prioritized EV use is a critical factor for EV success. As EV usage increases, the business case for EVs becomes stronger. Higher usage equates with decreased payback periods. Likewise, the payback from plug-in hybrids is greatest when you maximize the electric component of its use.

5.0 Implications of the Findings for Best Practices

Providing educational support to fleet managers is critical. The EV300 Program supported the development of new decision-support tools to inform fleet operators and give confidence before purchase. The education available during the purchasing process was critical to increasing familiarity with electric vehicles within fleets. Increased education and familiarity can lead to increased utilization.

Matching EVs to duty cycle requirements optimizes savings. Since each plug-in vehicle offers unique benefits, fleet managers that leverage EV modeling technology based on data about their own duty cycle can better match vehicle options to their fleet needs, optimizing cost savings and environmental benefits.

Action must be taken to reduce range anxiety. It's impossible for fleet operators to maximize their payback from conversion to all-electric vehicles unless they take all the steps outlined above to address and minimize their drivers' range anxiety.

GHG savings from EV fleet integration are substantial. The GHG emission savings of EV adoption is substantial, even with only a minority of the fleet converting to electric. This impact can be increased by prioritizing the use of all electric vehicles to increase their mileage, and by using hybrid vehicles in ways that optimize the use of their electric motors.

There are strategies to mitigate the range implications of EVs in cold weather. Although data showed that EVs lose electric driving range when temperatures get cold, the study also showed that this impact can be substantially mitigated by using seat warmers, pre-conditioning vehicles while still on plug, and driving efficiently.

There is an opportunity to use fleet EVs more often. Fleets with plug-in vehicles have not been using them as much as they could be used. Increasing electric vehicle utilization reduces payback periods so that fleets start to save their organization money sooner.

Fleets can increase electric utilization with better charging behaviours. Increasing opportunity charging throughout the day and bulk charging throughout the night enables higher utilization and ensures each day begins with maximum starting state of charge.

Good driving behaviour extends electric driving range. Fleet managers collecting EV utilization data can provide ongoing feedback to drivers to improve and maintain eco-driving performance and to maximize the benefits of EV adoption in their fleet. While idling should be reduced regardless of being in an EV, switching to an EV significantly reduces the GHG and cost impacts of idling.

6.0 Appendices

To review the full technical findings on EV300 as prepared by ChossChasm/FleetCarma please visit this link.