London Hydro Inc.

Status of the EV Industry and London Hydro Grid Preparedness

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Prepared By:	Reviewed By:
Allan Van Damme, P.Eng., CPA, CMA Director of Operations	William Milroy, P.Eng. Vice President of Engineering and Operations

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EXECUTIVE SUMMARY

The government of Ontario, along with many other jurisdictions across the world, has implemented Electric Vehicle (EV) friendly policies and programs in an effort to reduce Greenhouse Gases (GHGs) and achieve their environmental targets in an effort to mitigate the effects of climate change. This has created a consumer demand for EVs which will result in increased demand on the electrical grid.

A situational analysis was performed on factors relating to the EV industry and the adoption of EVs. The analysis showed increased government investment in this sector, increased investment from automakers, increased EV capabilities through improved technology (eg. range, charging capacity), increased availability of smart charging tools and smart energy initiatives, and exponential growth in sales.

In order for London Hydro to continue its path as a leader it is recommended that it participate in government programs such as the next phase of the Electric Vehicles Charges Ontario (EVCO) program, move forward with a smart charging program using real time energy consumption, contribute to the education its customers on smart use of EVs, implement smart reporting on the loading of its transformers using detailed load data and continue to leverage opportunities to green its fleet where cost effective.

London Hydro will be conducting a further analysis on its business role with respect to EVs and how to best serve all stakeholders.

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1.0 INTRODUCTION

The world is becoming increasingly concerned about the environmental impacts of Greenhouse Gases (GHGs) and their impact our climate. Governments around the world are looking for ways in which they can reduce their GHG emissions. The transportation sector represents more than one third of all GHGs in Ontario. Electric Vehicles (EVs) generally produce fewer GHGs than Internal Combustion Engines (ICEs). The Government of Ontario supports the use of EVs as a means to reduce GHGs and have demonstrated their support through financial incentives and other actions. This is resulting in a growth in EV sales and use. This growth directly impacts London Hydro's core business from a safety, reliability and financial point of view due to increased load.

The purpose of this report is to provide a foundational knowledge relating to the state of EV technology, EV market penetration and associated impact on London Hydro's grid. It incorporates a scan of the current state of the government programs, industry initiatives, EV technology, and EV sales projections. It then makes recommendations of actions to be taken by London Hydro in order to leverage opportunities and ensure continued reliable operation of the grid.

A subsequent report that leverages this foundational knowledge will be completed on possible business plans that London Hydro could implement with respect to the EV market.

2.0 SITUATIONAL AND ENVIRONMENTAL ANALYSIS

2.1 Alignment of EVs with London Hydro's Strategic Plan

Increased use of Electric Vehicles (EVs) in the Ontario market has the potential to have a significant impact on the safety and reliability of the distribution grid through increased demand. LDC's are in a position to influence the manner in which this increased demand is implemented through improved design standards and smart charging solutions. London Hydro's Mission and Vision support the study of EVs with respect to grid operation and the needs of the customer.

London Hydro’s **Mission** is: To provide safe and reliable electricity and value-added services.

London Hydro **Vision** is: To pursue excellence as an industry leader.

2.2 List of Relevant Corporate Pillars and Values

The following is a list of London Hydro pillars that are relevant to the advancement of the EV industry and the needs of EV owners.

Leadership

London Hydro is a leader in customer solutions and will seek opportunities to help set the course for the industry. London Hydro must ensure the additional load from EVs will not negatively impact grid safety or reliability.

Customer Care

London Hydro will continue to educate our customers on efficient and sustainable energy choices and support our community initiatives.

Financial Stewardship

London Hydro will leverage its reputation and expertise to explore opportunities to pursue prudent revenue streams that support our core business.

Technology

London Hydro is a leader that supports the efficient operation of its business and delivers value-added service through the offering of technology solutions.

Corporate and Social Responsibility

London Hydro is committed to being a financially, socially and environmentally sustainable company.

2.3 Stakeholder Needs and Preferences

The following points describe the specific needs and preferences of key stakeholders:

- London Hydro:
  - Pursue prudent revenue streams, educate customers on energy needs and options and enhance customer experience by expanding options available to them.
  - Ensure grid is able to accommodate EV loads.
  - Explore opportunities for smart control of EV loads and batteries to minimize impact on grid performance and reduce environmental impact.
- Government
  - Leverage EVs to achieve targets of the Climate Change Action Plan
  - Provide financial means to fund programs to encourage EV purchase and use.
- Industry Advocates (eg. Plug'n Drive, Electric Mobility Canada)
  - Educate and promote the use of EVs as a clean alternative mode of transportation.
- Automotive Manufacturers and Suppliers of Electric Vehicle Supply Equipment (EVSE)
  - Provide adequate supply to meet demand as it increases and establish market share.

- Electricians and Electrical Service Contractors
    - Looking for new niche market of EV charger installations and services.

2.4 External Environmental Scan

This section presents a scan of the external opportunities that London Hydro must be aware of in order to continue to meet and exceed the expectation of its customers. It discusses factors affecting the EV industry with respect to London Hydro.

2.4.1 Political Influences:

The Government of Ontario and industry regulators have taken several actions with respect to the use of EVs. They are listed below:

Ontario Energy Board (OEB) Position on LDC Ownership of EV Chargers – On July 7, 2016 the OEB released a bulletin which concluded that EV chargers are not part of the distribution grid and therefore a distributors license is not required to own EV chargers and owning and operating EV charging stations is an inherently competitive activity. However, section 71 (2) of the OEB Act provides an exemption that states, in part, that a distributor may provide services that would assist the Government of Ontario in achieving its goals in electricity conservation, among others, services related to “the promotion of electricity conservation and the efficient use of electricity” and “electricity load management”. The OEB has stated that the participation of distributors in owning and operating EV charging facilities stations may help facilitate electricity load management and the efficient use of electricity. In the OEB staff’s view, it then follows that licensed electricity distributors are not precluded from owning and operating EV charging stations so long as the equipment provides for the management of load in keeping with the Government's goals for electricity conservation[1]. On June 5, 2017, London Hydro further inquired to OEB staff as to whether or not an LDC is permitted to include the associated capital and operating costs of EV chargers in the distribution rate base. The OEB staff could not say what projects would or would not be approved for inclusion in rate base applications. The OEB replied as follows: "Distributors may apply to the Board for funding through distribution rates to pursue various activities such as CDM programs, demand response programs, energy storage programs and programs reducing distribution losses for the purpose of deferring the capital investment for specific distribution infrastructure. Any such application must include a consideration of the projected effects to the distribution system on a long-term basis."

EDA View on EV Chargers - The Electrical Distributors Associations (EDA) has requested that OEB allow EV chargers to become part of the rate base in order to encourage the development of charging infrastructure in Ontario, similar to the regulators reversal of their decision that occurred in California where utilities were eventually allowed to put chargers in their rate base.[2]

Fair Hydro Act, 2017 - On May 31st, 2017 the Ontario government passed legislation to lower electricity bills by approximately 25% for the next four years. This will be done in accordance with The Fair Hydro Act, 2017. This Act will refinance the Global Adjustment over the long term in order to limit electricity price increase to be in line with the rate of inflation for the next four years. The lower resultant price will be favourable for those residential user who use more electricity such as EV owners.[3]

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[1] Bulletin OEB "Electric Vehicle Charging, July 7, 2016 https://www.oeb.ca/oeb/_Documents/Documents/OEB_Bulletin_EV_Charging_20160707.pdf

[2] EDA Submission Paper - Ministry of Transportation (MTO) Discussion Paper on Electric Vehicle Incentive Initiatives under the Climate Change Action Plan dated November 14, 2016

[3] https://news.ontario.ca/mei/en/2017/05/ontario-passes-legislation-to-lower-electricity-bills-by-25-per-cent.html

LDC Distribution rate changes for Residential (fixed only vs fixed and variable) - Ontario is moving to a fixed only distribution rate over a four year period starting in 2016. Therefore in 2019 LDC distribution revenue will no longer be dependent on the volume of electricity consumed. The distribution revenue will be based on a fixed charge only versus a fixed and volumetric charge. This should have a positive financial impact on EV users since they will potentially be using more electricity, but will not have to pay a higher distribution charge as it will be fixed. The volumetric component of the charge will be removed completely from energy bills by 2019.[4]

Provincial Government – Climate Change Action Plan (CCAP) - On June 8, 2016, the Government of Ontario released its Climate Change Action Plan[5], targeting a major reduction in greenhouse gas (GHG) emissions. The Climate Change Action Plan states that increased electrification of the transportation system will be essential to achieving the GHG reduction targets. Guided by the Climate Change Action Plan, the Province intends to take action that will help get more people into electric vehicles and lower greenhouse gases. In order to support this goal, the plan sets out that the government will increase access to the infrastructure necessary to charge electric vehicles.[6]

More than one third of Ontario's greenhouse gasses are caused by the transportation sector with cars and trucks being responsible for more than 70% of that total. Since 1990, vehicle emissions have been steadily rising due to: increased number of vehicles,

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[4] OEB File No. EB-2012-0410 -

https://www.oeb.ca/sites/default/files/uploads/OEB_Distribution_Rate_Design_Policy_20150402.pdf

[5] Ontario's Five Year Climate Change Action Plan 2016 – 2020 - https://www.ontario.ca/page/climate-change-action-plan

[6] Ontario's Five Year Climate Change Action Plan 2016 - 2020 (https://www.ontario.ca/page/climate-change-action-plan), pages 20-21

increased commuter distances and population growth. A total of 11 million passenger and commercial vehicles are on the road in Ontario. The Province believes that a shift to electric vehicles is crucial if Ontario is to achieve its climate change targets.

By 2020, Ontario wants 5% of new passenger vehicles sold or leased in the province to be electric or hydrogen-powered. This works out to about 14,000 vehicles annually (note 284,000 passenger cars were sold in Ontario in 2015). The CCAP has also set targets for reduction of emissions. Ontario has set targets to reduce emissions from 1990 levels by 15% in 2020, 37% in 2030 and 80% in 2050. EVs have been identified as a key tool to helping achieve these targets.

The following details some of the programs the Government is developing or has developed in order to support and accelerate the adoption of electric vehicles in the province.

The Province intends to increase the use of electric vehicles through the following:

1. Maintain incentives for EVs by extending the rebate program to 2020 for leasing or buying (up to $14k per vehicle) including rebates for purchase and installation of charging stations (up to $1k per station). The Province allocated $140M to $160M in 2017.

    a. Electric Vehicle Incentive Program (EVIP) [7]– Ministry of Transportation (MTO) vehicle incentives range from $3,000 to $14,000 depending on battery capacity, year of manufacture, seating capacity, etc until 2020. It applies to both plug-in hybrid electric vehicles (PHEV) and battery electric vehicles (BEV). The

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[7] EVIP Incentive - http://www.mto.gov.on.ca/english/vehicles/electric/electric-vehicle-rebate.shtml

applicant must keep the vehicle for 12 months or return the incentive in full.[8] According to information provided by the MTO, 272 EV owners have qualified for this incentive in London Ontario as of April 12, 2017. It can be assumed that there are approximately 272 EVs owners in London, Ontario.

b. Electric Vehicle Charger Incentive Program (EVCIP) – MTO charger incentives cover 50% of the purchase costs up to $500 and 50% of the installation costs up to $500 for a maximum of $1,000 until 2020. Chargers must be Level 2 and used for residential or business vehicle use only (not public or the use of the business' customers).[9] It is noted that to date the MTO has estimated that only one quarter of new EV owners have applied for the EV charger incentive. This would indicate that three quarters of current new EV owners may be using the Level 1 charger that comes with the vehicle.

2. Eliminate HST on Zero Emission Vehicles - The Provincial Government intends to work with the Federal Government to introduce HST exemption for new BEV purchases in 2018.

3. Free overnight charging – The Province intends to establish a four year free overnight electric vehicle - charging program for residential and multi-unit residential customers starting in 2017 ($15M proposed).

4. Introduce a program to get older, less fuel efficient vehicles off the road by offering low and moderate income households a rebate on new or used electric or plug in hybrid vehicles. ($10M - $20M 2017/18)

5. Charging Infrastructure Investment

a. The Province will invest in rapid deployment of charging in workplaces, multi-unit residential buildings, downtowns and town centers. This will be done through the Electric Vehicle Chargers Ontario (EVCO) program. The province

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[8] Electric Vehicle Incentive Program (Program Guide) http://www.forms.ssb.gov.on.ca/mbs/ssb/forms/ssbforms.nsf/GetFileAttach/023-2096E~3/$File/2096E_Guide.pdf

[9] Electric Vehicle Charging Incentive Program - http://www.mto.gov.on.ca/english/vehicles/electric/charging-incentive-program.shtml

has allocated a total of $80M to the EVCO program.[10] The first phase included $20M in funding and will result in the installation of approximately 300 additional Level 2 chargers and 200 additional Level 3 chargers in Ontario. This will bring the total number of Level 2 chargers to approximately 750 and Level 3 chargers to a total of 205 in Ontario. It is expected that Phase 2 of the EVCO will be rolled out before the end of 2017 and will have $22M of funding which will target multi-unit dwellings and workplaces.

b. Electric-vehicle-ready homes – A new requirement has been approved for all new homes, detached, semi-detached and row houses containing no more than two dwelling units served with garages, carports or driveways to be constructed with a 200A panel, a conduit not less than 27mm and a square 4" 11/16" outlet box for charging vehicles starting in January, 2018. Home charging is the most common place for charging.

c. In 2018, the Province intends to require all new commercial office buildings and appropriate workplaces to have charging infrastructure (second most common place for charging). This is critical for those living in multi-residential buildings who don't have access to charging stations or 120V plugs. All new workplaces must have 20% of parking spaces with chargers and the remaining spaces shall be equipped with provisions that will permit the installation of chargers.

6. Starting in 2017, vehicle manufacturers that offer access to Ontario EV incentives must participate in an Electric and Hydrogen Vehicle Advancement Program that recognizes manufacturers that do well in sales, marketing, infrastructure and public awareness for EVs.

7. Increase public awareness through Plug'n Drive to showcase EVs across Ontario ($1.75M to $2M) in 2017/18. This has been demonstrated through the construction of Plug'n Drive's new Electric Vehicle Discovery Centre (EVDC) in North York, Ontario.

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[10] Electric Vehicle Chargers Ontario Program (EVCO) - http://www.mto.gov.on.ca/english/vehicles/electric/electric-vehicle-chargers-ontario.shtml

8. Increase use of low-carbon trucks and buses through a new Green Commercial Vehicle Program with incentives to eligible businesses including electric and natural gas-powered trucks, aerodynamic devices, anti-idling devices and electric trailer refrigeration ($125M to $170M in 2017/18).

9. Intends to allow Municipalities to require EV charging stations on municipal lots. (2017/18)

10. Green-up government vehicles - Ontario will buy or lease green plated eligible passenger vehicles wherever possible in an effort to showcase the viability and practicality of EVs. (2017/18)

Time-of-Use Pricing (TOU) – The provincial government has implemented time-of-use pricing in Ontario at a cost of about $2B to install 4.8 million smart meters in an effort to shift load from on-peak times to off-peak times.[11] The smart metering initiative has obtained limited success with less than 3% of load being shifted to off-peak times.[12]

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[11] Office of the Auditor General of Ontario – Smart Metering Initiative http://www.auditor.on.ca/en/content/annualreports/arreports/en16/v2_111en16.pdf

[12] The Impact of Time-of-Use Rates in Ontario – Neil Lessem, Ahmad Faruqui, Sanem Sergici and Dean Mountain http://brattle.com/system/news/pdfs/000/001/180/original/The_Impact_of_Time_of_Use_Rates_in_Ontario.pdf?1486594497#utm_source=Mondaq&utm_medium=syndication&utm_campaign=inter-article-link

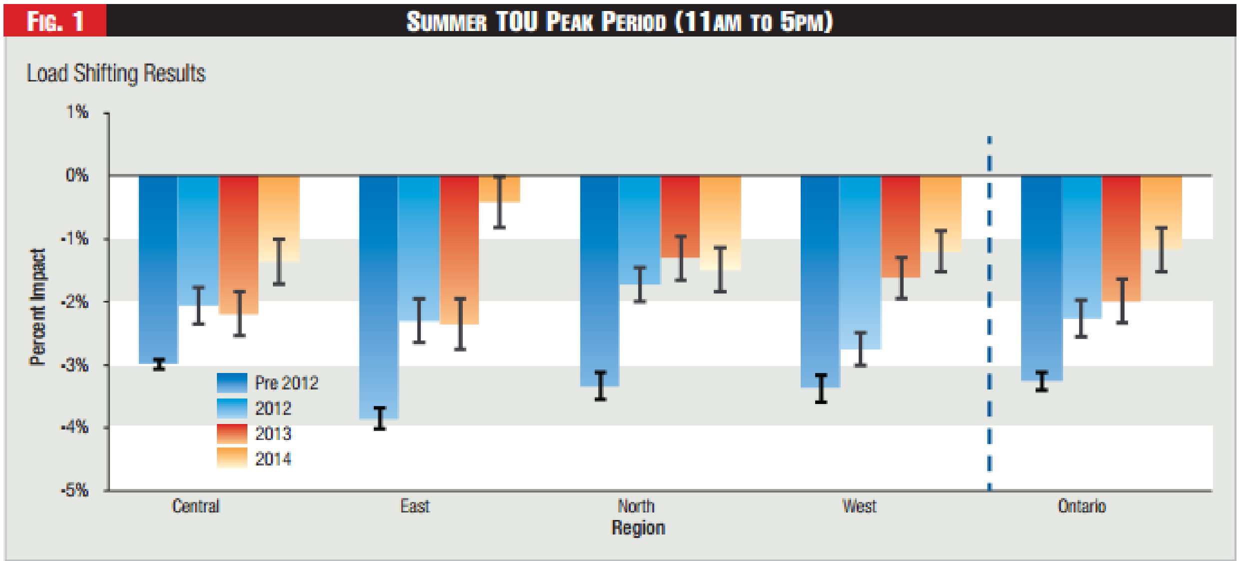

Figure 1 – Ontario Summer TOU Impact due to Load Shifting[13]

In contradiction to Ontario's experience, a recent study conducted by the Sacramento Municipal Utility District (SMUD) confirmed that TOU pricing does have an impact on the consumption patterns of study participants.[13] The success of TOU pricing is dependent on the price differential. The success is greater when there is a larger differential in off-peak to on-peak prices.

ConEdison in New York has offered special TOU rates for residential customers to encourage off-peak charging as per Table 1. The rates offer a very significant differential between on-peak and off-peak as an incentive for charging off-peak.[14] It is noted that the on-peak time is much higher than the standard delivery non-TOU rate. It is important to know that customers can also elect to have a separate meter for their EV only. This allows their home to stay on Standard Delivery rates while their vehicle is charged at the lower TOU rate between midnight and 8 a.m.

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[13] Is TOU pricing enough for electric vehicle charging? - Fleetcarma - http://www.fleetcarma.com/tou-pricing-smart-charging/

[14] ConEdison TOU Rates - https://www.coned.com/en/save-money/energy-saving-programs/time-of-use

Residential Time Periods and Delivery Rates*

	Peak	Off-Peak
Hours	8 a.m. to midnight	Midnight to 8 a.m.
TIME-OF-USE DELIVERY RATES		
June 1 to Sept 30	20.53 cents/kWh	1.45 cents/kWh
All other months	7.60 cents/kWh	1.45 cents/kWh
STANDARD DELIVERY RATES	First 250 kWh	Over 250 kWh
June 1 to Sept 30	9.627 cents/kWh	11.067 cents/kWh
All other months	9.627 cents/kWh	9.627 cents/kWh

Table 1 - ConEdison TOU Rates

By increasing the differential, there is a concern that TOU pricing could simply create a new peak at the start of the off-peak period. One of the proposed solutions is to mitigate the creation of a new peak by using smart charging which is controlled by the LDC to stagger the start times of the EV charging cycles while still satisfying the needs of the EV owner.[15]

Quebec's Energy Board has recommended that Hydro Quebec adopt variable pricing based on time of day and the demand for electricity. The intent is to allow customers to save money during off-peak times and lessen demand on the grid. The Quebec Energy Board feels that a pricing structure such as four cents per kWh off-peak and 12 cents per kWh on-peak would provide an incentive for customers to repurpose used EV

[15] http://www.fleetcarma.com/tou-pricing-smart-charging/

batteries for load shifting by charging them off-peak and discharging on-peak.[16] This would also provide a means to lower the overall ownership costs of EVs by being able to sell the used batteries after 8 to 10 years of use.

Ontario's Green License Plate Program – The provincial government has established that all Plug-in Hybrid Electric Vehicles (PHEV) and Battery Electric Vehicles (BEV) are eligible for green license plates which are permitted to access High Occupancy Vehicle (HOV) lanes and High Occupancy Toll (HOT) lanes on 400-series highways and the Queen Elizabeth Way (QEW) at no cost. This is permitted even when there is only one occupant in the vehicle. This is intended as an incentive to purchase an EV.[17]

2.4.2 Market Conditions:

EV Sales – In 2005, EV sales worldwide were measured in hundreds, now there are more than 2 million EVs and PEVs on the road compared to 1.4 billion internal combustion engines globally. This represents a 42% growth rate over 2015. If this rate continues, it would mean that 8 out of 10 vehicles would be an EV by 2030.[18]

[16] Opinion: How variable pricing at Hydro-Quebec could give electric cars a boost - http://montrealgazette.com/opinion/opinion-how-variable-pricing-at-hydro-quebec-could-give-electric-cars-a-boost

[17] Ontario's Green Licence Plate Program - http://www.mto.gov.on.ca/english/vehicles/electric/green-licence-plate.shtml

[18] Global Plug-in Sales for 2016 - http://www.ev-volumes.com/country/total-world-plug-in-vehicle-volumes/

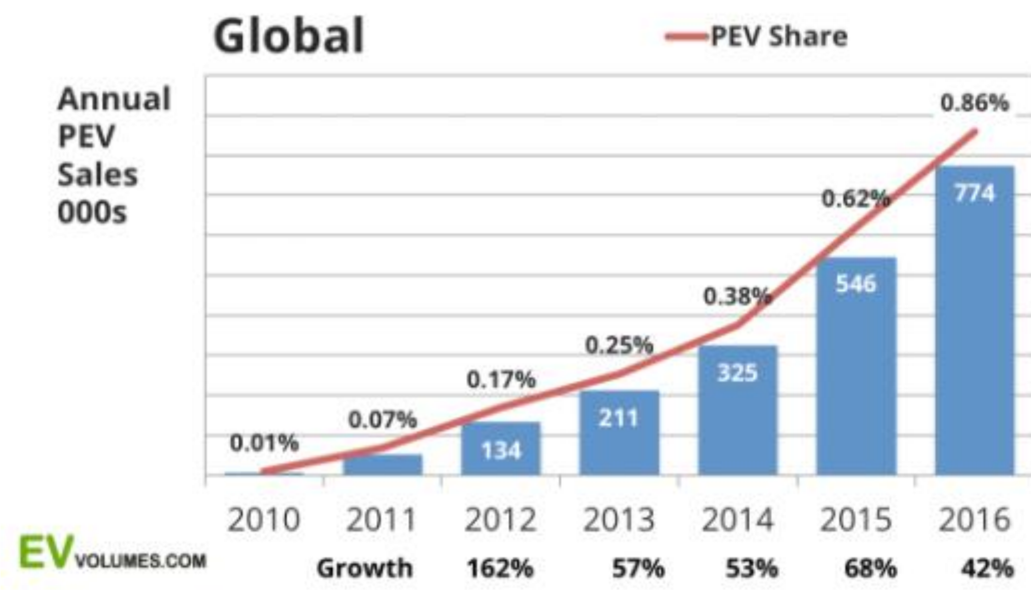

Figure 2 – World EV Sales[18]

Automaker Investments - EVs have shown tremendous growth since 2010. Automakers have announced that more than 40 new or revised EV models will be available sometime between 2017 and 2020. Long range EVs that are less than $30k US are now available from automakers such as Nissan, Chevrolet, Ford, Volkswagen, Hyundai, and KIA.

Some of the significant investments by automakers are as follows[19]:

- General Motors – The Chevrolet Bolt has a range of 383 km, fast charging and a price under $30,000 after rebates.
- Ford has announced it will spend over $4.5 billion US to have 40% of its fleet (including electrifying 13 future vehicles) electrified by 2020.[20]
  The Ford Focus Electric is a fully electric car with a range of approximately 185 km, fast charging and a price under $20,000 after rebates.

[19] Major Electric Vehicle Programs in the Works – Fleetcarma - http://www.fleetcarma.com/7-automakers-electric-vehicle-programs/

[20] IEEE Electrification Magazine - The Future is Electric, March 2017

- Volkswagen has set a goal of 30 new EVs and more than two million plug-in sales by 2025 which would represent nearly one quarter of the automaker's current sales volume.[21] The e-Golf is an all-electric vehicle with a range of 201 km, fast charging and a price under $20,000 after rebates.
- The Tesla Model 3 will be released later in 2017. Tesla's Model 3 had 400,000 sales reservations in the first month. As a reference the best-selling car in the US sells about 387,000 units in a year. Reservations for the Model 3 are now backed up to mid-2018 or later for delivery.
- Hyundai will release the Ioniq in 2018 which will provide a range of 200 km at a price of approximately $22,000 after rebates.

[21] VW plans huge investments to become electric cars leader – BBC News - http://www.bbc.com/news/business-36548893

It is predicted that the sales of EVs will follow that of an “S” curve similar to that observed for the refrigerator, colour tv, computer and cell phone. This is due to the merging of several factors such as: decreasing battery costs, increased range, increased availability, increased selection and increased public awareness of the environmental impact of EVs and available financial incentives. One of the factors that inhibit the wide adoption of EVs is the time it takes to design, manufacture, test and release an EV to market (i.e. 5 to 10 years).

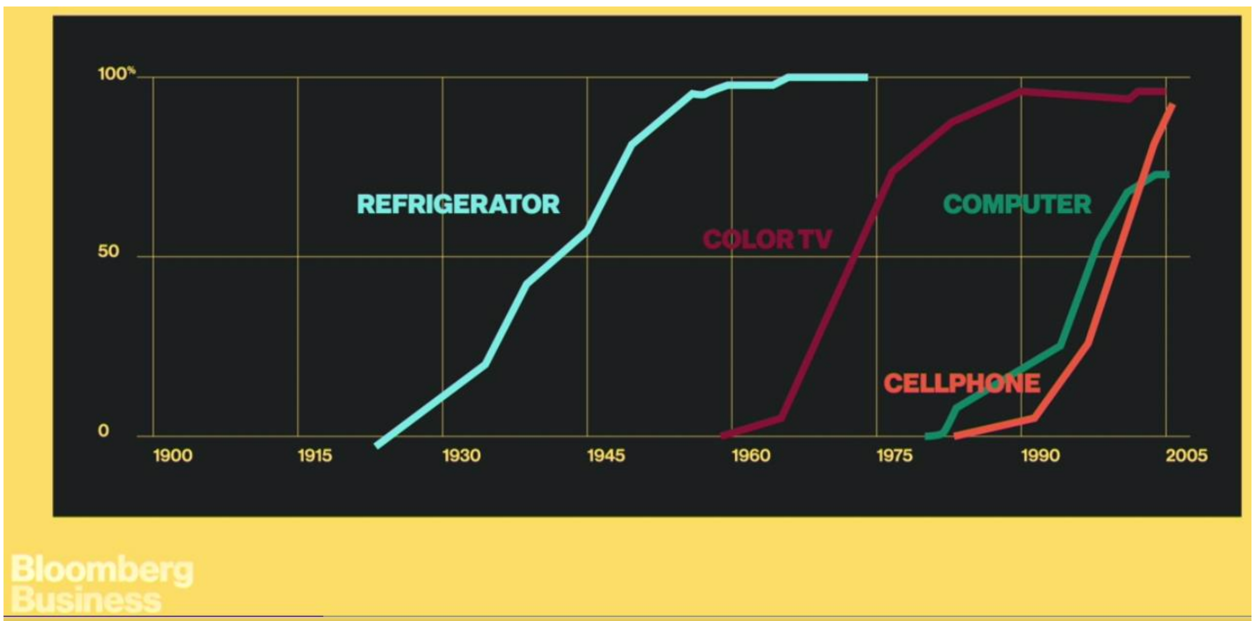

Figure 3 – “S” Curve for Technology Products – Bloomberg Business

It is projected that by 2020 EVs will cost the same as their internal-combustion counterparts. It is further estimated that EVs will make up 35% of all new sales by 2040 as shown in Figure 4.[22]

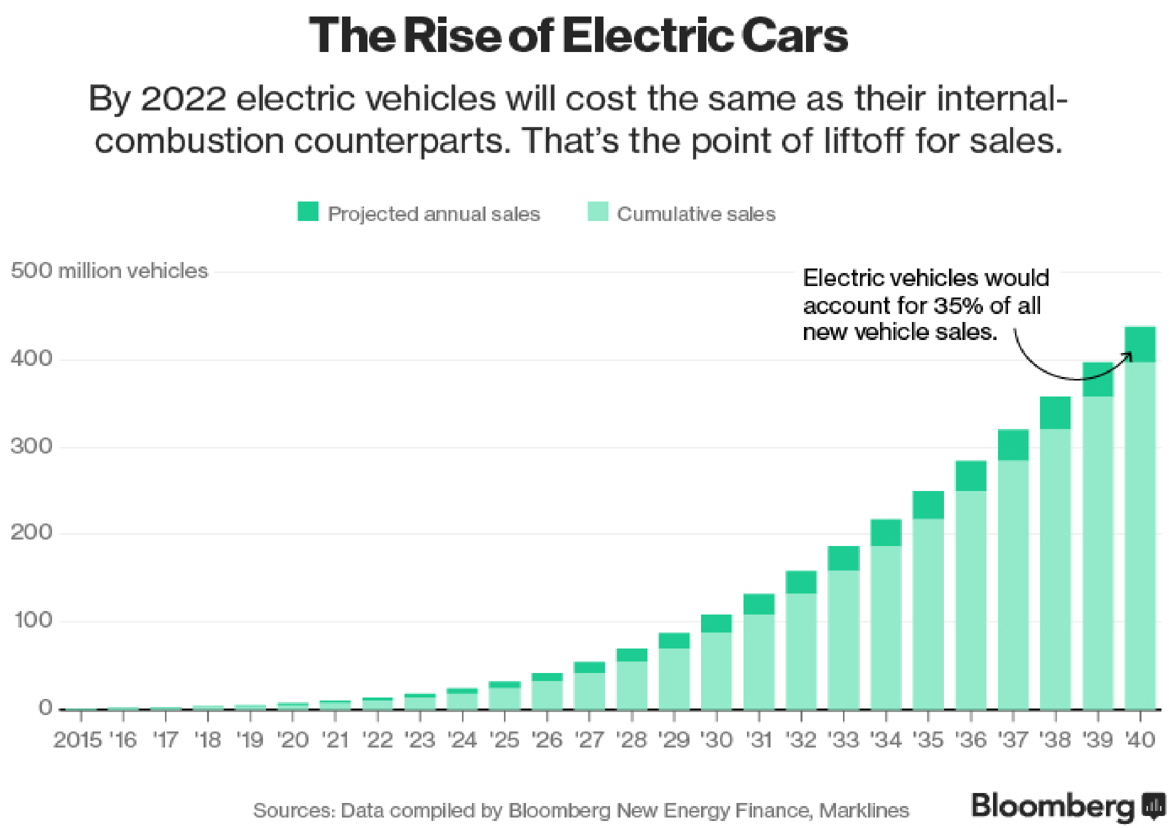

Figure 4 – Projected Sales of EVs World Wide

[22] Here's How Electric Cars Will Cause the Next Oil Crisis – Bloomberg by Tom Randall, Feb. 25, 2016 https://www.bloomberg.com/features/2016-ev-oil-crisis/

The graph shown in Figure 5 illustrates that Quebec, Ontario and British Columbia represent 95.8% of all EV sales in Canada. Their success is due to their purchase incentives and information programs relating to EVs. Gasoline prices are also typically higher in these provinces.

If these incentives were to be eliminated or removed the sales would also be drastically lower as shown in provinces that do not offer incentives.

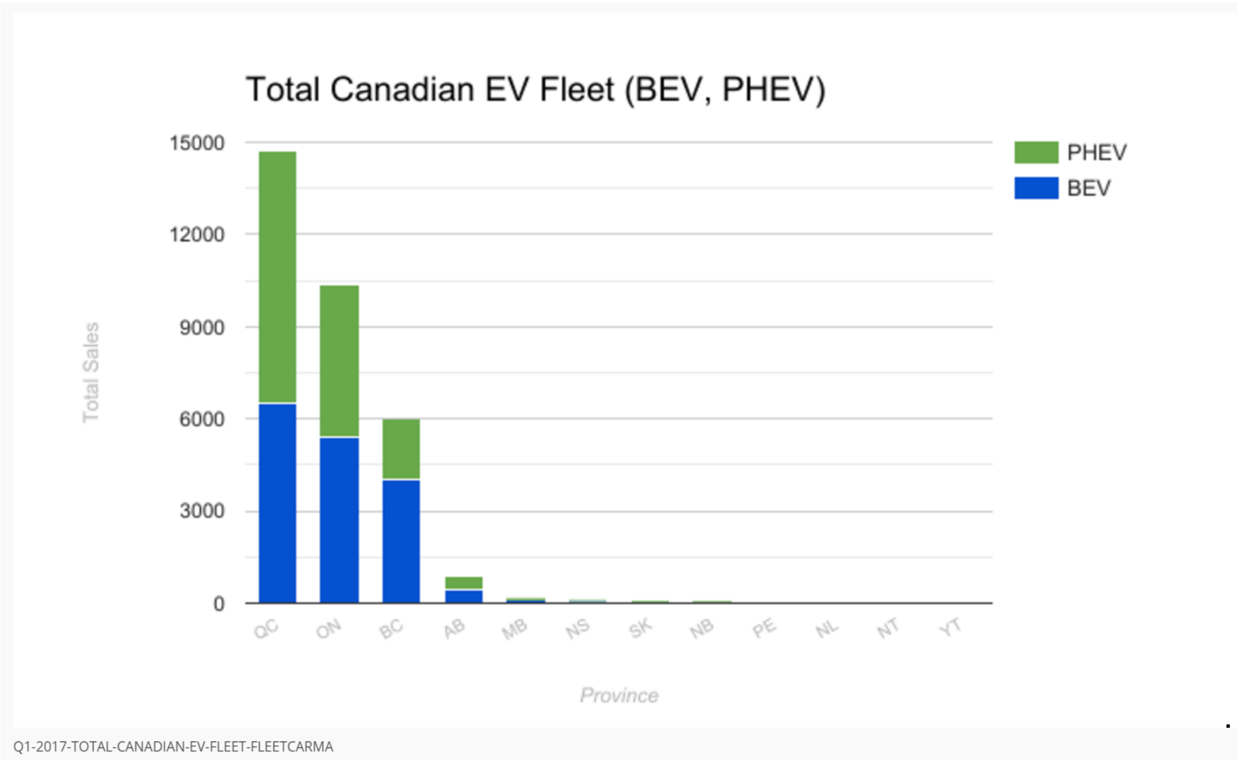

Figure 5 – EV Sales in Canada by ProvinceQ1 – 2017[23]

[23] Fleetcarma Q1 Sales – 2017 - https://www.fleetcarma.com/electric-vehicle-sales-canada-q1-2017/

The sales of passenger EVs is rising exponentially as shown in Figure 6. It is expected that the sales will rise at a faster rate as new EV models enter the market place, information on the incentives becomes wider spread, and public awareness increases.

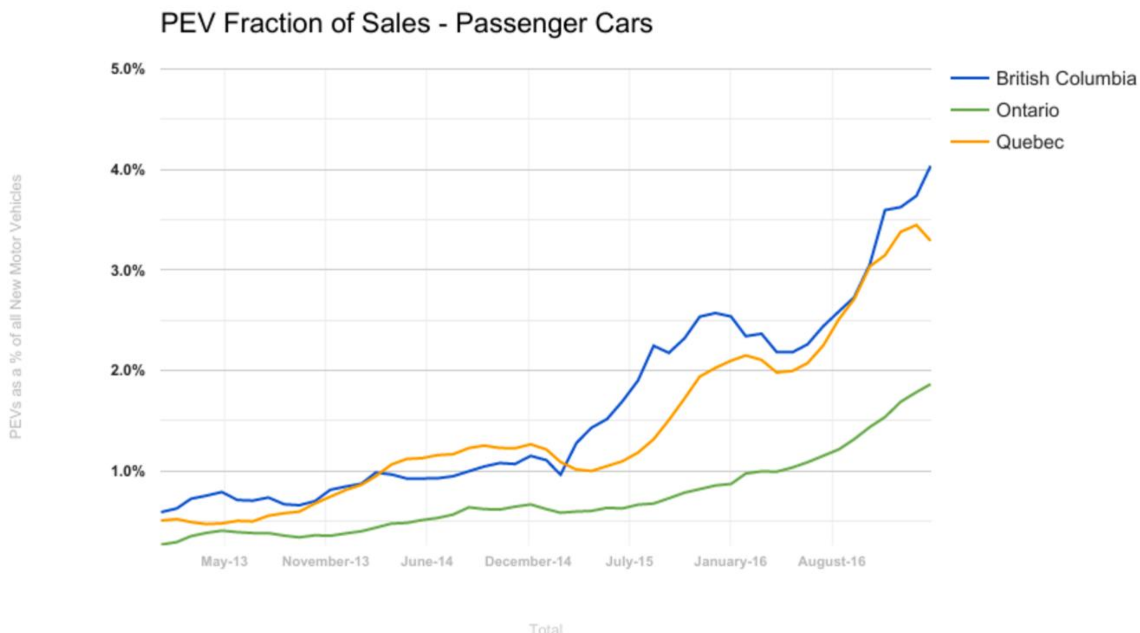

Figure 6 – EVs as a Percentage of New Passenger Car Sales by Province[24]

[24] Fleetcarma Q1 Sales – 2017 - https://www.fleetcarma.com/electric-vehicle-sales-canada-q1-2017/

The graph shown in Figure 7 illustrates that the quarterly Ontario EV sales have doubled when compared with sales for the first quarter of 2016.

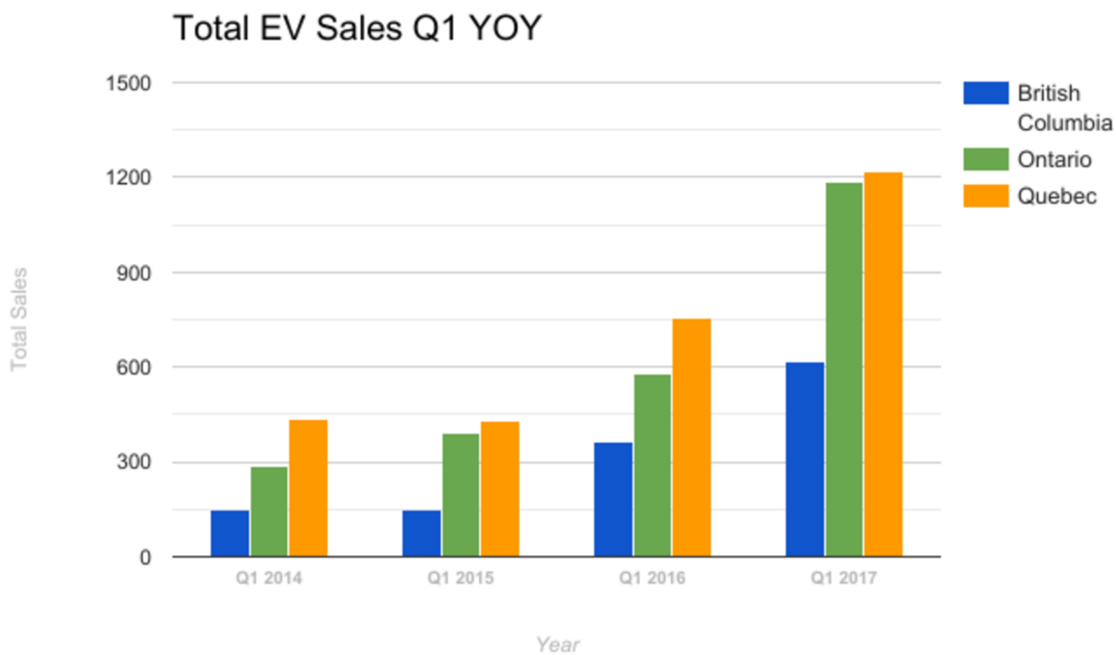

Figure 7 – EV Sales Comparison for Top Three Canadian Provinces

In the short term EV sales are being supported by government incentives, low manufacturer profit margins and the willingness of early adopters to pay more. However, in order for the above long term EV sales projections to be achieved it will be necessary for battery prices to continue to decline as they currently represent about one third of the costs of an EV. The graphs in Figure 8 show past and projected pricing trends for lithium-ion batteries illustrating the possibility for an EV market that is viable long term.

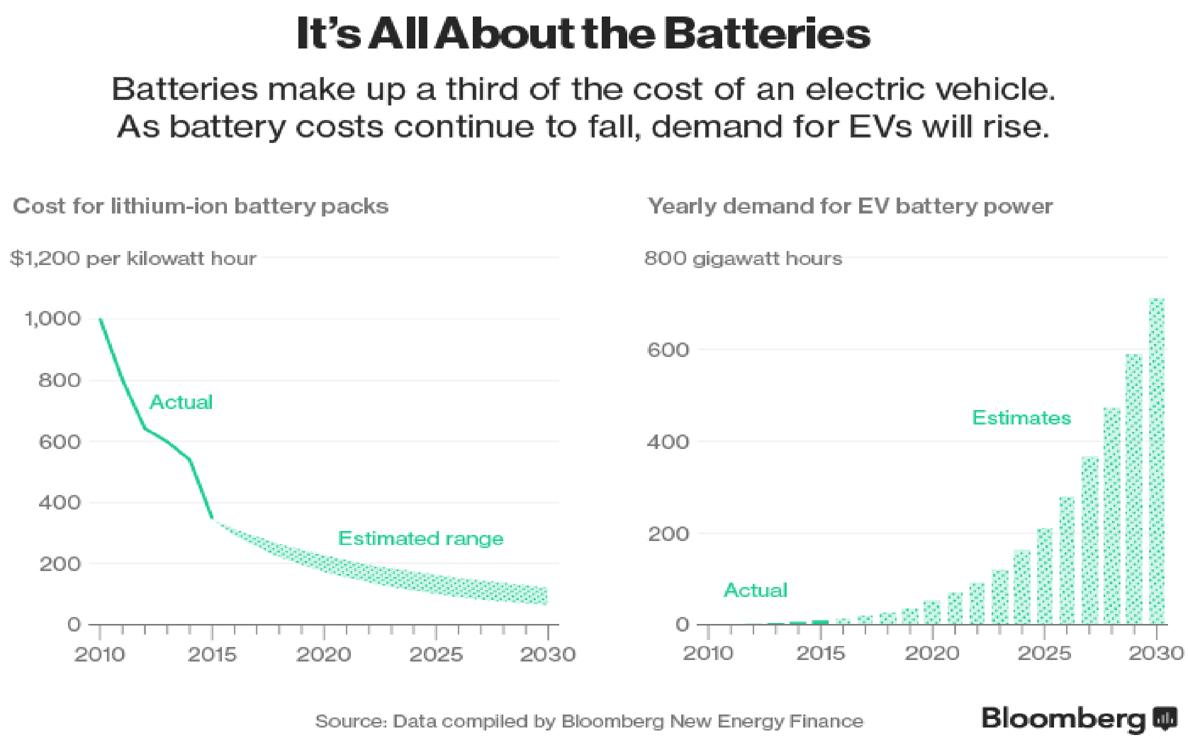

Figure 8 - Lithium-Ion Price Trends

2.4.3 Existing Electric Vehicle Initiatives around the world:

<u>ChargeTO Pilot Project (funded by the Smart Grid Fund)</u> – The ChargeTO project involved Toronto Hydro, and Fleetcarma and thirty EV owners. Participants were provided with a free EV charger to participate and also gained access to detailed data on their EV charging usage. The essence of the program involved installing a Fleetcarma Smart Device into the OBD-II port of the EV which could communicate the present state of charge of the EV to the smart EV charger. The EV owner was able to specify two desired operating parameters for charging: the minimum acceptable battery charge level (eg. 30 to 50% of capacity) and the time of day that they wanted the EV to be fully charged by (eg. 100% charged by 6:00am). The utility was then able to control the load to reduce peaks within these parameters. As a result, the utility was able to shift approximately 50% of the daily peak charging load when compared with the non-smart charging option.

It was noted that nearly three out of four EV owners would not have participated in the smart charging program if they had not been able to specify the two parameters which restrict utility load control. [25]

Smart Charge Rewards Program - Fleetcarma and ConEdison are moving forward with a SmartCharge Rewards program for EV owners to incentivize off-peak charging. The program offers incentives for participation including a free FleetCarma device that provides EV drivers with feedback on how they compare to other EV owners and how to earn rewards (gift cards or points which can be redeemed) for charging during off-peak times on the electricity grid[26]. The rewards are typically funded by the utility as they are intended to encourage off-peak usage patterns and defer investments in infrastructure required to support peak times.

- The benefits of the program are:
    - ConEd gets insight on increased EV use and impact on the grid to help guide investment.
    - Provides EV owners with information they can use to save money on more efficient driving and charging.

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[25] ChargeTO Pilot Program - https://evroadmapconference.com/program/presentations16/MattStevens.pdf

[26] Smart Charge Rewards Program - http://www.fleetcarma.com/press-release-con-edison-smartcharge-rewards/

- Owners can engage with the EV community and earn financial rewards by converting a kWh of off-peak charging into rewards points redeemable for online gift cards each month.[27]

Autolib Paris France – In this car sharing program users are able to pay a monthly subscription (10 EUR) plus a pay-per-use (e.g. 20 minutes for a fee of 4.66 EUR plus an additional 0.23 EUR per minute fee)[28]. This includes the charging, use of the vehicle, insurance and parking. Autolib also allows the public to use its chargers for a fee. For example, a member of the public can become a member for 15 EUR and charge their personal car for 1 EUR for the first hour, and 3 EUR for additional hours with a cap at night time[29].

Electric Vehicle Chargers Ontario (EVCO) – In this program, the Province is working with 24 public and private sector partners to create a network of EV stations in cities along highways and at workplaces and public places across Ontario. As an example, a local supplier from Woodstock, Arntjen Solar North America Inc, installed $611,987 worth of chargers with Chargepoint. The EVCO program covers the costs of the EV charger and installation. The charger owner can determine the rates which are charged to the EV owner. The charge has typically been based on a charge per minute which is variable based on duration and the capacity of the charger. The following illustrates some of the charging rates being used:

- Level 2 Charger (240V_{ac} ~ 3.6 to 6.6 kW)
  - First 5 minutes are free
  - Five cents per minute after that
- DC Fast Charger (DCFC 400V_{dc} ~ 50 kW to 120 kW)
  - First 5 minutes are free

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[27] Smart Charge Rewards FAQs - http://www.fleetcarma.com/smartchargenewyork/#faq

[28] Autolib Membership - https://www.autolib.eu/subscribe/offer_choice_session/

[29] Autolib Charge Rates - https://www.autolib.eu/subscribe/offer_choice_session/charge/

- Twenty-five cents per minute after that

In some locations, the 5 minutes of free fast charging had to be discontinued as users began charging in 5 minute intervals to avoid financial charges.

New EV Purchase Charging Incentives – EVgo, a supplier of fast charging public EV charging stations in the US has teamed up with auto manufacturers BMW, Nissan and Ford to offer free charging to owners of newly purchased EVs. The automakers special offers typically includes two years of free charging for 30 minute durations for new owners at the DC fast charging locations provided across the US by EVgo. These programs which are enabled by EVgo are branded as follows: BMW – “ChargeNow” by EVgo, Ford - “EV 1-2-3 Charge”, Nissan – “No Charge to Charge”.[30]

European Car Sharing Program : DriveNow – BMW and Mini are continuing to roll out their DriveNow program that is based on a car sharing program that includes all costs (eg. fuel, parking, insurance, mileage, etc) for one low price per minute. This program is currently available in Germany, Austria, United Kingdom, Denmark, Sweden, Belgium, Italy and Finland and they are currently greening their fleet by adding 550 EVs to its New Hamburg fleet in Germany.[31]

Light & Charge - BMW along with Eluminocity US have teamed up in Seattle to unveil their new Light & Charge locations which leverage streetlights to become public charging stations. BMW is investing $1.2M in the Light & Charge program.[32] Each pole includes high efficiency LED lighting, EV chargers, and a sensor bus that connects the site to the cloud. The chargers are a combination of either DCFC or Level 2 chargers.

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[30] Charging Incentives for new EV owners - https://www.evgo.com/special-offers/

[31] BMW EV Car Sharing Initiatives - https://electrek.co/2017/05/11/bmw-electric-vehicles-hamburg-car-sharing/

[32] BMW Turning Light Poles Into EV Charging Station in Seattle - http://gas2.org/2017/05/17/bmw-turning-light-poles-ev-charging-stations-seattle/

Figure 9 – Sample Light and Charge Installation

2.4.4 Social Influences regarding EVs

There is a desire to reduce greenhouse gas (GHG) emissions in Ontario to combat climate change. The province's transportation sector is responsible for more than one third of the provincial GHGs.[33]

The following observations are based on highlights of a public survey that was completed by Plug'n Drive in May of 2017 entitled "Driving EV Uptake in the Greater Toronto and Hamilton Area (GTHA) – How Driver Perceptions Shape Electric Vehicle Ownership in the GTHA" . The survey included 1,192 vehicle owners (1,000 gas and 192 electric).

[33] "Driving EV Uptake in the Greater Toronto and Hamilton Area (GTHA) – How Driver Perceptions Shape Electric Vehicle Ownership in the GTHA", Plug n' Drive, May 2017.

- In general, 31% of gas vehicle owners are hesitant to purchase an EV as they feel that the initial purchase price is too expensive when compared with a gas vehicle. Gas owners do not seem to be informed on the lower operating costs associated with EVs. Also, 13% of gas vehicle owners are concerned with range anxiety.
- Only 5% of gas vehicle owners are knowledgeable about Ontario's financial incentive programs on EVs and chargers.
- As many as 30% of the gas car owners still do not understand the link between EVs with clean energy sources and the positive impact on climate change.
- Almost 40% of EV owners have an undergraduate degree with a concentration in engineering and technology related fields.

The above factors indicate that there is a general need for more education on EVs in order to increase the EV uptake in Ontario.

Where Do People Choose to Charge?

The vast majority of plug-in vehicle drivers do nearly all of their charging at home. Overall, the cars in the Department of Energy (DOE) survey used home charging more than 85 percent of the time. Roughly half of drivers relied on public or workplace chargers for less than 5 percent of their total use. One fifth of the vehicles in the study accounted for 75 percent of away-from-home charging.[34]

[34] Where do the LEAF and Volt Charge? (Fleetcarma - http://www.fleetcarma.com/comparing-charge-patterns-leaf-volt/)

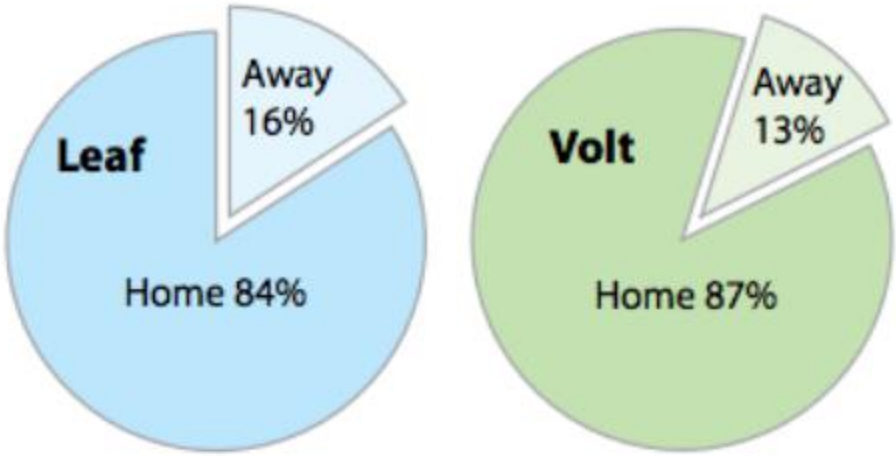

Figure 10 – Charging Location of Preference

(Idaho National Laboratory)

2.5 Electric Vehicle Technology

There are several key components involved in the operation of an EV. These components include:

- Electric Vehicles including Battery Electric Vehicles (BEV), Plug-in Electric Vehicles (PHEV) and Fuel Cell Electric Vehicles (FCEV)
- EV chargers (known as Electric Vehicle Supply Equipment - EVSE)
  - AC Levels 1, 2 and 3
  - DC Fast Charge (CHAdeMO, SAE Combined Charging System (CCS) and Tesla Superchargers
- Batteries – Lithium Ion

These items are described in the following sections.

2.5.1 Electric Vehicle Types

A number of different types of electric vehicles are currently available with varying abilities to move using electric power. The following is a list of types of electric vehicles:

- Hybrid Electric Vehicle (HEV): A vehicle with both internal combustion and electric powertrains, that cannot be charged from the grid and requires refueling using gasoline or other fuel.
  Examples: Toyota Prius, Ford Escape Hybrid, Honda Civic Hybrid

- Battery Electric Vehicle (BEV): A vehicle that is solely powered by an electric powertrain recharged from the electric grid.
  Examples: Chevy Bolt, Nissan Leaf, Tesla Model S, BMW i3, Ford Focus Electric, Volkswagen e-Golf

- Plug-in Hybrid Electric Vehicle (PHEV): A Hybrid Electric Vehicle that can be recharged from the electric grid, typically with the ability to travel short distances without burning fuel, but with a combustion powertrain that can enable longer distances and faster acceleration.
  Examples: Chevy Volt, Toyota Prius PHV, Ford C-Max Energi, Ford Fusion Energi

A summary of EVs available in Canada is provided in Appendix A. This table provides a summary of the models, charging capacities, range, price and applicable provincial purchase incentives.

Fuel Cell Electric Vehicle (FCEV): Fuel cell vehicles are an emerging technology with limited commercialization. A FCEV has an electric powertrain which may include a battery but primarily relies on a hydrogen fuel cell for power and can only be refueled with hydrogen.
Examples: Toyota Mirai (available in Japan, parts of Europe and California), Hyundai Tucson FCEV (available in Vancouver, BC – Limited by fueling stations)

FCEV Benefits[35]

[35] California Energy Commission - http://www.energy.ca.gov/drive/technology/hydrogen_fuelcell.html

- Fuel cell vehicles emit no tailpipe GHGs, only heat and water. Producing the hydrogen for FCEVs can generate GHGs but is much less compared to gasoline vehicles.
- FCEVs reduce our dependence on foreign oil. In some cases hydrogen is produced from water through electrolysis.
- Typical refueling time for an FCEV is approximately 3-5 minutes and the range is around 240-350 miles.

FCEV Challenges

The challenges currently outweigh the benefits.

- Few FCV models are available for sale or lease and they are limited to areas with hydrogen fueling stations. FCVs also have a high capital equipment, operation and maintenance cost.
- FCEVs are currently the most expensive vehicle option compared to other EV types and internal combustion engine (ICE) vehicles.
- The current infrastructure for producing and getting hydrogen to consumers cannot yet support the widespread adoption of FCEV.
- Existing fuel cell systems are not as reliable as internal combustion engines, especially in some temperature and humidity ranges.

Consumers will have concerns about the safety and dependability of FCVs because of the new fuel type (hydrogen). [36]

There is a rising interest in Hydrogen powered vehicles in Japan.[37] The support is driven by faster fueling times and longer range vehicles. If this trend continues,

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[36] US Department of Energy Benefits and Challenges- https://www.fueleconomy.gov/feg/fcv_benefits.shtml#climate

[37] Japan's Big Carmakers Gang Up In Support of Hydrogen Fuel Cell Vehicles, At Least Officially - https://www.forbes.com/sites/bertelschmitt/2017/05/19/japans-big-carmakers-gang-up-in-support-of-hydrogen-at-least-officially/#8fb6cee1a9d6

Hydrogen could become a competitor for EV market share.. At present the Japan market has many more EVs than hydrogen powered vehicles.

Ontario is also presently the feasibility of using hydrogen fuel cells to power electric trains on the GO Transit rail network.[38] These are trends that need to be monitored as they will affect the penetration rate of EVs.

2.5.2 Electric Vehicle Supply Equipment (EVSE) - Chargers

EVSE is available in both AC and DC as shown in Figure 11. This section will further discuss the charging modes that are available.

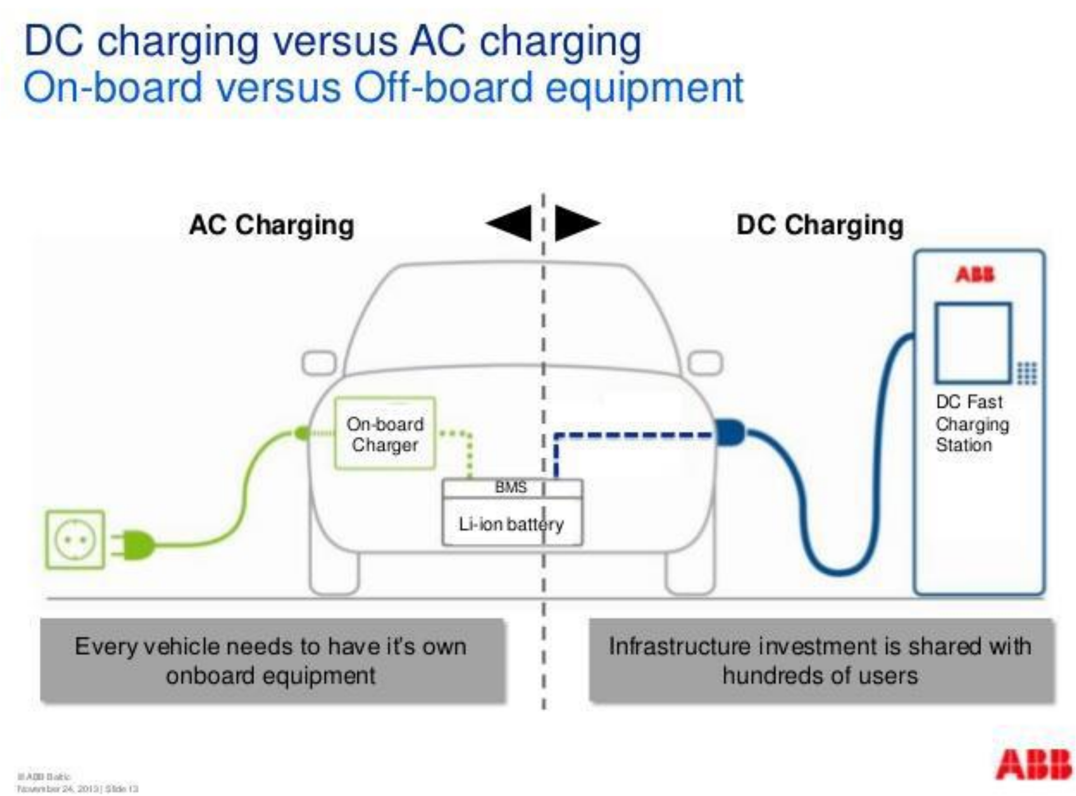

Figure 11 - EV Charging (AC and DC)

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[38] Ontario studying using hydrogen fuel cells to power GO trains - http://www.torontosun.com/2017/06/15/ontario-studying-using-hydrogen-fuel-cells-to-power-go-trains

AC Charging (level 1,2,3)

AC charging is where AC power is brought directly to the vehicle's charge port. All passenger EVs sold in North America comply with the SAE J1772 standard which defines a standard connector and communications protocol for AC charging of electric vehicles. The J1772 standard ensures that a vehicle is aware of the limitations of the circuit it is connected to, power is only applied when the vehicle is actively requesting power (preventing bad connections, arcing and potential fire risks), and prevents the vehicle from being driven while a charging cable is still attached. A J1772-compliant charging station or EVSE essentially acts as an extension cord with these safety features built-in. An EVSE may either be a fixed piece of equipment, or a portable cordset that is kept with the vehicle in order to plug into existing outlets.

AC Level 1 charging is the slowest form of charging. It is quite versatile due to how common 120V outlets are. Many PHEV owners and some BEV owners get by with only Level 1 charging at home. This is reflected that only 25% of new EV owners in Ontario actually submit claims for the charger incentive program to install Level 2 chargers. Four hours of charging with a Level 1 charger can provide approximately 30km worth of range. Overnight charging or while charging at work may be sufficient for daily driving within a city or town. Long distance travel with a Level 1 charger becomes more problematic. Level 1 charger's only provide approximately 1.5 kW on a 15A circuit. A full charge for a Nissan Leaf (30kWh battery) would take approximately 20 hours. A full charge for a Tesla Model S85 (85kWh battery) would take approximately 56 hours.

AC Level 2 charging stations are the most common type of public charging infrastructure in North America, with over 35,000 Level 2 charging ports active as of August 2016. The charging rate is typically more than doubled that of a Level 1 charger, this is due to a higher voltage (240V vs 120V) as well as higher amperage circuits (40A being the most common). The J1772 standard supports Level 2 charging at rates between 1.4kW and 19.2kW. The actual charging rate will depend on the minimum of either the EVs maximum charging rate or the EVSE's available power. Most PHEVs and some BEVs are only capable of charging at 3.3-3.6kW due to the limitation of the onboard charger. Most BEVs now support Level 2 charging at 6.6-7.2kW (eg Nissan Leaf, Ford Focus EV, Volkswagen e-Golf). The Tesla Model S can draw up to the maximum 19.2kW allowed by the J1772 standard, provided the EVSE and electrical panel have sufficient capacity.

AC Level 3 is a new category of charging that is in development as part of the SAE J3068 standard. It is intended for larger plug-in vehicles such as electric buses and trucks; vehicles which would likely charge in commercial/industrial settings with access to high amperage 3-phase AC power. The standard is still under development but expected output power is 66 kW with a connector similar to the Mennekes Type 2 plug, which is common in Europe instead of SAE J1772. An advantage of this charging configuration is a symmetrical three phase load, which helps preserve grid stability. Higher power levels could be possible as it uses a similar connector to the Tesla Superchargers which deliver up to 140 kW DC.

The city of London presently has 31 publicly accessible charging locations (Level 1 or Level 2) according to the Plugshare website.[39]

[39] PlugShare Website - https://www.plugshare.com/

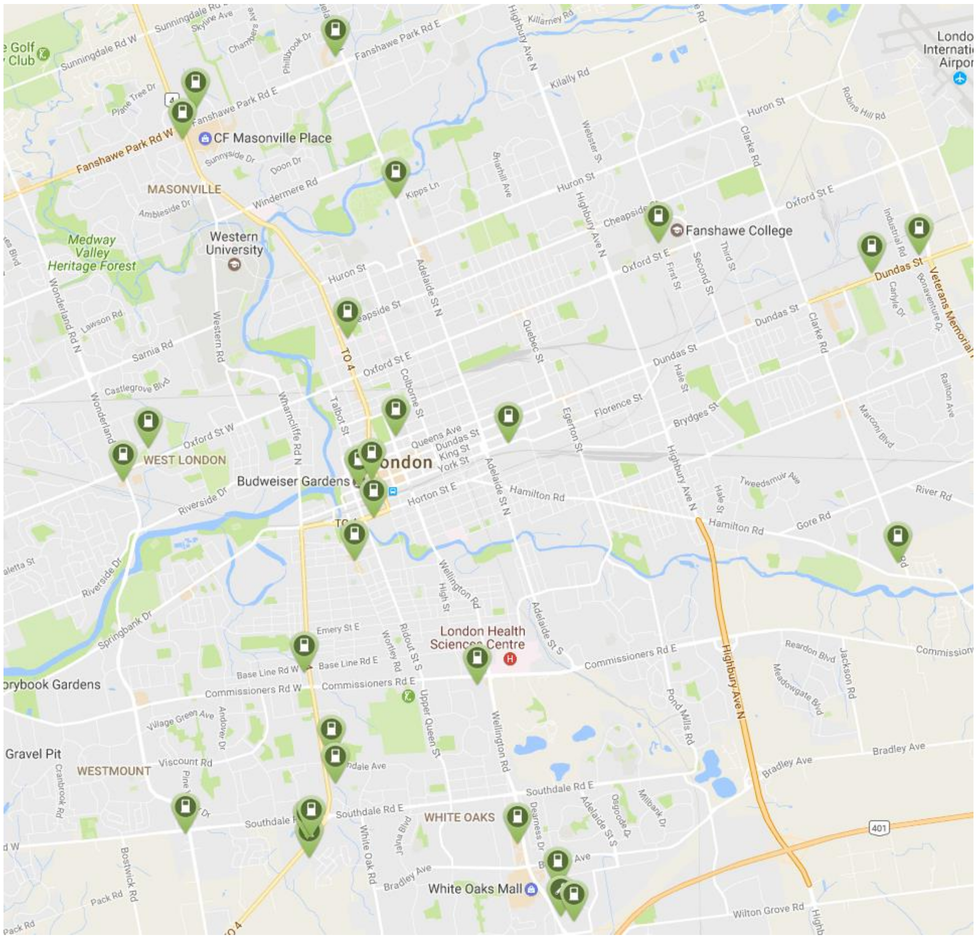

Figure 12 – Public EV Charge Stations Level 1 and 2 - PlugShare Website June 18, 2017

<u>DC Fast Chargers (DCFC)</u>[40], previously referred to as Level 3, enable EVs to charge much more quickly than Level 2 and Level 1 chargers. DCFC connects the charging station directly to the vehicle's battery. This charging format used to be referred to as "Level 3" charging, but this nomenclature was revised in 2011 in order to distinguish between the different charging configurations. These chargers typically have capacities in the range of 50kW to 120 kW; however there are plans to increase this to 150 kW and even 400 kW.

[40] Why Can't all EVs Just Use the Same Network? – Fleetcarma - http://www.fleetcarma.com/dc-fast-charging-guide/

There are currently three different standard connection types for DCFC. They include the Asian standard CHAdeMO (commonly used by Hyundai, Nissan, Kia and Mitsubishi), the European/North American standard SAE Combined Charging System (CCS) (commonly used by BMW, Chevrolet, Ford, and Volkswagen) and the Tesla-only standard Supercharger. Having several standards in the technology field is unfortunately a common occurrence and is often driven on the fact that various manufacturers do not agree on which is best. This does complicate issues when making decisions on the installation of DCFC charging infrastructure. It is common to install both CHAdeMO and CCS side by side at one charging location.

The *CHAdeMO* standard (DCFC type) is the most common worldwide. Common charging levels are 40 to 60 kW but can be as high as 100 kW,CHAdeMO has been in use the longest. The CHAdeMO format is only compatible with DCFC charging. The connector is shown below.

Figure 13 – CHAdeMO Standard Charging Interface

The *CCS* standard (DCFC type) has come to market later than the other standards and has a smaller existing market share. The CCS standard allows for three speeds of charging from a single port (ie. Level 1, Level 2 and DCFC). This format typically supplies approximately 40 to 60 kW but is capable of handling a maximum of 350 kW. The connector is shown below.

Figure 14 – CCS Standard Charging Interface

The *Tesla Supercharger* standard (DCFC type) typically supplies 120 kW and has strategically installed chargers to provide adequate coverage across the US and Ontario. Tesla intends to double the number of Supercharger stations in 2017. The connection type is shown below.

Figure 15 – Tesla Supercharger Standard Charging Interface

DCFC capabilities are most commonly available with BEVs. Generally speaking, PHEVs have sufficient power from the gasoline portion of the powertrain to support long distance travel without the need for recharging.
Unfortunately, the cost of installing a DCFC charger can be very expensive and is often in the range of $15,000 to $35,000 for the charger itself plus the cost of electrical infrastructure. The cost of installation could bring the overall costs between $70,000 to $120,000. Also many EV manufacturers still offer DCFC charging capability as an option at an incremental cost of $700 on some models. This is illustrated in the table

provided in Appendix B.

2.5.3 Smart Charging

Smart Charging is a term used to describe the optimization of EV charging according to the electrical infrastructure conditions or electricity market conditions. Modern smart EV chargers, such as those manufactured by Chargepoint or AddEnergie/Flo, are capable of controlling when the EV is permitted to charge and at what rate of charge. The user can use parameters such as price, available circuit capacity and time to control the operations of the chargers. Commercially available chargers also permit spatial grouping of chargers to monitor group load and initiate group control. This can be helpful if trying to manage load on a transformer or feeder circuit to prevent an overload.

On a more localized scale, smart chargers are capable of communicating between each other to share available capacity to prevent overloading of a circuit panel or branch circuit. As an example, chargers in a multi-unit dwelling such as an apartment building can be programmed to share the capacity of a 40 Amp circuit among multiple chargers connected to the circuit. Chargers can be throttled back (eg. 30% of total capacity) to meet the desired limits of loading.

In general, charger owners can develop their own control algorithms using Application Program Interfaces (APIs) to control the demand management of the chargers.

EVs are also equipped with a user interface built into the information display of the car that allow the user to program when they want the car to charge. For an example, an EV owner can set their car to only charge between the hours of 7:00pm to 7:00am.

Vehicle-to-Grid

Vehicle-to-Grid (V2G) is the most common term used to describe the concept of an EV providing electric power back to the electrical grid. This configuration is not commonly available; however, several pilot programs have been conducted throughout the world. This configuration allows the EV to act as a source of generation on the grid. V2G pilots are being conducted to allow the vehicle to synchronize and charge back into the grid and also to simply provide backup power to the home in an islanded configuration. (Vehicle to Home – V2H).

Automakers have been hesitant to offer V2G capability due to the fact that it can shorten battery life and impact the warranty as a result of the additional battery cycles. However, in recent years the battery performance has become more robust and these concerns are decreasing.

It is estimated that nearly 4,000 customers in Japan are currently using EVs to manage their home energy usage with two-way power flow. Hundreds of customers are testing V2G applications using Nissan Leafs in the UK and Denmark. In the US, there are several pilots including the LA Air Force Base to see how well EVs can provide ancillary services.[41] Despite all of the pilots, none of the EV manufacturers have released V2G enabled vehicles for sale to the public.

Wireless Charging

There are presently no commercially available EVs that are manufactured with wireless charging however there are companies that provide aftermarket adapter kits to enable wireless charging. Some examples of wireless providers are: Qualcomm Halo[42], Plugless[43], and Elix[44].

Wireless charging is possible through inductive power transfer using magnetic fields to transfer energy from a transmitting coil in the parking pad to a receiving coil in the vehicle adapter. There are also other technologies that use Magneto-Dynamic Coupling (MDC) technology which uses the interaction between magnetic fields to charge the

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[41] Nissan, Honda Tease New Evs with Grid Services Capabilities – Green Tech Media https://www.greentechmedia.com/articles/read/nissan-honda-tease-new-evs-with-grid-service-capabilities

[42] https://www.qualcomm.com/products/halo

[43] https://www.pluglesspower.com/

[44] https://elixwireless.com/

battery.[45] Power transfer can range from 1 kW to 40 kW and efficiencies can range between 86% and 90%.

Automakers are working to establish standards for wireless charging. In early 2016, SAE published the J2954 "Technical Information Report" which is a specification guideline that will evolve into a formal standard once field data can be collected. Wireless charging has advantages with respect to convenience and the enabling of autonomous driving vehicles. However, these advantages come with a decrease in overall efficiency when compared with corded charging.[46]

Honda is presently designing a NeuV concept car that not only features inductive charging, but also autonomous driving features and charging intelligence. The charging intelligence charges when electricity prices are low and sells back to the grid during peak times. The artificial intelligence called the Honda Automated Network Assistant (HANA) serves as the electricity market trader.[47]

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[45] Magneto-Dynamic Coupling - https://elixwireless.com/#technology

[46] https://elixwireless.com/

[47] https://techcrunch.com/2017/01/05/hondas-neuv-is-a-mini-electric-concept-car-with-emotional-intelligence/

2.5.4 Electric Vehicle Batteries

The typical charging cycle for a depleted lithium-ion EV battery has a curve similar to that shown in Figure 16.[48] There is a small ramp up time followed by a full rate charge cycle followed by a ramp down period. It is beneficial to understand the charging curve for an uncontrolled EV so that we can assess the impact on the grid.

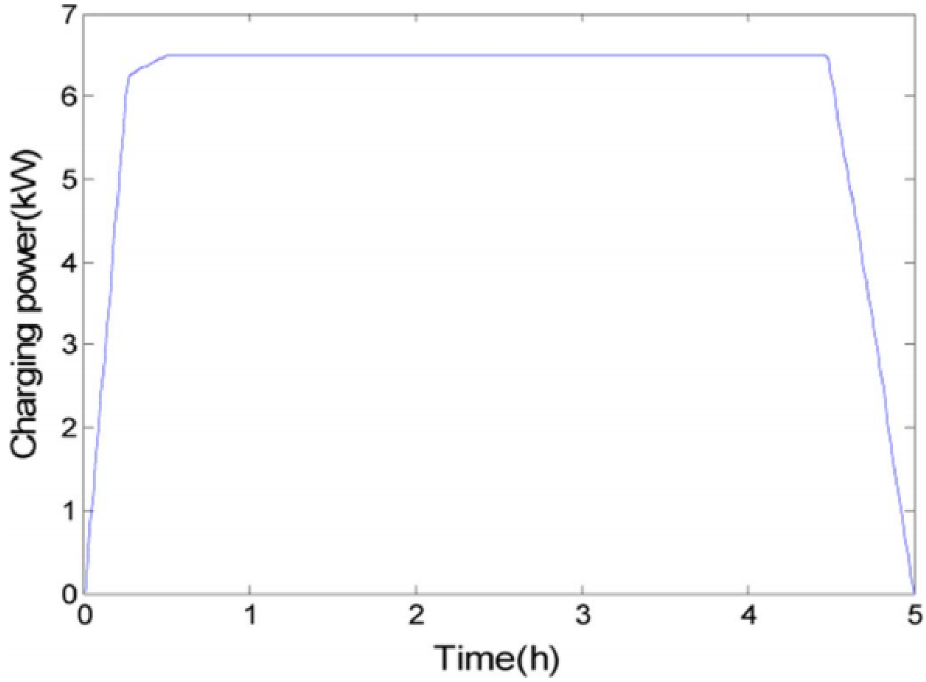

Fig. 3. The charging curve of the lithium-ion battery equipped in Nissan Altra EV.

Figure 16 - Typical Level 2 Battery Charge Curve

Battery degradation is a concern that many potential EV buyers share. This is largely based on their experiences with other consumer electronics that use older battery technologies.

Battery performance is affected by many factors including the number of charge/discharge cycles, state of charge during storage, and high temperatures.

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[48] An Optimized EV Charging Model Considering TOU Price and SOC Curve – IEEE Transactions on Smart Grid, Vol. 3, No. 1, March 2012 - http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5978239

Modern EVs use lithium-ion batteries which typically come with an 8 to 10 year battery warranty. The lithium-ion technology is relatively robust and flexible and is less prone to degradation from partial charge or discharge cycles. Most automotive manufacturers have implemented advanced battery climate control strategies to manage battery temperatures and minimize battery degradation. Tesla has demonstrated that the battery used in the Model S generally only loses five percent of capacity within the first 80,000 km and then less than eight percent after 160,000 km.[49]

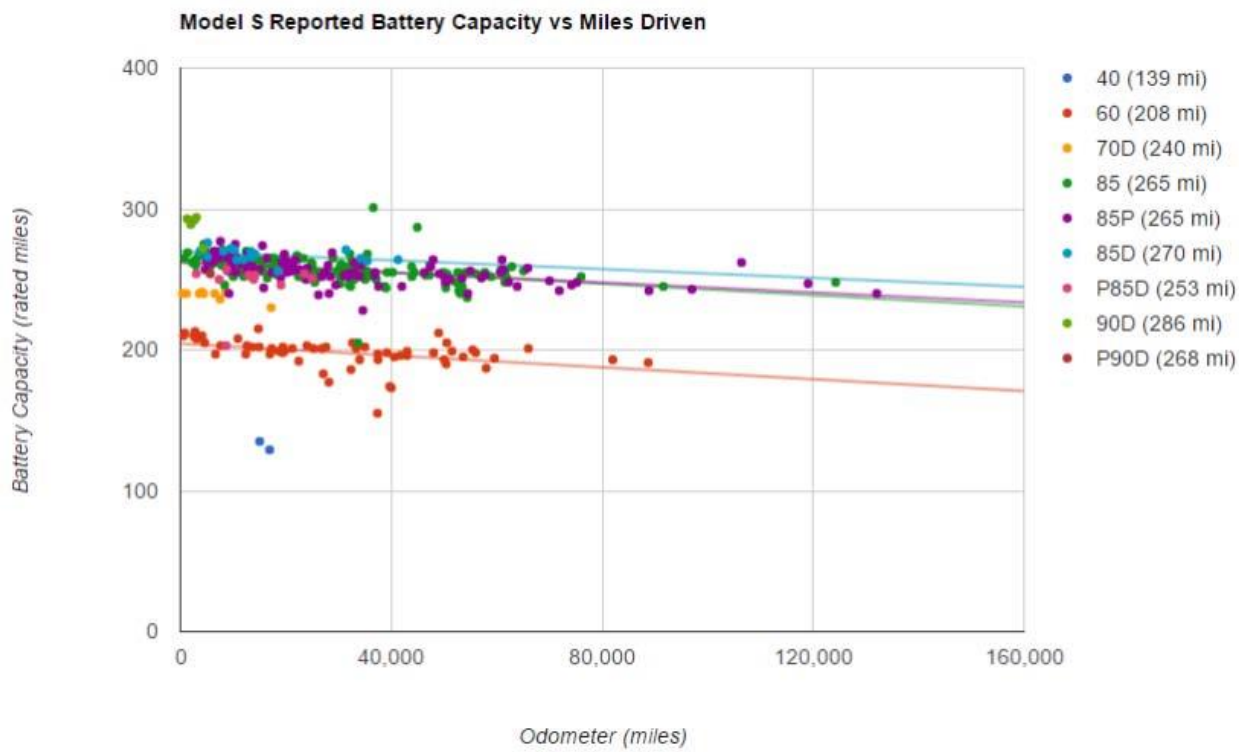

Figure 17 – Battery Degradation for Tesla Model S

There were also some concerns that DC fast charging could negatively impact long term battery performance. Idaho National Laboratory (INL) has studied the effects of DC fast charging on battery life and found that it was not a significant factor in the long-term performance of the battery. The tests were performed in Phoenix, Arizona and it is

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[49] Tesla Model S battery pack data shows very little capacity loss over high mileage – Electrek - https://electrek.co/2016/06/06/tesla-model-s-battery-pack-data-degradation/

felt that the hotter continuous temperatures played a larger role in the degradation of the battery.[50] This is illustrated in Figure 18 through the comparison of battery range for vehicles that were charged with Level 2 chargers and vehicles that were charged with DCFC chargers. The tests were done in three environments: the lab, on a track and on the road. It was noted that the tests done between 20 to 30 miles and 30 to 40 miles were done in the highest ambient temperatures and experienced the largest change in capacity. The speed of the charging session was observed to have a less significant impact. It was observed that high ambient temperatures and battery temperature had a higher impact than fast charging.

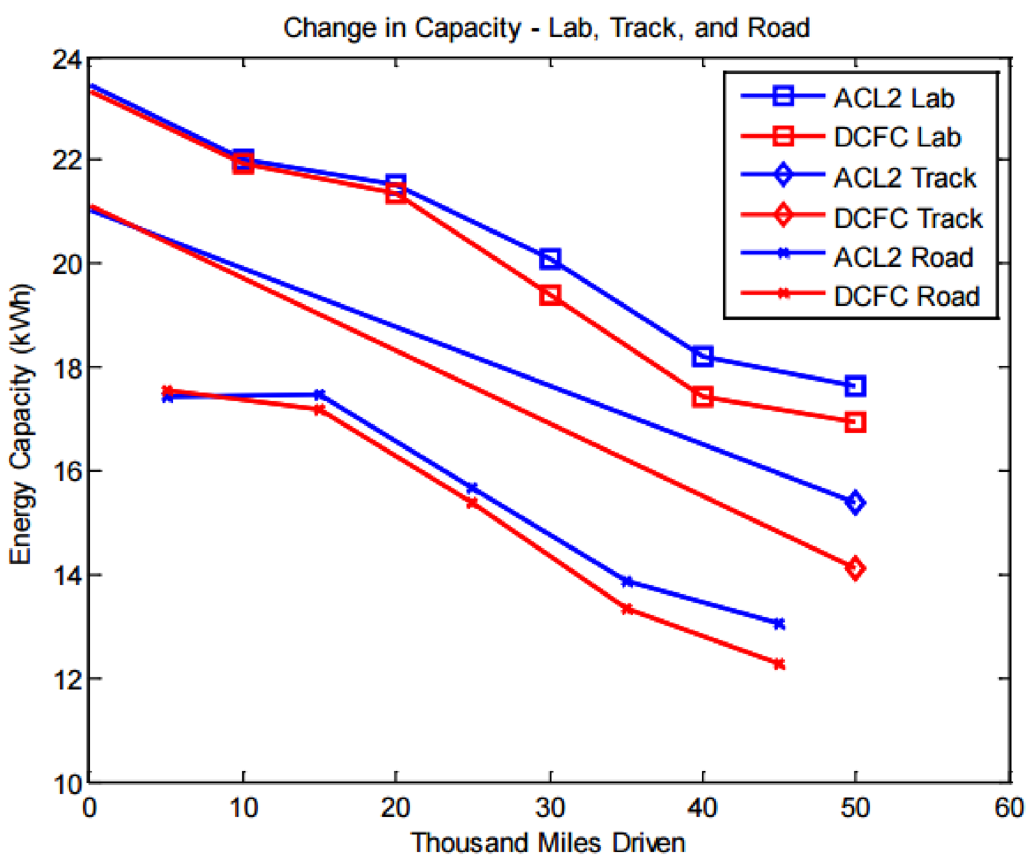

Figure 18 – IDL - Battery Energy Capacity Remaining after 50k Miles

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[50] Effects of Electrice Vehicle Fast Charging on Battery Life and Vehicle Performance – Idaho National Laboratory - https://avt.inl.gov/sites/default/files/pdf/vehiclebatteries/FastChargeEffects.pdf

The largest factors that affect range are driving habits and ambient temperature. Fleetcarma has conducted several studies on the impact on range. The follow graph illustrates the effect of ambient temperature using a Chevy Volt.

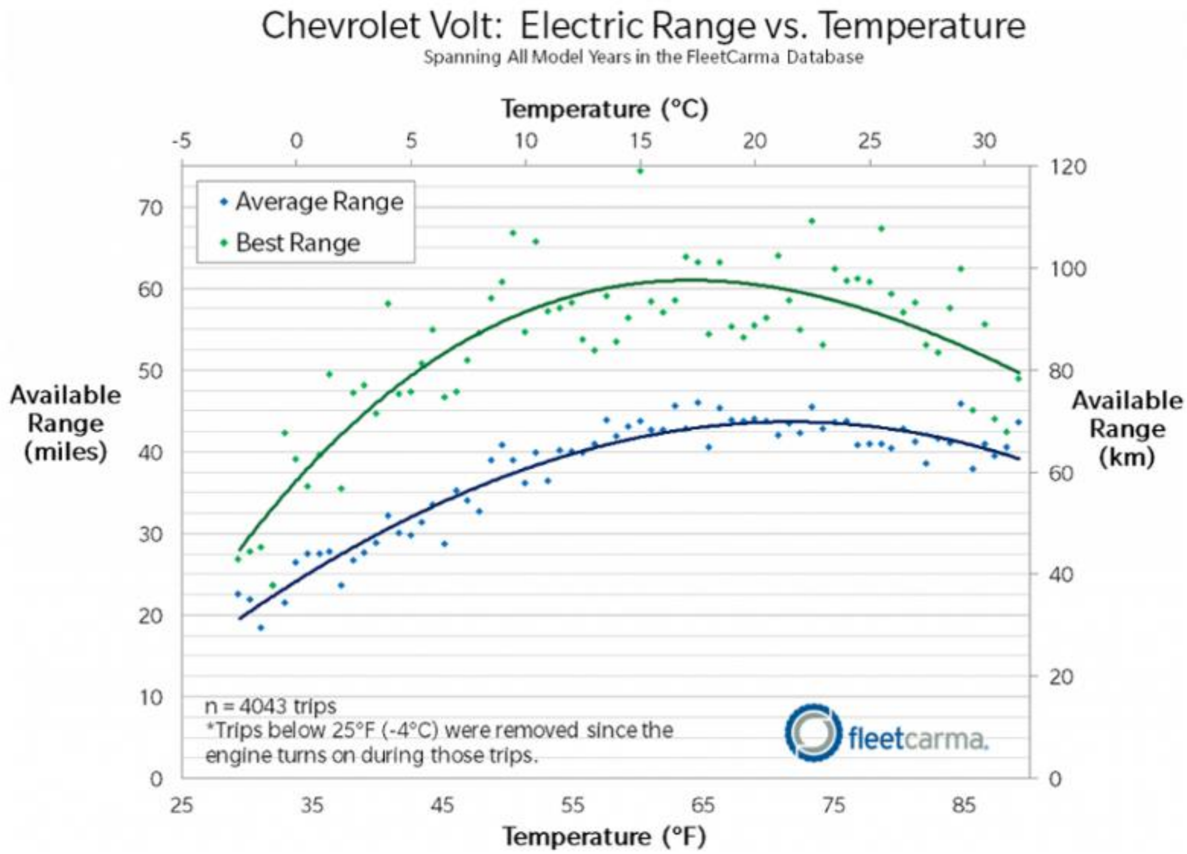

Figure 19 – Effect of Temperature and Driving Habits on Range[51]

It can be seen from the above graph that the temperature greatly affects the use of auxillary loads such as the cabin heater and fan, component heaters (battery), and defrosting elements. Range is maximized when these loads are not required as shown at approximately 16 degree Celsius. Driving habits have a large impact on range such as aggressive accelerating, high cruising speeds and aggressive braking. Aggressive braking reduces the opportunity for regenerative breaking which recharges the battery during deceleration.

[51] Real-world range ramifications: heating and air conditioning – Fleetcarma - http://www.fleetcarma.com/electric-vehicle-heating-chevrolet-volt-nissan-leaf/

Batteries that are cold have greater resistance to charging and do not hold a charge as well as they would in moderate temperatures. The effect of ambient temperature on range was also confirmed by the INL who found that variations in weather can affect the range of plug-in EVs by more than 25%. Cold winter temperatures in Chicago resulted in the range of Nissan Leaf drivers to be decreased by 26%.[52] One way to mitigate the impact of extreme temperatures on EVs is to pre-heat or pre-cool the cabin air while the EV is still plugged in so the range is not affected.

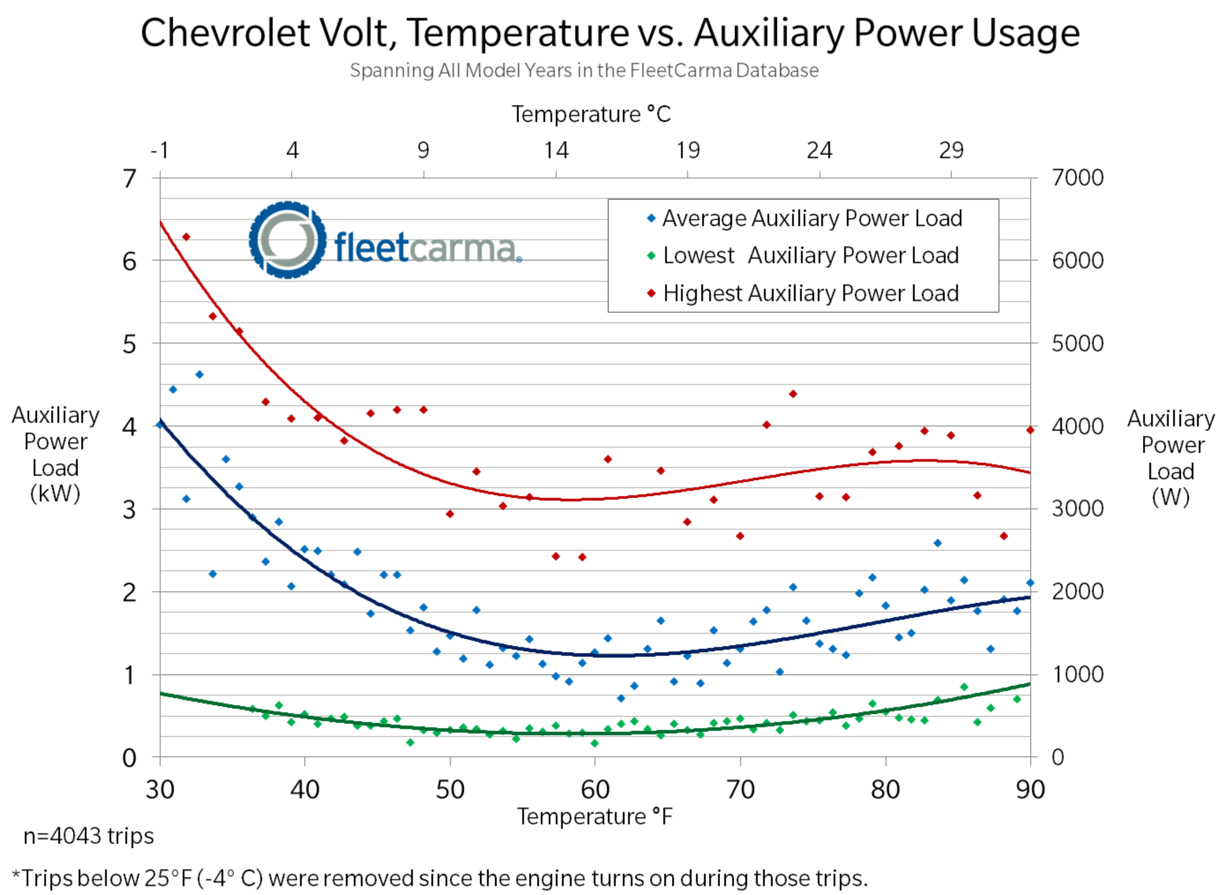

Figure 20 – Magnitude of Auxiliary Loads under cold temperatures

[52] Maximizing Electric Cars' Range in Extreme Temperatures - https://energy.gov/eere/electricvehicles/maximizing-electric-cars-range-extreme-temperatures

2.6 Comparison of Ownership costs of EV vs ICE Vehicles

The information provided below for passenger EVs demonstrates the lower total ownership costs of some passenger EVs when compared with their ICE equivalents. This is due to the current incentives being offered by the provincial government and other factors such as lower fuel costs. The combination of these factors have decreased the financial barrier for entry of these vehicles.

The graphs provided in the following Figures illustrate the total ownership costs of an EV such as a Ford Focus Electric vs an ICE Ford Focus and a Chevy Bolt vs a comparable ICE vehicle such as a Honda Civic. In many cases the EVs present a lower overall total ownership costs. The graphs also illustrate the tremendous benefits in GHG emissions for passenger EVs.

The Ford Focus Electric has a lower overall purchase price and produces ongoing savings in fuel.

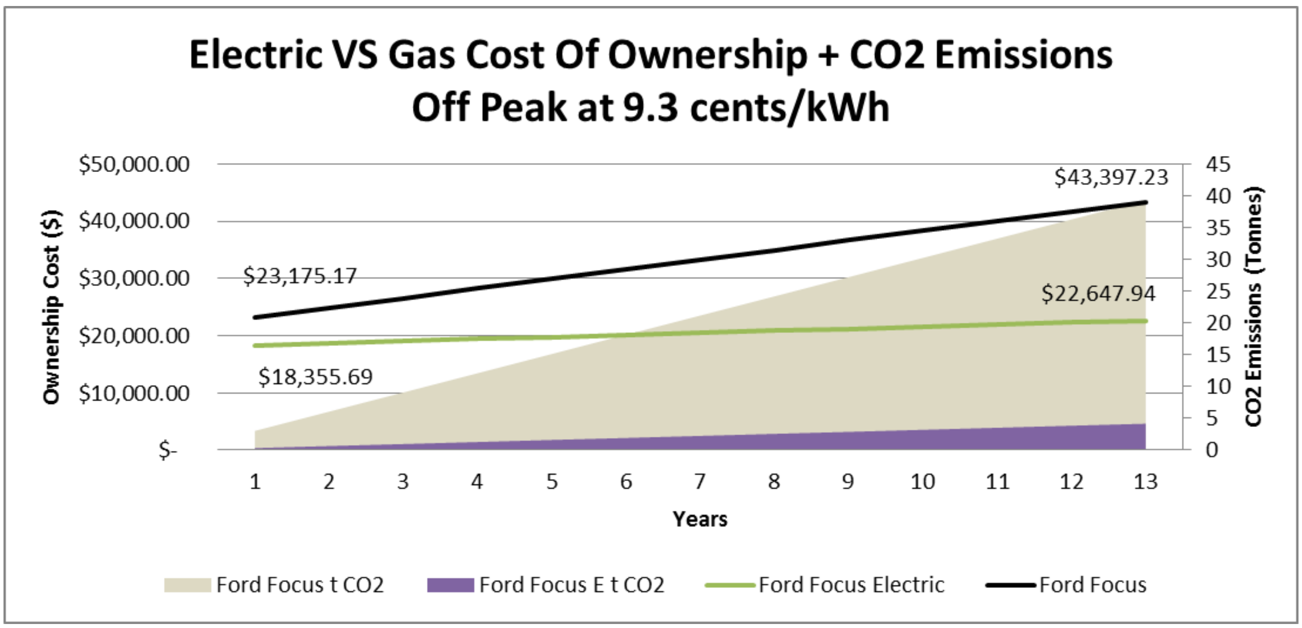

Figure 21 – Comparison Ford Focus and Ford Focus Electric

The Chevy Bolt has a higher initial purchase price but overall lower ownership cost due to fuel savings.

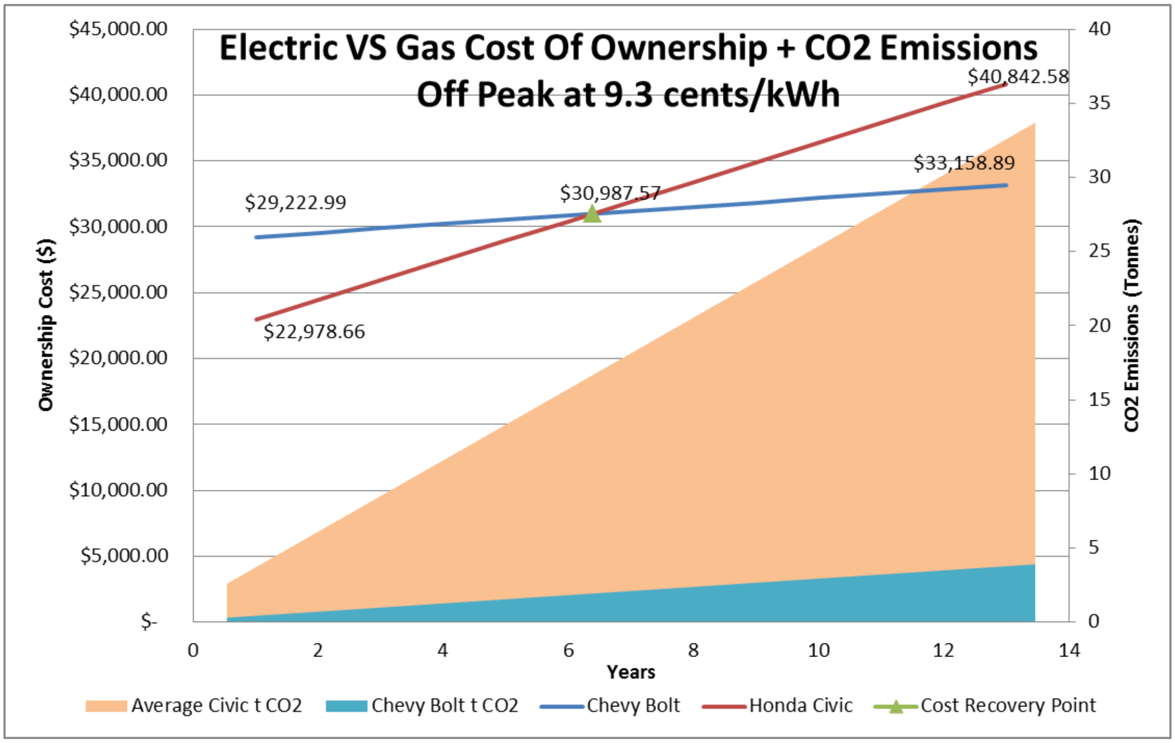

Figure 22 – Comparison Honda Civic and Chevy Bolt

It is noted that even if the initial purchase price is higher, the overall ownership costs are more comparable depending on the amount of driving and length of ownership.

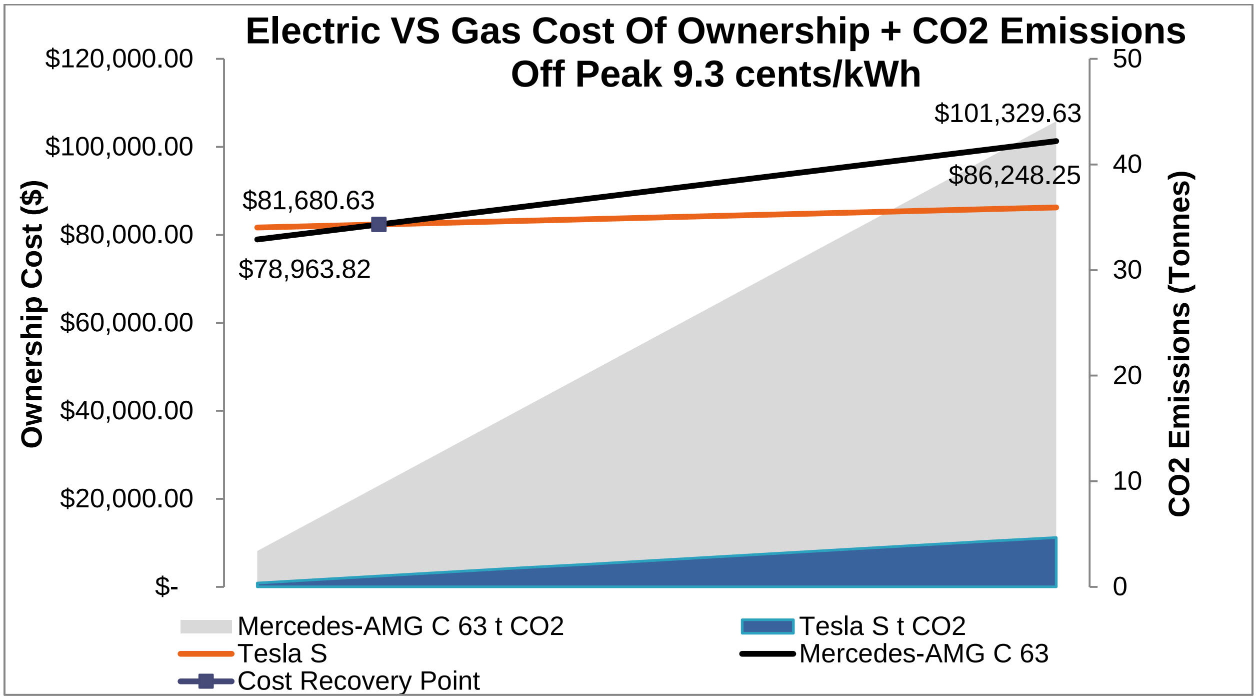

Figure 23 – Comparison Mercedes-Benz and Tesla S

<u>Comparison of Fuel Costs – EV vs. ICE</u>

One of the largest factors in favour of the EVs is the difference in fuel costs. If EVs are charged during off-peak hours the cost is approximately $0.018/km whereas the cost of an ICE is approximately $0.077/km to $0.10/km[53] (as shown in Figure 24). If the EV owner charges during on-peak hours the cost rises from $0.018/km to $0.032/km.

If a driver were to drive 16,000 km in a year the fuel costs would be as follows:
Electric Vehicle = $288
Internal Combustion Engine = $1,232
This represents an annual difference of $944.

[53] Based on the average Ontario gas price of $1.12 per litre on June 1, 2017

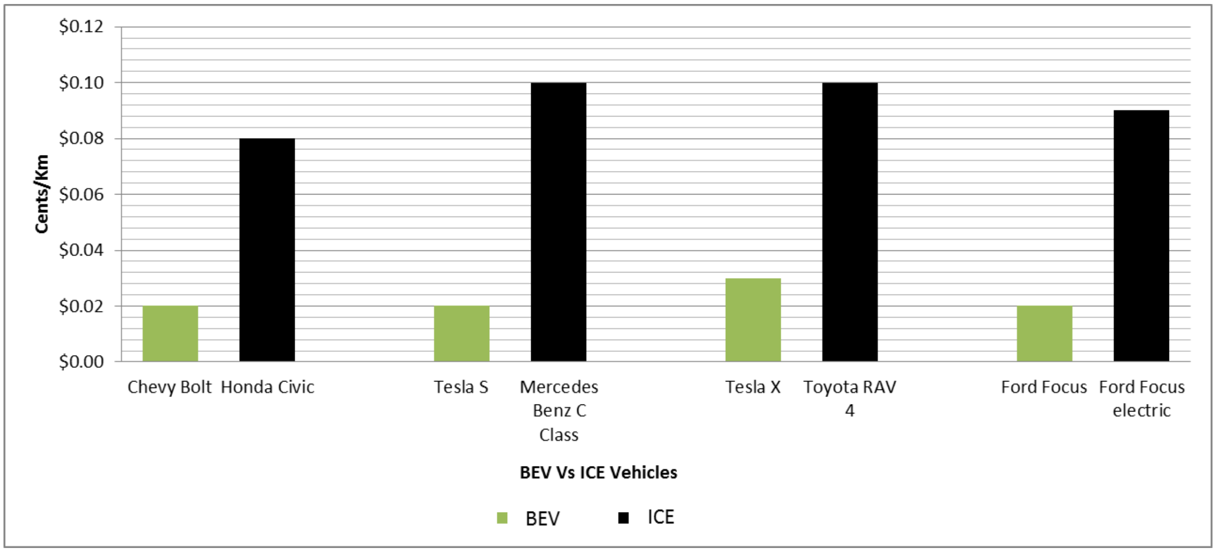

Figure 24 – Fuel Cost Comparison of EV (Off-Peak Charging) vs ICE

2.7 Environmental Aspects of Electric Vehicles

The Provincial Government is focused on reducing GHG emissions through initiatives such as the Climate Change Action Plan. Ontario plans to reduce overall GHGs by 15% below 1990 levels by 2020, 37% by 2030 and 80% by 2050. The transportation sector represents a total of 35%[54] of all GHG emissions as shown in Figure 26. This sector provides a great opportunity for reduction through the increased use of EVs given Ontario electricity is largely generated from clean sources.

According to the IESO, Ontario's electricity generation output is largely free of GHG emissions with only 10% emitting GHG as shown below. It is important to note that most of the 10% GHG emissions occurs during peak times. This positions EVs as an effective means to reduce GHGs in Ontario especially if charging occurs during off-peak times.

[54] Ontario's Climate Change Actions & Transportation – Ministry of the Environment and Climate Change http://www.pollutionprobe.org/wp-content/uploads/Alex-Wood.pdf

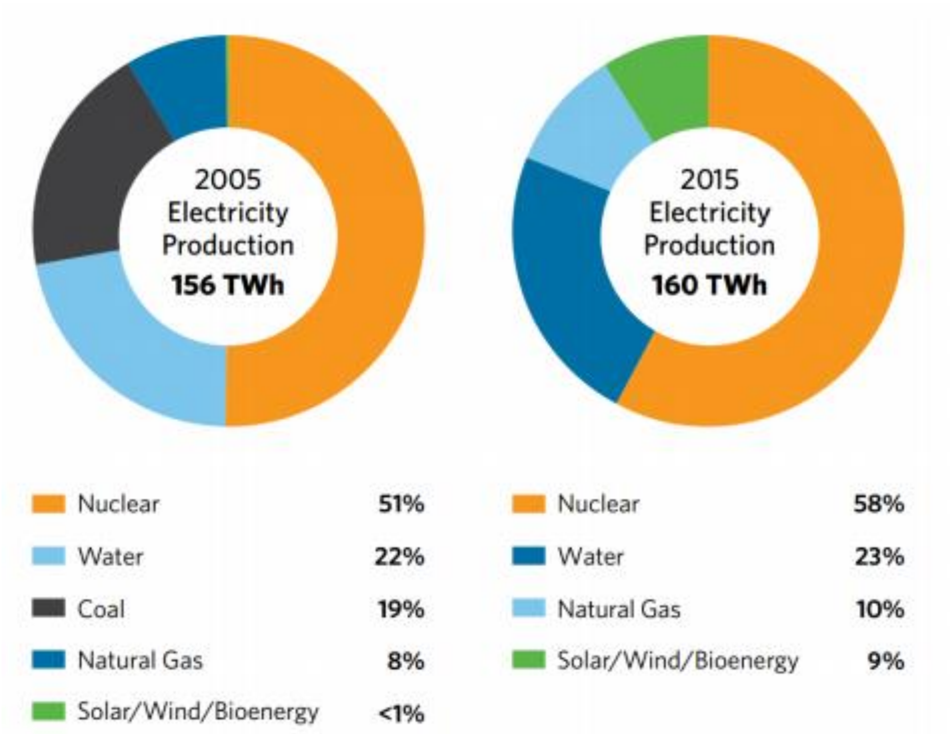

Figure 25 – Changes in Electricity Production - IESO

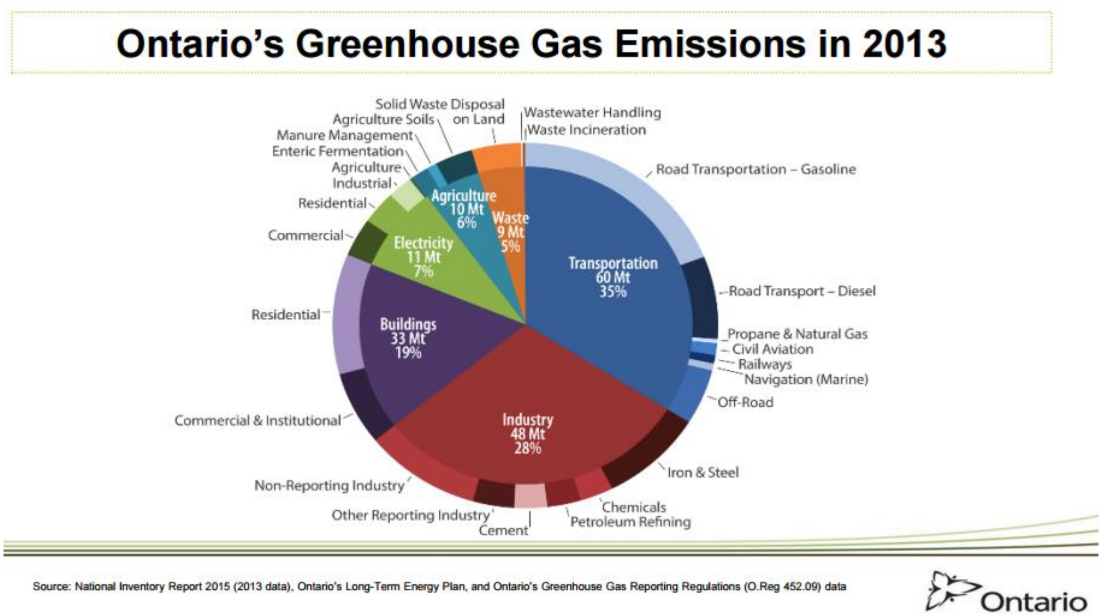

Figure 26 – Ontario's Greenhouse Gas Emissions

In order for EVs to be effective as a GHG solution, the electricity which it consumes must be produced from environmentally clean sources. The term "Well to Wheel" has been used in the industry to perform a total lifecycle analysis. It considers the environmental impact of generating the electricity which powers an EV to obtain a more holistic view of the operation of an EV. The Table below shows that EVs which are supplied by coal based power plants provide no environmental benefit when compared with a gasoline engine. However, EVs supplied by non-emitting sources such as hydro provide great environmental benefits.[55]

As a reference, Figure 26 illustrates the equivalent tonnes of carbon dioxide produced for every gigwatt-hour of energy for each generation fuel source.

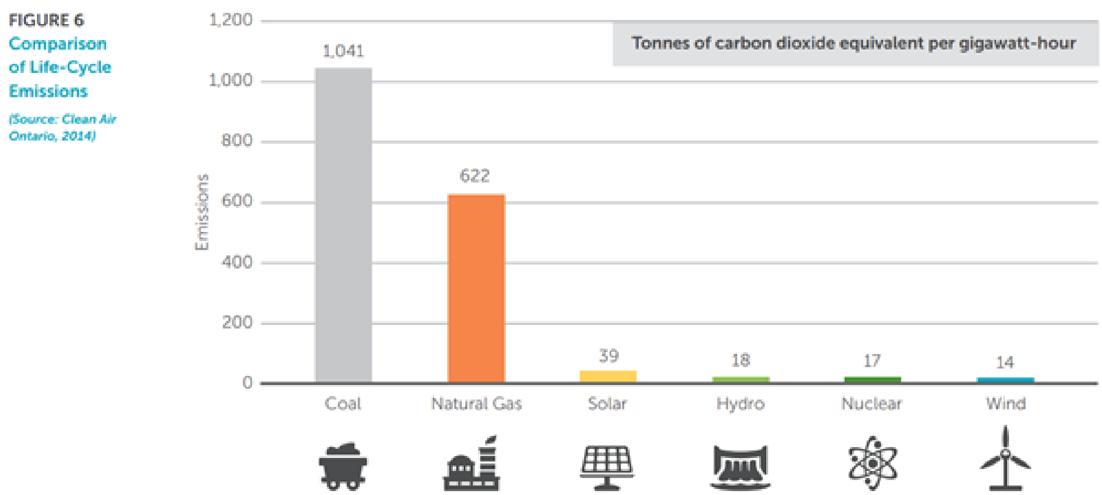

Figure 27 - Equivalent CO2 Emissions for Various Generation Sources

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[55] Cleaner Cars from Cradle to Grave – Rachael Nealer, David Reichmuth, Don Anair
http://www.ucsusa.org/sites/default/files/attach/2015/11/Cleaner-Cars-from-Cradle-to-Grave-full-report.pdf

TABLE 1. **Well-to-Wheels BEV Miles-per-Gallon Equivalent (MPG_{ghg}) by Electricity Source**

Electricity Source[1]	Gasoline Vehicle Emissions Equivalent (MPGghg)[2,3]	% Reduction from Average New 2014 Car[4]
Oil	29	0%
Coal	29	1%
Natural gas	58	51%
Geothermal	310	91%
Solar	350	92%
Nuclear	2,300	99%
Wind	2,500	99%
Hydro	5,100	99%

Notes:

(1) Represents electricity available at the wall outlet and includes emissions from power plant feedstocks (e.g., coal mining) and power plant combustion. Power plant construction emissions are also included; they are the only emissions associated with solar, wind, geothermal, and hydro sources.

(2) Gasoline vehicle emissions equivalents account for oil extraction and refining of crude oil, but not refinery construction.

(3) Average new car (excluding truck) fuel economy for model year 2014 is 28.7 MPG. Sources: EPA 2014; ANL 2014A.

(4) To calculate the MPG_{ghg} estimate, we use the 2014 average sales-weighted efficiency of 0.33 kWh/mile, regarding both plug-in hybrid and battery-electric vehicles (see Table 3, p. 10).

Table 2 – Well-to Wheels BEV Equivalent (MPGghg) by Electricity Source

Based on Ontario's clean sources of electricity it is estimated that EVs could reduce GHG emissions by as much as 66% to 95% when compared to other vehicle types as shown below.[56]

Vehicle Type	Average GHG emissions per 20,000 km driven	Source of GHG emissions
Average Battery Electric Vehicle	233kg	Electricity Generation
Average Plug-in Hybrid Electric Vehicle	1,294kg	Electricity Generation and Gasoline
Average Compact Gas Car	3,948kg	Gasoline
Average Mid-Size Gas Car	4,700kg	Gasoline
Average Full-Size Gas Car	5,029kg	Gasoline

Figure 1 - Average Annual Greenhouse Gas Emissions by Vehicle Type (2015-2050)

Table 3 – Average Annual Greenhouse Gas Emissions by Vehicle Type (2015 - 2050)[56]

3.0 OPERATIONAL ANALYSIS

Understanding how EVs are likely to change the profile of power demand at the neighbourhood level is critical to making informed, strategic and effective investments in technology and infrastructure in order to maintain and improve quality of service. At the same time, it is important for the LDC to clearly understand the impact of EV penetration across the entire electricity distribution system. For example, the Provincial Government has a target of 5% EV sales by 2020. If there was a residential penetration rate of 5% for EVs in London it would represent a potential load of 25 to 47 MW of load. The following section outlines both the process and the key findings of the electricity distribution system assessment, beginning with a discussion of the key variables predicted to have an effect on the capacity of the neighbourhood-level distribution

[56] Electric Vehicles: Reducing Ontario's Green house Gas Emissions – Plug n Drive - https://plugndrive.ca/sites/default/files/Electric%20Vehicle%20-%20Reducing%20Ontario's%20Greenhouse%20Gas%20Emissions%20-%20A%20Plug'n%20Drive%20Research%20Report.pdf

system to support EV-related loads. This is followed by an investigation of the effects of EV charging on the lifespan of a transformer.

3.1 Investigating Key Variables

The first set of scenarios tested the capacity of the electricity distribution system at the neighbourhood level to accommodate the potential loading from EV charging. These scenarios were developed based on the predicted home charging patterns of early adopters of EV technology, three on-board charger capacities and the assumption that ambient temperature can create additional stress for the neighbourhood-level distribution system. While these conditions are not likely to occur simultaneously, this investigation allows for a better understanding of possible worst-case scenarios and key factors that could limit the number of EVs that can be accommodated by the electricity distribution system without having to invest in additional infrastructure. Scenarios were developed and tested based on a number of key variables predicted to have the greatest potential for impacts on the capacity of the system to support EV-related loading.

The variables investigated were

- EV on-board charger capacity
- Transformer loading
- EV penetration rate
- Secondary distribution
- Ambient temperature

The key variables investigated are described in greater detail below.

3.2 Electric Vehicle On-Board Charger Capacity

Most EVs can be charged using a standard 120 V household outlet (Level 1 charging). If a vehicle is charging at Level 1, power flows through the on-board charger at a lower rate than when charging at 240 V (Level 2 charging). For example, the 2017 Nissan

LEAF can charge at 6.6 kW at 240 V, but power flows at 1.2 kW when the vehicle is charging at 120 V.

A number of EVs on the market have an on-board charger rated at 3.6 kW (e.g., the 2017 Chevrolet Volt plug-in hybrid electric) or 6.6 kW (e.g., 2017 Nissan LEAF) when charging at 240 V. Compared to a 3.6 kW charger, a 6.6 kW charger significantly reduces the length of time required to charge the vehicle but it also doubles the demand for power from the electricity distribution system. Even more powerful on-board chargers are also available, such as the 20 kW rated charger on board the Tesla Model S.

Table 4 summarizes the specifications for three popular EV models used as examples of the charger capacities investigated in this section of the report. Looking at a range of charger capacities allows for more in-depth analysis of the extent to which conditions such as ambient temperature or time of charge can affect the capacity of the electricity distribution system to meet the additional demand for EV charging. Market research indicated that charging at Level 1 would likely take longer than the typical early adopter may be willing to wait. At the same time, the load associated with charging an EV at Level 1 would have relatively little effect on the electricity distribution system. As such, Level 1 charging is not investigated in this report.

EV Model	Charging Level	On-board Charger Capacity	Battery Size
2017 Chevy Volt	240 V	3.6 kW	18.4 kWh
2017 Nissan LEAF	240 V	6.6 kW	30 kWh
2017 Tesla Model S	240 V	20 kW	100 kWh

Table 4 – Typical Charger and Battery Specifications for Various Electric Vehicle Models

3.3 Transformer Loading

The degree to which EV charging could contribute to a reduction in the lifespan of a transformer was thoroughly investigated in London Hydro's 2014 EMAP report. In summary, the heating and reduced cooling cycle of the transformer due to EV charging at night, negatively impacts the lifespan of the transformer. However, it did not impact the present expected life span for a transformer in London Hydro's distribution network which is 40 to 50 years.

The demand for electricity is higher in summer months due to air conditioner load. Although not as high as the summer demand, there is a greater demand for power during the winter months as people tend to stay inside longer, with the lights on and furnace fans and heaters running. This means that the electricity distribution system could reach capacity during the summer and winter months at a lower EV penetration rate than it would during the times of the year with less extreme temperatures.

The scenario investigating the effect of ambient temperature is based on transformer load data from the day of the previous summer peak when demand for power was greatest, September 7, 2016. The data represents the worst-case demand scenario for summer (i.e., summer peak) and also the rest of the year. Since the previous year's winter peak was below the summer peak and winter provides the benefit of cooler ambient temperatures on the equipment, the winter transformer loading was excluded from the analysis. The impacts of EV charging on transformers would therefore pose a greater risk during the summer months and was further examined. In the analysis, the peak kilowatt hour data was used from all single-phase residential transformers at the time of the 2016 system peak, on September 7, 2016 between 4pm and 5pm. This timing coincides with the time at which a typical EV owner would come home from work and plug in their EV for charging in the absence of any smart charging control.

To determine the percentage at which each individual transformer was loaded, the transformer's overall load for the summer peak was divided by its rated capacity. For example, a transformer rated at 50 kVA with a load of 25 kVA during the summer peak would be considered to be loaded at 50 percent of the rated capacity.

Each transformer was assigned to one of the following three categories based on its loading percentage:

- **lightly loaded:** less than 50 percent loaded
- **moderately loaded:** between 50 and 100 percent loaded
- **overloaded:** anything above 100 percent loaded

Figure 28 and Figure 29 show the distribution of transformers within the London Hydro service area based on the above three categories for the day with the greatest demand for power in 2016 (i.e., September 7, 2016). Each colored area represents either a transformer or a group of transformers from the same category (e.g., green areas represent a grouping of lightly loaded transformers - Figure 29) within the service area. These figures indicate that for the time period investigated, 98 percent of transformers in the London Hydro service area have available capacity. This means that the majority of transformers on which an EV is likely to be connected (i.e.120/240V residential transformers), there is additional capacity to accommodate new EV loads. However, it should be noted that the period investigated represents each transformer's loading during the overall system peak (kW) and not necessarily the individual transformer's annual peak (kW). The level of EV penetration will be examined in the following section.

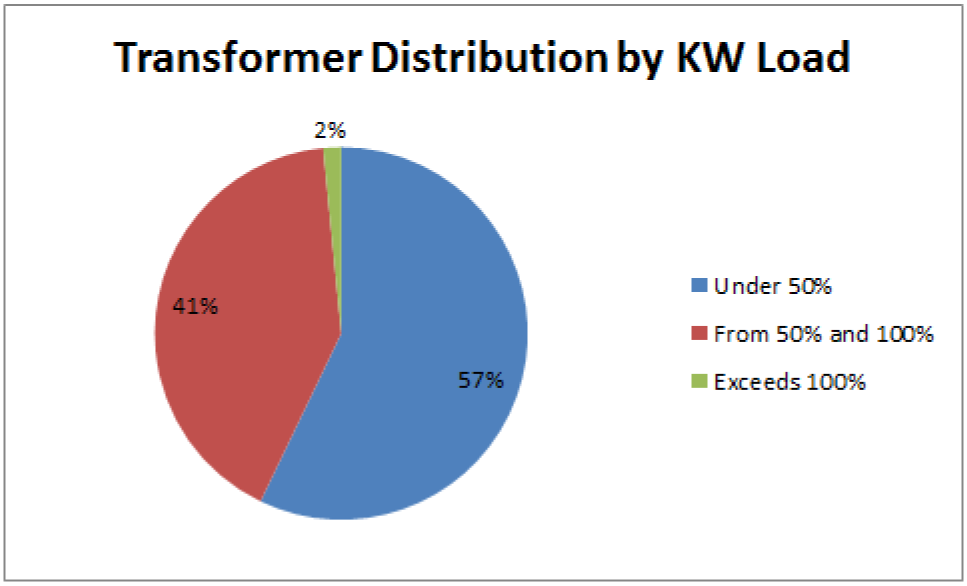

Figure 28 – Transformer Population by Summer Peak Loading (September 7, 2016)

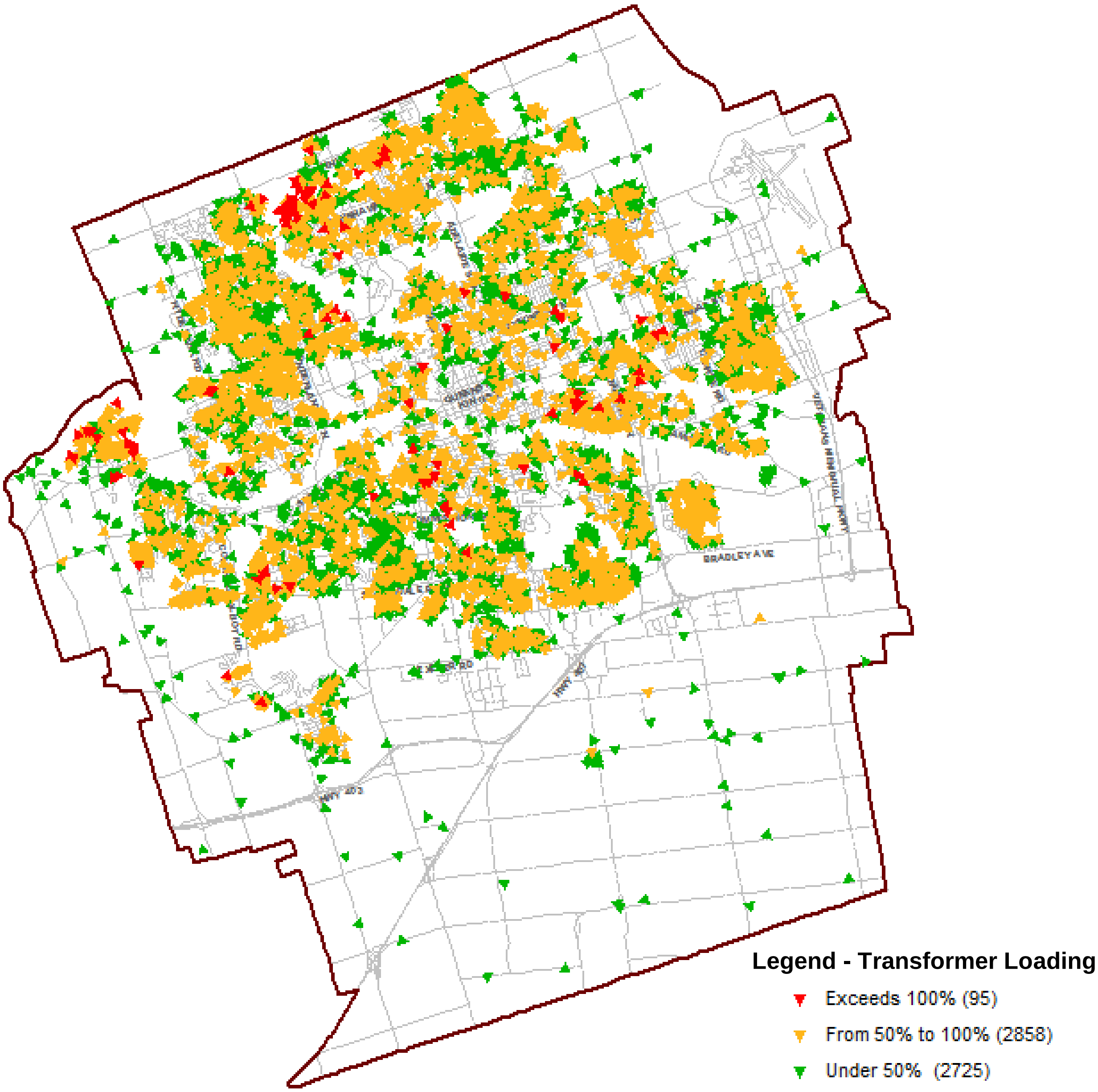

Figure 29 – Transformer Loading on Day with Greatest Demand for Power (September 7, 2016)

3.4 Electric Vehicles Penetration

Three scenarios were investigated based on the capacity of the vehicle's on-board charger (i.e., 3.6 kW, 6.6 kW and 20 kW) to determine the average number of EVs that could be accommodated by transformers across the electricity distribution system. In Figure 28, each of the 9,512 transformers were assigned to one of the three previously described categories (i.e. lightly loaded, moderately loaded or overloaded) based on the percentage of the rated capacity at which they were loaded during the summer peak. Similarly, in Figure 30, the transformers are categorized by summer peak loading and distinguished by whether they are in the overhead or underground orientations.

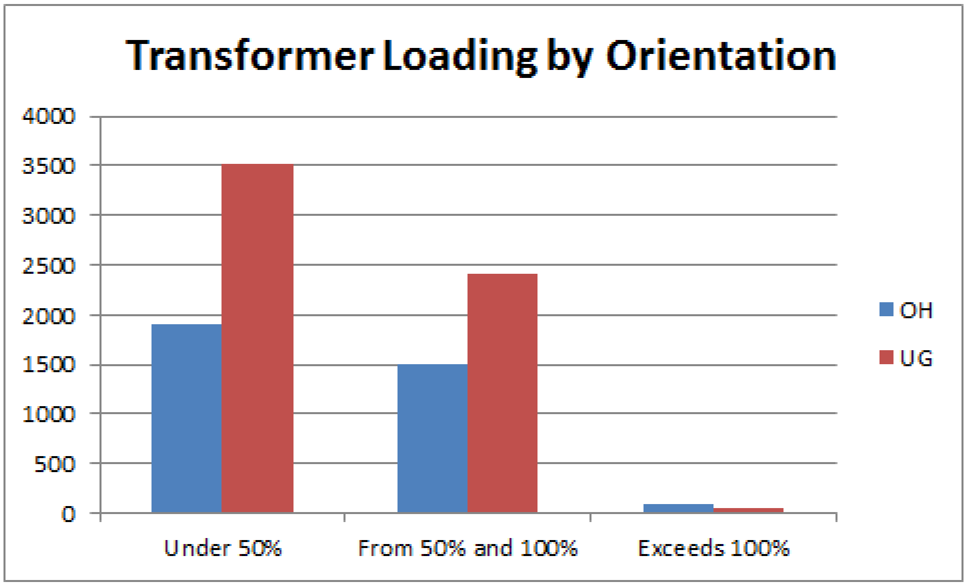

Figure 30 – Overhead vs Underground Transformer by Summer Peak Loading

The key finding here is that the number of underground transformers that are lightly loaded are almost double the number of lightly loaded overhead transformers. This is typically due to the larger number of customers that are connected to overhead transformers. Underground transformers are limited to 16 connections or less due to physical limitations on the transformer bushings. These scenarios investigated all common transformer capacities found within the London Hydro service area including 10 kVA, 25 kVA, 37 kVA, 50 kVA, 75 kVA, 100 kVA and 167 kVA. By plotting the number of transformers from each of these KVA sizes, it is shown in Figure 31Figure that the 50 KVA transformer size is by far the most commonly used transformer in the London Hydro service area. Thus, the 50 kVA transformer population was used to determine the impacts of EV penetration.

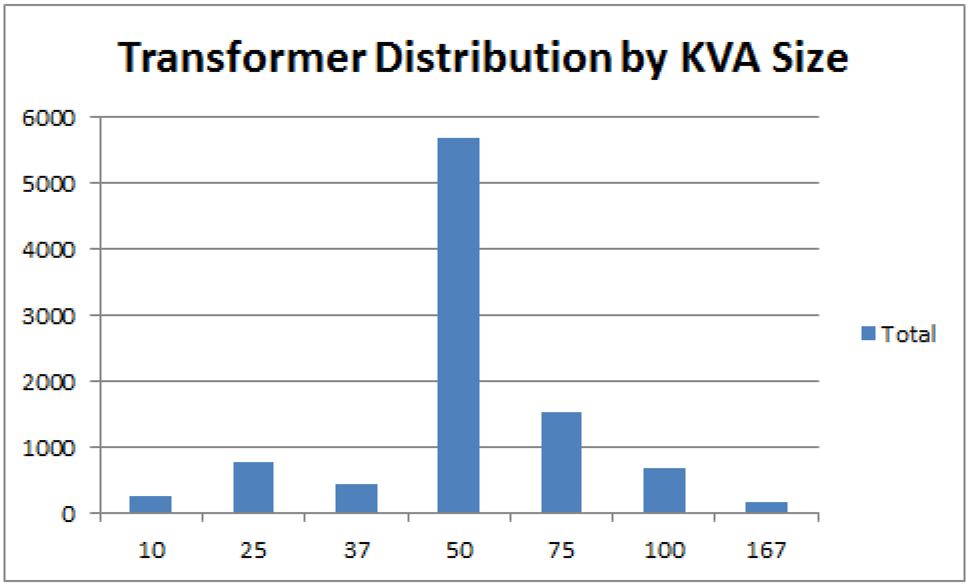

Figure 31 – Most Commonly used Residential Transformers by KVA Size

Table 5 shows the average number of customers connected to a single transformer is 13 with an average per customer load of 2.16 kW, irrespective of transformer size, and 2.2 kW for the most commonly used 50 kVA transformer size. Table 6 shows that the capacity of the vehicle's on-board charger is a key factor in determining the EV penetration rate. For example, the EV penetration rate for vehicles with an on-board charger rated at 20 kW is much lower than for those rated at 3.6 kW during the system peak. The greater the transformer load before EV charging, the fewer EVs that can be accommodated before exceeding its rated capacity. In addition, fewer vehicles can be accommodated on-peak when the demand for power is greatest, than off-peak. It should be noted that the number of EVs is an average and incorporate only 50 kVA transformers across the service area.

Of course, by upgrading the transformer size we can accommodate additional EVs. For example, 16 EVs with a 3.6 kW charger may easily be accommodated by a transformer rated at 75 kVA or greater, depending on its spare capacity. The same number of vehicles on a 25 kVA transformer would cause overloading. Therefore, the size and spare capacity of each transformer should both be taken into consideration when determining the effects of EV charging on the electricity distribution system.

Transformer Size	Avg. Peak Load	Avg. # of Customers (Connected Meters)	Avg. Customer Load
All Sizes (10 to 167 KVA)	28.08 kW	13	2.16 kW
50 KVA	28.65 kW	13	2.20 kW

Table 5 – Average Customer Load across the London Hydro Service Area

To evaluate the average number of EVs that could be accommodated by each 50 kVA transformer before exceeding its rated capacity, the average spare capacity for each of the 5,677 transformers was first determined for the system peak hour. The off-peak scenario is even better for our system (for handling EV penetration) but not considered in the analysis in order to account for a worst-case scenario. Similar to Figure 28, Figure 32 confirms there are only 2% of 50 KVA transformers that are considered overloaded during the 2016 summer peak demand. The average spare capacity of each transformer for these time periods was then divided by the capacity of the EV on-board charger (i.e., 3.6 kW, 6.6 kW or 20 kW) to determine the total number of vehicles that can be accommodated during the system peak hour. Shown in Table 6, these figures were averaged across each loading category (i.e., less than 0.5, between 0.5 and 1.0 and greater than 1.0) to determine the total number of EVs that could charge on average without exceeding the transformer's rated capacity. The EV penetration rate was then calculated as a percentage by taking the average number of EVs that could charge for each transformer and dividing it by the number of customers fed by the same transformer. For example, if the transformer could accommodate five EVs and it provides power to 10 customers, the EV penetration percentage would be 50 percent or one EV for every two households. As a final step, the EV penetration percentage for each of the transformer loading categories was averaged to determine an overall EV penetration rate for each vehicle on-board charger size. From Table 6, the penetration rates for the 3.6 kW, 6.6 kW and 20 kW on-board chargers are 54%, 31%, and 8%

respectively. The assumption here is a 50 kVA transformer size, system peak load demand (worst-case), for transformers with varying degrees of preexisting load.

Further calculations confirm the number of allowable EVs that a 50 kVA transformer can accommodate before overloading translates to an average of 24 kW, or half of the transformer capacity. Combining the average EV load (24 kW) with the average customer house load (28.65 kW from Table 5) results in a total transformer load of 52.65 kW or 105% loading. The loading in this hypothetical scenario is acceptable, however it is crucial to be able to measure real transformer loads and determine excess capacity prior to connecting EV loads. The EV penetration rate depends directly on the transformer size, available capacity, and the size of EV on-board chargers that customers purchase. For the utility, it is difficult to predict which on-board charger a customer will purchase with their new EV however, as the distributor we have the means to monitor/manage transformer loads. By actively monitoring our transformer loading, London Hydro can proactively identify any potential risks of overloading prior to mass EV adoption. For instance, the 95 transformers identified in Table 6, are currently overloaded and do not have excess capacity for new EV loads. It is apparent that the transformer loading and excess capacity is directly dependent on the number of connected customers. The analysis reveals that lightly-loaded transformers have an average of 11 customers, moderately-loaded transformers have an average of 16 customers and overloaded transformers have around 20 customers. Therefore, by limiting the number of customers connected to a transformer to a reasonable count, say 13 customers, the transformer loading can be acceptable and allow excess capacity for future EV loads. Alternatively, transformer loads can be closely monitored and managed through the use of smart charging technology. Active load demand management is an approach that can eliminate the need for system reinforcements (i.e. transformer upgrades) while providing flexibility to the utility in managing EV loads during high demand hours.

The following section will further examine distribution system constraints for adding EV loads.

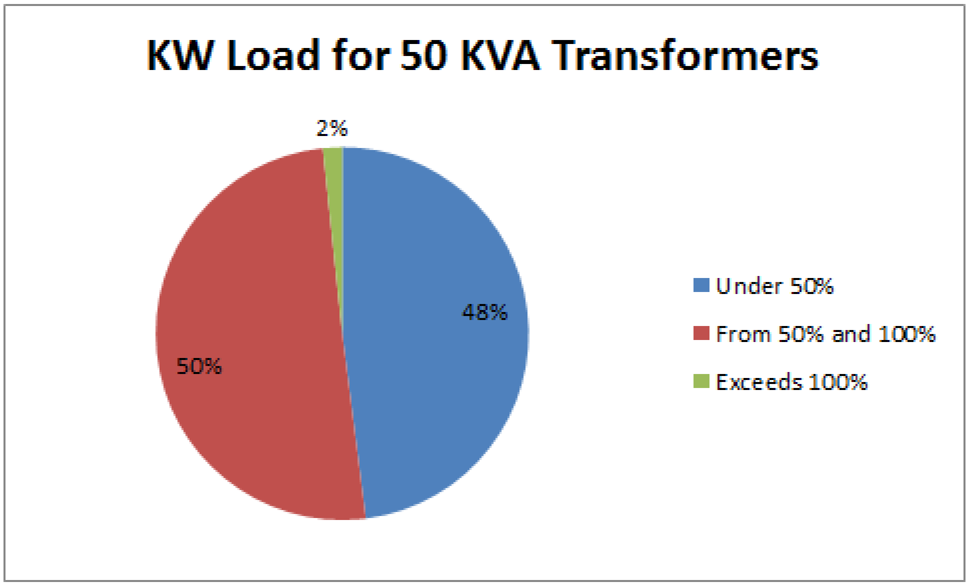

Figure 32 – 50 KVA Transformer Loading on Day with Greatest Demand for Power (September 7, 2016)

50 kVA Transformer Analysis			System-peak Penetration Rate (%)		
Loading Factor	**Tx Count**	**Avg. # of Customers**	**Scenario 1 (3.6 kW)**	**Scenario 2 (6.6 kW)**	**Scenario 3 (20 kW)**
Tx < 0.5	2724	11	9.1 (83%)	5 (46%)	1.6 (15%)
0.5 ≤ Tx < 1	2858	16	4.7 (29%)	2.6 (16%)	0.9 (6%)
Tx ≥ 1	95	20	-	-	-
Average Allowable Number of EVs:			7 (54%)	4 (31%)	1 (8%)
Equivalent Load (kW):			25.2	26.4	20

Table 6 – EV Penetration Across the London Hydro Service Area

3.5 Secondary Distribution

The capacity of the secondary cables to accommodate EV charging without overloading varies based on the current capacity and physical characteristics of the conductor. In the overhead system, the secondary drop lead, secondary bus and service cable most commonly used were investigated as shown in Figure 33. The current construction standard (250 kcmil Al) and the previous #3/0 ASC standard represent the vast majority of installations; as a result, they were used in the secondary analysis. The most common service conductor 1/0 AL, was used in the analysis. The configuration in Figure 33 shows a typical residential overhead bus configuration.

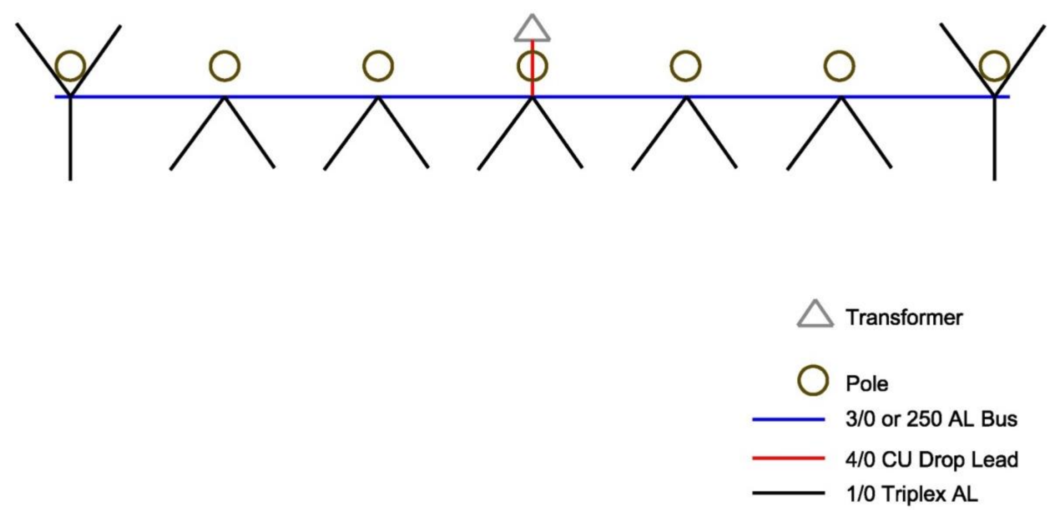

Figure 33 – Typical Overhead Secondary Bus Configuration

Figure 33 shows the overhead configuration that was used to perform the secondary conductor analysis below. Sixteen homes are connected to the overhead bus with two of the services connected directly at the point that the drop lead connects to the bus. The drop lead used is 4/0 CU which is used for 50kVA and 75kVA transformers. These transformer sizes represent the majority of the transformers in London Hydro's service area. For transformers 100kVA and greater, 350 CU is used but the results as it pertains to the analysis below were negligible.

The analysis shown in Table 7 shows what effect the number of EVs connected to the bus system would have on the ampacity rating of 3/0 AL and 250 AL bus. It is important to note that the bus is evenly distributed and hence only eight homes are affected by the voltage drop in one direction as illustrated in Figure 33. Since one house is connected to the same point that the drop lead is connected to, it did not contribute significantly to the current load seen by the bus. Thus, the value 64.4 A was used (7 houses) in Table 7 instead of 73.6A (eight houses). The ampacity values for each conductor have been determined by using Engineering Instruction EI-15-R1: Ampacity of Neutral - Supported Service Cables and Field - Lashed Bus Assemblies.

EV Charger	3/0 AL Ampacity	250 AL Ampacity	House Load (7 houses)	Allowable Number of EVs	
				3/0 AL	250 AL
3.6 kW	261A	331A	64.4A	26	34
6.6 kW	261A	331A	64.4A	14	18
20 kW	261A	331A	64.4A	4	6

Table 7 – Secondary Bus Capacity (Amp)

The analysis shown in Table 8 displays what effect voltage drop will have on the number of EVs that can be connected to an overhead system when using 3/0 AL or 250 AL as the bus conductor. The study takes into account the voltage drop of our standard 4/0 CU drop lead. The 350 CU drop lead used on larger transformers was also studied but the results indicated there was a minimal difference between the two sizes of drop leads. It is assumed the average home would have a peak demand of 2.2kW. The worst-case scenario is considered where EV's are added to the homes at the end of the bus progressing towards the transformer until five percent voltage drop is reached.

EV Charger	Voltage drop 3/0 AL			Voltage drop 250 AL		
	At end pole	At house (30m Span 1/0 AL)	Allowable number of EV's	At end pole	At house (30m Span 1/0 AL)	Allowable number of EV's
3.6 kW	4.31%	4.65%	16	2.94%	3.28%	16
6.6 kW	4.54%	5.00%	6	3.95%	4.47%	10
20 kW	4.52%	5.81%	0	3.06%	4.35%	1

Table 8 - Bus Voltage Drop

The analysis shown in Table 9 looks at an underground subdivision where individual service conductors are installed for each home. Table 8 shows how far service conductors can be run while maintaining a five percent voltage drop. The installation of a charger of any size will not require any change to our underground service cables. Our standard practice for underground subdivisions is to install 1/0 AL up to 95m after which point we transition to 4/0 AL.

Max length of 1/0 AL service conductor with an assumed 2.2kW load and a 5% voltage drop			
EV Charge Size	**3.6 kW**	**6.6 kW**	**20 kW**
	363 m	240 m	95 m
Max length of 3/0 AL service conductor with an assumed 2.2kW load and a 5% voltage drop			
EV Charge Size	**3.6 kW**	**6.6 kW**	**20 kW**
	559 m	367 m	146 m
Max length of 4/0 AL service conductor with an assumed 2.2kW load and a 5% voltage drop			
EV Charge Size	**3.6 kW**	**6.6 kW**	**20 kW**
	648 m	427 m	169m

Table 9 – Maximum Underground Service Length

In summary, the major limiting factor in an overhead subdivision with a bus configuration, as shown in Figure 33, is the use of one 4/0 CU drop lead to supply the bus. In underground subdivisions, it was found that the service conductors did not limit the installation of EV's.

When EV charging becomes more prevalent in overhead subdivisions, as stated above, the ampacity of the drop lead will limit the number of EV's that can be connected to the transformer. Once the maximum ampacity of the drop lead is reached, a simple solution would be to install parallel 4/0 CU drop leads. The second limiting factor in this system is the size of the bus. The industry is moving towards using 6.6kW chargers and as seen in Table 7, the size of the conductor limits the number of EV's that can be connected while maintaining a maximum of five percent voltage drop. The simplest solution would be to install 250 AL bus in neighborhoods with 7-10 EV's and install parallel 250 AL bus in neighborhoods with more than 10 EV's.

The alternative solution to both the limitations mentioned previously would be to introduce smart chargers. This would allow London Hydro to stagger the charging of vehicles at each home as well as to scale back the onboard charging during peak periods or shift the charging of the EV's to off peak hours where demand is lower. Smart chargers offer London Hydro the most flexibility in mitigating the impacts to our grid.

4.0 CONCLUSION

The review of the political influences demonstrates that Ontario is making an unprecedented effort through both policy and financial incentives to promote the use of EVs. The Climate Change Action Plan is the means through which the Government is encouraging EV use to help achieve its environmental goals. Significant government initiatives include: large EV (up to $14,000) and EVSE (up to $1,000) purchase incentives, building code changes to make buildings EV ready, investment in charging infrastructure, lowering electricity rates, offering “free charging at night”, public charger installation incentives (EVCO) and funding for EV education. All of these contribute to increasing EV adoption.

The overall number of EV sales remains small at approximately 1% of all sales but is rising exponentially. Automotive suppliers will be releasing approximately 40 new EV enabled vehicles by 2020, resulting in increased selection. Availability of EVs at dealerships has been a limiting factor on sales. The additional models along with increased availability and increased driving range at a valued price will lead to increased adoption. The government’s goal of having EVs represent 5% of all new sales by 2020 is achievable.

Smart charging capabilities are now available commercially and APIs can be used to develop schemes to avoid charging on peak during high loads and expensive rates.

Other jurisdictions have implemented various initiatives to EV owners. These include rewards/points from utilities for charging off peak, free charging for two years for new EV owners from automotive manufacturers, and various car sharing models.

Another factor hampering EVs sales is the lack of education among the public in Ontario. Many Ontario residents are unaware of the various incentives, environmental benefits, and fuel and maintenance savings.

London Hydro's grid is positioned well to handle EVs loads at moderate penetrations levels. If penetration rates of EVs increase and approach 35% there is the potential to exceed tolerable voltage limits on the overhead low voltage bus systems. There is also a potential to overload transformers where an average of seven or more 3.6 kW chargers or four or more 6.6 kW chargers are supplied from a transformer. In these cases, it is important to monitor transformer loading. The addition of 20 kW charging systems to the residential grid needs to be reviewed by London Hydro's engineering team to identify if system upgrades to the transformer and low voltage bus are needed. It is anticipated that chargers of this size will be rare.

5.0 RECOMMENDATIONS

The next phase of the EVCO program is to be released before the end of 2017. It is supposed to be focused on multi-unit dwellings and workplaces. London Hydro should make contact with large employers in London to increase their awareness of this program (e.g. Western University, Fanshawe College, General Dynamics, Masonville Mall, White Oaks Mall, London Hydro, etc). This also includes large multi-unit dwellings (e.g. Tricar highrises) to determine if there is an interest in the submission of a bid. This will provide London Hydro with valuable experience with these types of installations and user patterns while at the same time educating the owner.

Based on the cost effective nature of new passenger EVs London Hydro should ensure that it purchases EV enabled fleet vehicles where suitable and cost competitive. This will benefit the environment, provide educational value to employees and save money. These vehicles should include some form of green branding as research has shown that the best promoter of an EV is an EV owner.

It has been identified that education is lacking with respect to EVs and their lower overall ownership costs. London Hydro should investigate hosting an open house for automotive dealers and EV owners to educate them on the benefits of TOU charging and smart charger capabilities so that the owner benefits financially and environmentally. It will also help grid performance. London Hydro needs to develop promotional material that educates the customer on how to charge wisely and encourages them to contact London Hydro so that we can learn from them. Our website and Innovation Centre can be enhanced to help achieve the missing education piece.

In order to gain experience with smart charging, London Hydro should conduct a proof of concept to leverage real time data (building on or similar to London Hydro's existing proposal for the Quick Ramp-Critical Peak Pricing pilot) in combination with real-time control of smart chargers through APIs. This could be demonstrated by leveraging our chargers in the employee parking lot. If successful, this would be an extremely effective tool in mitigating the risk of overloading components on our grid.

London Hydro should continue to leverage the Amazon Red Shift smart meter initiative and implement a monthly transformer loading program that identifies all transformers that are overloaded in compliance with the IEEE transformer loading standard. This report will consider relevant variables of load, duration of load and ambient temperature.

London Hydro should levage opportunities to influence electrical rate design with the Ministry and the OEB for EV charging. By having a significant differential between on-peak and off-peak rates it is possible to influence when EV owners charge their vehicles and thereby reduce their impact on the grid.

London Hydro should continue to support the option of LDC ownership of EV charging equipment and inclusion of this equipment in its rate base. LDC ownership of EV charging equipment will allow the LDC to make a positive contribution towards the implementation of EVs. LDCs will have more information on where the chargers are located and knowledge on how to minimize any possible negative impacts on the grid through smart technologies.

The next report on EVs will look at ways in which London Hydro can participate in the EV market space from a business perspective.

APPENDIX A – EVS AVAILABLE IN CANADA

	Make	Model	Electric Range (Km)	Total Range (Km)	Category	Charge time in hours (level 2)	Level	Battery (kWh)	Max Charging Rate (kWh)	Cost	Incentive	DCQC
Electric Range Under 200 Km	Audi	A3 Sportback e-tron	26	665	PHEV	2.5	2	8.8	3.3	$39,200	$8,095	NO
	BMW	330e	22	358	PHEV	2	2	7.6	3.7	$52,100	$7,730	NO
	BMW	740 Le XDrive	22	524	PHEV	3	2	9.2	7.2	$107,900	$3,000	NO
	BMW	i3 (REX)	183	250	BEV	4.5	2 & 3	33	7.4	$47,300	$13,000	SAE Combo (S)
	BMW	i8	24	509	PHEV	2	2	9	3.3	$150,000	$3,000	NO
	BMW	X5 xDrive40e	28	695	PHEV	2.5	2	9	3.5	$74,000	$8,460	NO
	Cheverlot	Volt	85	675	PHEV	4.5	2	18.4	3.6	$39,590	$14,000	NO
	Chrysler	Pacific	53	864	PHEV	3.5	2	16.7	6.6	$56,495	$14,000	NO
	Ford	C-Max Energi	32	856	PHEV	2.5	2	7.6	3.3	$39,729	$7,730	NO
	Ford	Focus Electric	185	185	PHEV	5.5	2	33.5	6.6	$31,998	$14,000	SAE CCS
	Ford	Fusion Energi	34	884	PHEV	2.5	2	7.6	3.3	$36,399	$7,730	NO
	Hyundai	Sonata	43	925	PHEV	3	2	9.8	3.3	$43,999	$8,460	NO
	Kia	Optima	47	982	PHEV	3	2	9.8	3.3	$42,995	$8,460	NO
	Kia	Soul	149	149	BEV	5	2 & 3	27	6.6	$35,395	$14,000	CHAdeMO (S)
	Mercedes-Bens	GLE 550e	30	850	PHEV	3	2	8.8	3.3	$83,000	$3,000	NO
	Mercedes-Bens	S 550e	22	724	PHEV	2.5	2	8.7	3.3	$102,600	$3,000	NO
	Hyundai	IONIQ	170	170	BEV	4.5	2 & 3	28	6.6	$35,649	$14,000	SAE Combo
	Mitsubishi	i-MiEV	100	100	PHEV	5	2 & 3	16	3.3	$27,998	$10,000	CHAdeMO (S)
	Nissan	LEAF	172	172	BEV	4.5	2 & 3	30	3.3 or 6.6	$37,398	$14,000	CHAdeMO (O)
	Porsche	Cayenne S E	22	772	PHEV	1.5	2	10.8	3.6 or 7.2	$89,400	$3,000	NO
	Porsche	Panamera S E	25	850	PHEV	3	2	9.4	3	$106,600	$3,000	NO
	Volvo	XC90 T8 Twin Engine	22	563	PHEV	2.5	2	9.2	3.3	$73,400	$3,000	NO
	Volkswagen	e-golf	201	201	BEV	5	2 & 3	35.8	7.2	$35,995	$14,000	CCS
Electric Range Over 200 Km	Cheverlot	Bolt	383	383	BEV	9.5	2 & 3	60	3.6	$42,895	$14,000	CCS
	Tesla	Model S	435	435	BEV	9	2 & 3	60	10 or 20	$95,300	$14,000	Supercharger (O)
	Tesla	Model X	413	413	BEV	11	2 & 3	75	10 or 20	$132,000	$14,000	Supercharger (S)

APPENDIX B – EV CHARGERS AVAILABLE IN CANADA

EVSE Manufacturer	EVSE Family Name	Eligible EVSE Model	Levels	Voltage & Breaker Current	Peak Current	Data Tracking*	Description of Functionalities		
							Load Management	Communication Method	Interface
AddEnergie	NA	Curbside Charger	Level 2	208/240 VAC; 40A	30 A	Yes	Yes	3G Cellular and Zigbee	SAE J-1772
AddEnergie	NA	SmartTWO	Level 2	208/240VAC; 40A	30A	Yes	Yes	LAN - ZigBee; WAN - 3G	SAE J-1772
AddEnergie	NA	Core+	Level 2	208/240VAC; 40A	30A	Yes	Yes	LAN - ZigBee; WAN - 3G	SAE J-1772
AddEnergie	NA	Smart DC	Level 3	408V	80 A	Yes	Yes	Zigbee, 3G	CHAdeMO and SAE J1772
FLO	NA	G5	Level 2	208/240 V; 30A	Unavailable	Unavailable	Unavailable	Unavailable	SAE J-1772
FLO	NA	X5	Level 2	208/240 V; 30A	Unavailable	Yes	Unavailable	Unavailable	SAE J-1772
AeroVironment	NA	Turbodock	Level 2	240 VAC	16 A	No	None	LAN - Bluetooth	SAE J-1772
AeroVironment	NA	TurboCord	Level 2	208/240VAC; 20A for L2 & 120V; 12A for L1	16A	No	None	None	Unavailable
AeroVironment	NA	EVSE-RS	Level 2	208/240VAC; 40A	30A	No	None	None	Unavailable

EVSE Manufacturer	EVSE Family Name	Eligible EVSE Model	Levels	Voltage & Breaker Current	Peak Current	Data Tracking*	Description of Functionalities		
							Load Management	Communication Method	Interface
ChargePoint	**CT600**	CT600	Level 2	208/240VAC; 40A	32A	Yes	No	LAN - ZigBee; WAN - 3G	SAE J-1772
	CT4000 Family	CT4011	Level 2	208/240VAC; 40A	32A	Yes	Yes	LAN - ZigBee; WAN - 3G	SAE J-1772
		CT4021	Level 2	208/240VAC; 40Ax2	32A	Yes	Yes	LAN - ZigBee; WAN - 3G	SAE J-1772
		CT4013	Level 2	208/240VAC; 40A	32A	Yes	Yes	LAN - ZigBee; WAN - 3G	SAE J-1772
		CT4023	Level 2	208/240VAC; 40Ax3	32A	Yes	Yes	LAN - ZigBee; WAN - 3G	SAE J-1772
		CT4025	Level 2	208/240VAC; 40Ax2	32A	Yes	Yes	LAN - ZigBee; WAN - 3G	SAE J-1772
		CT4027	Level 2	208/240VAC; 40Ax2	32A	Yes	Yes	LAN - ZigBee; WAN - 3G	SAE J-1772
	Chargepoint Express	CPE100	Level 3	480 VAC	62 A	Unavailable	Unavailable	3G GSM, 3G CDMA	Choose between CHADeMO or SAE J-1772
		CPE200	Level 3	480 VAC	125A	Unavailable	Unavailable	3G GSm, 3G CDMA	CHAdeMO, CSS1 (SAE J-1772 Combo)
		CPE250	Level 3	380/480 VAC	156 A	Unavailable	Yes	3G GSm, 3G CCDMA and LTE	CHAdeMO, CSS1 (SAE J-1772 Combo), CCS2
	Express Plus	NA	Level 3	380/480 VAC	1250 A	Yes	Yes	3G GSm, 3G CDMA and LTE, LAN-2.4 and 5 GHz wifi	CHAdeMO, CSS1 (SAE J-1772 Combo), CCS2,GB/T

EVSE Manufacturer	EVSE Family Name	Eligible EVSE Model	Levels	Voltage & Breaker Current	Peak Current	Data Tracking*	Description of Functionalities		
							Load Management	Communication Method	Interface
Elmec	NA	EVC30T-2530-00000	Level 2	208/240VAC; 30A	30 A	No	No	None	SAE J-1772
		EVC30T-2530-00001	Level 2	208/240VAC; 30A	30A	No	No	None	SAE J-1772
		EVC30T-04	Level 2	208/240VAC; 40A	30A	No	No	None	SAE J-1772
		EVC30T-05	Level 2	208/240VAC; 40A	30A	No	No	None	SAE J-1772
eMotorWerks	NA	JuiceBox 40	Level 2	100/250 VAC; 40A	Unavailable	Yes	Unavailable	Unavailable	SAE J-1772
		JuiceBox Pro 40	Level 2	100/250 VAC; 40A	Unavailable	Yes	Unavailable	Unavailable	SAE J-1772
Leviton	NA	EVR40-B25	Level 2	208/240 VAC; 50A	40A	Unavailable	Unavailable	Unavailable	SAE J-1772
		EVB32-H18	Level 2	208/240VAC; 50A	40A	No	No	None	SAE J-1772
		EVB32-H25	Level 2	208/240VAC; 50A	40A	No	No	None	SAE J-1772
		Evr-Green 4000	Level 2	208/240VAC; 40A	30A each	No	Yes	LAN - Wi-Fi; WAN - Cellular	SAE J-1772
		EVR30-B18	Level 2	208/240 VAC; 40A	30 A	Unavailable	Unavailable	Unavailable	SAE J-1772

EVSE Manufacturer	EVSE Family Name	Eligible EVSE Model	Levels	Voltage & Breaker Current	Peak Current	Data Tracking*	Description of Functionalities		
							Load Management	Communication Method	Interface
GE	WattStation	EVWSWBC-CP01	Level 2	208/240VAC; 40A	30A	No	None	None	SAE J-1772
GE	WattStation	EVWSWBH-CP03	Level 2	208/240VAC; 40A	30A	No	None	None	SAE J-1772
GE	WattStation	EVWWR38WXCGB	Level 2	208/240VAC; 40A	30A	(Optional)	None	CAT5 and Wifi	SAE J-1772
GE	WattStation	EVWWR38ZXCGB	Level 2	208/240VAC; 40A	30A	(Optional)	None	Cellular	SAE J-1772
GE	WattStation	EVWPR3GEXXGB	Level 2	208/240VAC; 40A	30A	(Optional)	None	CAT5	SAE J-1772
GE	WattStation	EVWPR3GWXXGB	Level 2	208/240VAC; 40A	30A	(Optional)	None	Wifi	SAE J-1772
GE	WattStation	EVWPR3GZXXGB	Level 2	208/240VAC; 40A	30A	(Optional)	None	Cellular	SAE J-1772
GE	DuraStation	EVDSWGH-CP01	Level 2	208/240VAC; 40A	30A	No	None	None	SAE J-1772
GE	DuraStation	EVPN3	Level 2	208/240VAC; 40A	30A	No	None	None	SAE J-1772
GE	DuraStation	EVWN3	Level 2	208/240VAC; 40A	30A	No	None	None	SAE J-1772
GE	DuraStation	EVSN3	Level 2	208/240VAC; 40A	30A	No	None	None	SAE J-1772
GE	DuraStation	EVDN3	Level 2	208/240VAC; 40A	30A	No	None	None	SAE J-1772
GE	DuraStation	EVDPR3GEXXGB	Level 2	208/240VAC; 40A	30A	(Optional)	None	CAT5	SAE J-1772
GE	DuraStation	EVDPR3GWXXGB	Level 2	208/240VAC; 40A	30A	(Optional)	None	Wifi	SAE J-1772
GE	DuraStation	EVDPR3GZXXGB	Level 2	208/240VAC; 40A	30A	(Optional)	None	Cellular	SAE J-1772

EVSE Manufacturer	EVSE Family Name	Eligible EVSE Model	Levels	Voltage & Breaker Current	Peak Current	Data Tracking*	Description of Functionalities		
							Load Management	Communication Method	Interface
Schneider		EV230WS	Level 2	208/240VAC; 40A	30A	No	None	None	SAE J-1772
		EV230WSR	Level 2	208/240VAC; 40A	30A	No	None	None	SAE J-1772
		EV230WSRR	Level 2	208/240VAC; 40A	30A	Yes	None	None	SAE J-1772
		EV230PSR	Level 2	208/240VAC; 40A	30A	No	None	None	SAE J-1772
		EV230PDR	Level 2	208/240VAC; 40A	30A	No	None	None	SAE J-1772
		EV230PSRR	Level 2	208/240VAC; 40A	30A	No	None	None	SAE J-1772
		EV230PDRR	Level 2	208/240VAC; 40A	30A	Yes	None	None	SAE J-1772
		EV230PSRACNG	Level 2	208/240VAC; 40A	30A	No	None	ZigBee	SAE J-1772
		EV230PDRACNG	Level 2	208/240VAC; 40A	30A	No	None	ZigBee	SAE J-1772
		EV230PSRACGC	Level 2	208/240VAC; 40A	30A	Unavailable	Unavailable	ZigBee, WI-FI, Cellular	SAE J-1772
		EV230PDRACGC	Level 2	208/240VAC; 40A	30A	Unavailable	Unavailable	ZigBee, Wi-FI, Cellular	SAE J-1772
		EV230WDRACNG	Level 2	208/240VAC; 40A	30A	No	No	ZigBee, WI-Fi	SAE J-1772
		EV230WDRACGC	Level 2	208/240VAC; 40A	30A	Unavailable	Unavailable	ZigBee, Wi-Fi, Cellular	SAE J-1772
SemaConnect	ChargePro 620	ChargePro	Level 2	208/240VAC; 40A	30A	Yes	Yes, not released to everyone	WAN - CDMA or GPRS cellular, Wi-Fi	SAE J-1772
Siemens	VersiCharge	VC30XXXU	Level 2	208/240VAC; 40A	30A	Yes	No	Zigbee, Wi-Fi, Cellular	SAE J-1772
		VC30XXXHW	Level 2	208/240VAC; 40A	30A	Yes	No	Zigbee, Wi-Fi, Cellular	SAE J-1772

EVSE Manufacturer	EVSE Family Name	Eligible EVSE Model	Levels	Voltage & Breaker Current	Peak Current	Data Tracking*	Description of Functionalities		
							Load Management	Communication Method	Interface
Sun Country Highway (Clipper Creek)	NA	SCH25	Level 2	208/240VAC; 25A	20A	Yes-must be installed with revenue grade meter or Hydro Smart Meter	No	Unavailable	SAE J-1772
		SCH25P	Level 2	208/240VAC; 25A	20A		No	Unavailable	SAE J-1772
		SCH40	Level 2	208/240VAC; 40A	32A		Yes	Unavailable	SAE J-1772
		SCH60	Level 2	208/240VAC; 60A	48A		Yes	Unavailable	SAE J-1772
		SCH100	Level 2	208/240VAC; 100A	80A		Yes	Unavailable	SAE J-1772
		EV40	Level 2	208/240VAC; 40A	32A		No	Unavailable	SAE J-1772
		EV40 All-in-One	Level 2	208/240VAC; 40A	32A		No	Unavailable	SAE J-1772
		EV40P	Level 2	208/240VAC; 40A	32A		No	Unavailable	SAE J-1772
		EV60	Level 2	208/240VAC; 60A	32A		No	Unavailable	SAE J-1772
Tesla	NA	HPWC	Level 2	208V VAC wye 240 VAC delta ; 100A	80 A	Unavailable	Unavailable	Unavailable	Unavailable