Durham Strategic Energy Alliance
Electric Vehicle Charging Station Demonstration Project

FINAL REPORT

Sponsored By:

LDC Tomorrow Fund
&
Ontario Power Generation

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ACKNOWLEDGEMENTS

Project Sponsors:	**Project Contributors:**
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EXECUTIVE SUMMARY

Durham Strategic Energy Alliance (DSEA) is pleased to submit this report on EV Charging Station Demonstration Project to the LDC Tomorrow Fund. This report provides an impact assessment of EV charging on the electrical grid.

This project brought together numerous subject matter experts of the DSEA for the purposes of this project. The project group membership was comprised of local businesses, government and academia located within the Durham Region.

The integration of Electric Vehicles (EV) into the grid poses challenges as well as offers potential benefits to utilities. By incorporating EV technology into the portfolio of energy management, utilities can participate in the reduction of dependence on fossil fuels for vehicles and facilitate the transition to a more sustainable energy future.

This project study facilitated development of a business model related to commercialization of EV charging stations which is of particular interest to the project partners.

After considering the technical requirements for an EV charging station, the project team selected the Siemens Community Multi-Level EV Charging Station. This charger was selected because it was the only charger on the market at the time which was CSA approved. However other EV chargers are currently available in the market and could have been used for this study.

The following six pilot locations were identified within the Durham Region for the purposes of installation and testing of EV Charging Stations on the present grid arrangement.

1. Durham College, Whitby Campus - 1610 Champlain Avenue, Whitby
2. UOIT – ACE Building – 2000 Simcoe St. North, Oshawa
3. Oshawa PUC Networks Inc. – 100 Simcoe St. South, Oshawa
4. Veridian Connections Inc – 55 Taunton Road, Ajax
5. Ontario Power Generation – 1675 Montgomery Park Road, Pickering
6. Whitby Hydro -100 Taunton Road East, Whitby

The network connectivity of charging stations was achieved utilizing the ChargePoint® network service provider, which is a public cellular service and includes charging station locations, trip mapping and billing information.
The EV Charging stations were installed in accordance with ESA guideline as required by Ontario's Electrical Safety Code.

From the Siemens charger specifications, the level 1 charge is 2 kW and the level 2 charge is 7.2 kW. For planning purposes, a typical gas heated residential home

represents a load of 4 kW, therefore, the level 1 EV load is equivalent to ½ of a full home load and a level 2 EV load is equivalent to almost 2 full homes. So adding EV charging may overload existing transformers. Those areas with higher concentrations of EV charging stations may be particularly at risk.

When looking at the provincial demand curve, it is clearly seen that peaks occur between 10:00 AM and 9:00 PM. It is expected that most drivers will return home and plug-in between 4-8 PM, resulting in an increase to the afternoon peak. If charging habits could be modified so that charging for homeowners commenced after 9:00 PM the effect would be to "fill" in the valleys, the result would be an improved provincial Load Factor (LF) which implies better utilization of the power system.

Many of the participants in this pilot demonstration utilized fleet vehicles for EV loads; in particular, the Chevy Volt is one vehicle that has been used. The following is a partial listing of various manufacturers' rechargeable energy storage systems:

Vehicle:	**Battery Type:**	**Rating (kWh):**
Chevy Volt	Lithium-ion	16
Nissan Leaf	Lithium-ion	24
Mitsubishi iMiEV	Lithium-ion	16
Toyota Prius	Lithium-ion	4.4

Table A: Battery Operated Vehicles in the Market

One of the barriers to EV market penetration is capital cost. Offsetting this barrier is the cost savings in fuel/energy required to operate the EV. The table below is a summary comparison between Battery Operated and Gas-engine cars.

Battery Operated:	**Gasoline:**
No tail pipe emissions	Greenhouse gases/pollution
100 km range +/-	500 km range +/-
Hours to recharge	Minutes to refuel
\$0.027 / km @ \$0.10/kWh	\$0.075 / km @ \$1.25/l and 6 l/100km

Table B: Battery Operated Versus Gas Engine Car

To study the impact of a single charging station on the grid, a generic EMTP simulation model was developed. Since specific details of the charging station were not available, the scope of this model was limited. However, useful information from this model is available with regards to harmonics generated from the charging station. Future work on the model with regards to multiple charging stations and their impact on the grid will be useful if system data from utilities and charging station manufacturers is forthcoming.

There are several different billing options available from pricing by time, session, or by kWh.   In addition, by combining pricing with custom access control, pricing can vary for preferred employees, customers or residents and take advantage of Time of Use (TOU) energy prices by varying station pricing by time of day. Cities, parking operators, retail stores and workplaces will have a choice of billing options.

Charging at home, off peak likely appeals to majority of private vehicle users from a cost standpoint and supports the off peak rationale which is desirable for distribution utilities and generators.

The business case for public charging would appear less desirable due to cost, and the potential to aggravate peak demand. A series of variables could either promote or discourage adoption of Electric Vehicles. Such factors include; if the price of electricity rises substantially or EV rebates are eliminated the adoption could adversely affected, if the price of fuel rises substantially, or further incentives or carbon taxes are introduced the adoption may be favoured.

The Electric Vehicle Charging Station Demonstration Project is a stepping stone for further studies on:

1. Effects that charging EVs will have on residential transformer loading.
2. Effects that charging EVs will have on electric system voltage and current balance.
3. EVs as a means of energy storage and their impact on the grid.

DSEA and it’s members are committed to supporting commercialization of EV charging stations and smart grid related studies.

REVISION HISTORY

REV. NO	ISSUE DATE	DESCRIPTION OF REVISION
00	2012-06-28	Draft Issue for LDC Tomorrow Fund
01	2012-07-30	Final Issue for LDC Tomorrow Fund

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Appendices

1.0 INTRODUCTION

1.1 BACKGROUND – EV CHARGING AND THE SMART GRID

Effective management of electrical energy resources can be achieved through the adoption of smart grid technologies**.** The integration of Electric Vehicles (EV) into the grid poses challenges as well as offers potential benefits to utilities ability to provide reliable power to its customers.

Plug-in electric vehicles unleash a world of possibilities by:

- Reducing our fossil fuel dependency
- Lowering our dependence on foreign oil
- Cutting greenhouse gas emissions
- Presenting business opportunities

Challenges lie in the development of the robustness of the present grid system and educating the consumers of EV products on appropriate charging times. Incorporating smart grid technology would allow for monitoring of charging activities and provide ‘real time’ data to utilities.

The current Durham Region LDC distribution infrastructure is capable of handling a significant uptake of EVs. To affect the local grid, there would have to be a very large and concentrated penetration of EVs charging during peak hours. The existing distribution transformer loading is such that 50% of the households on a given transformer would have to charge their EVs simultaneously during peak hours in order to cause a rating issue. In general, this degree of uptake is not envisioned for quite some time. Localized concentrations are conceivable, and would need to be managed on a case by case basis.

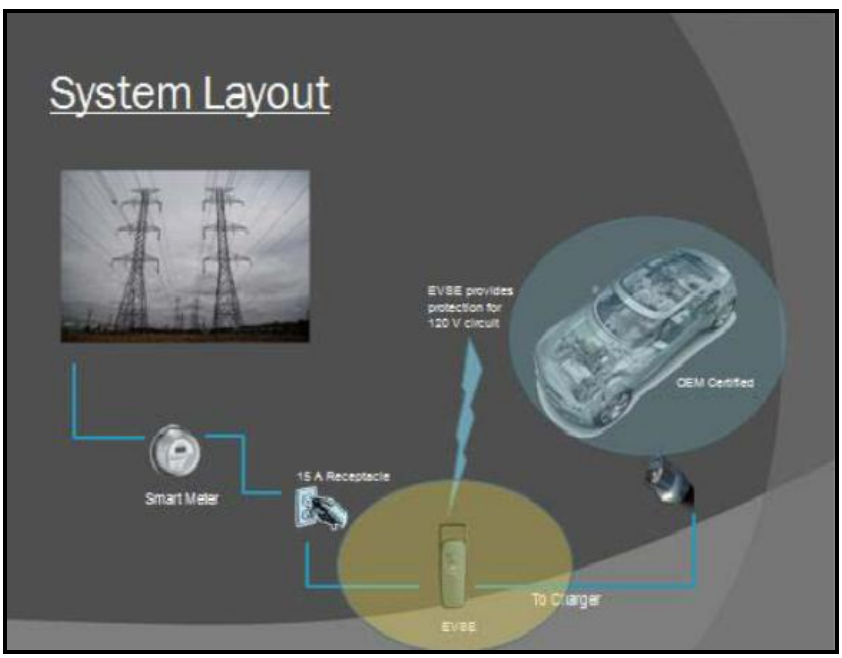
On a provincial basis, it is not likely that EVs will overload the existing grid infrastructure since it is expected that the majority of charging will likely occur in the evening during off peak hours. For example, if 100,000 EVs at 16 kWh each were quick charged (Level 2) the resulting 400MW would represent only 1.5% of the provincial summer all time peak of 27,005 MW (Aug 1, 2008).

By incorporating EV technology into the portfolio of energy management, utilities can participate in the reduction of dependence on fossil fuels for vehicles and facilitate the transition to a more sustainable energy future. The effective management of charging times, either by smart gird or voluntary individual behaviours, has the potential to fill 'valleys' in daily electricity demand.

Currently during off peak hours there is a surplus of base load generation. Charging during these hours takes advantage of low emission hydroelectric and nuclear power generation which are virtually free of emissions and therefore not contributing to climate change.

- With real-time pricing and increased knowledge, consumers can make better decisions about when to use energy, especially when charging plug-in vehicles. In fact, they will be motivated to charge up their vehicles when electricity prices are cheaper, during off-peak hours.
- Smart grid technologies could help automatically take care of the recharge process once the consumer preferences have been set, much like a computer automatically runs back-ups and retrieves your e-mail messages.
- With the right infrastructure in place, smart-grid technologies will help ensure that the right vehicle account is billed for vehicle charging, much like cell phone users are appropriately billed even while roaming out of their own service network.

Figure 1: System Layout for Electric Vehicle Charging



1.2 Project Overview

This pilot project installed EV charging stations within the Durham Region to assess the impact of EV charging on the electrical grid and to determine the future power consumption and storage requirements of the region with respect to EV.

Multiple benefits are potentially realized by various stakeholder groups, with the most significant advantages being in the form of short-term and long-term employment opportunities as well as providing local economic stimulus for the region. The project also positioned Durham Region as a leader in the development of smart grid technologies, as well as a responsible community initiative towards developing renewable, and sustainable energy resources.

The development of business cases to evaluate the viability of commercializing associated technologies is of particular interest to the project partners. The information gathered will allow project partners and future participants the ability to organize operational plans to coincide with the development and implementation of smart grid technologies and EV charging stations.

1.3 Project Partners

The Durham Strategic Energy Alliance (DSEA), supported by the Local Electrical Distribution Companies (LDC) Tomorrow Fund and Ontario Power Generation (OPG), in partnership with Whitby Hydro, The Town of Whitby, Veridian Connections, Tetra Tech, Intellimeter Canada, WireIE, eCamion, Durham College, University of Ontario Institute of Technology (UOIT), Oshawa PUC and Siemens Canada, installed six EV charging stations in Durham Region to study the impact EV charging will have on the electrical grid.

The DSEA is a not-for-profit organization headquartered in Durham Region (Ontario's Energy Capital) comprising of business, government and education institutions working together for the advancement of energy initiatives. The DSEA is funded primarily through the Ontario Ministry of Economic Development and Innovation, Ontario Centers of Excellence, the Region of Durham, and DSEA membership fees.

The EV Charging Station Demonstration Project brought together several members of the DSEA and other partners to evaluate EV Charging Stations and their impact on the grid.

1.4 PROJECT SPONSORS

The two main project sponsors are LDC Tomorrow Fund and Ontario Power Generation (OPG).

The LDC Tomorrow Fund's main purpose is to fund research projects and finance energy innovation and opportunities for LDC's in Ontario.

Ontario Power Generation (OPG) is the largest utility in Ontario producing 60% of province's electricity. As a leader in electricity generation, OPG is proud of their commitment to encourage and support community partners especially in field of research and innovation.

The other project partners provided in-kind support such as equipment (i.e. electric vehicles, batteries i.e.), facilities, and organization employees time towards the EV Charging Station Demonstration Project.

2.0 CHARGING STATION DETAILS

The Project Team considered the technical requirements for an EV charging station for the Durham Region and selected the Siemens Community Multi-Level EV Charging Station. This charger was selected because it was the only charger on the market at the time which was CSA approved.

2.1 PRODUCT CAPABILITIES

Siemens' portfolio of EV charging stations offers municipalities, corporations, fleets and utilities the high-reliability, plug-in EV charging that drivers prefer. The easy-to-use stations provide multiple power options, integrating aesthetics and ergonomics with sturdy construction – ideal for residential, commercial and outdoor public applications.

The community multi-level charging stations (as used in the DSEA Project) are dual output stations designed for public outdoor applications for the North American marketplace. The 7.2-kW output delivers Level II (208/240V @ 30 A) charging via a standard SAE J1772™ connector and fixed 18-foot cable. The 2-kW output delivers Level I (120 V @ 16A) charging via a standard NEMA 5-20 receptacle protected behind a locking door. Both outputs can deliver energy simultaneously.

To eliminate energy theft and to enhance safety, users access and energize the station with a network card, such as Charge Pass™, or contactless credit card. The station's highly visible display guides users with instructive messages and can be used to display custom advertisement or greetings. Access and network features can be modified to suit user specific application needs.

2.1.1 NETWORK ENABLED

The EV chargers can be equipped with connectivity via network service providers, such as ChargePoint®, which includes 24/7 driver assistance, station location, station availability, trip mapping, driver billing and driver notification services. The devices are compatible with remote management, billing, maintenance and other on-demand software applications.

2.1.2 SMART CARD READER

The chargers feature an integrated standards-based Radio-Frequency Identification (RFID) reader that accepts network cards or contactless credit cards. This feature provides optional user billing and custom access control, preventing electricity theft and enhancing safety.

2.1.3 INTELLIGENT POWER CONTROL

Secure access control ensures power is delivered only when a user is authorized and the EV connector is properly inserted.

2.1.4 LOCKING DOOR

The locking door mechanism protects the power insertion point and retains the EV Charging cord to prevent theft during charging.

2.1.5 VACUUM FLUORESCENT DISPLAY WITH MULTIPLE LANGUAGE SUPPORT

A bright, easy-to-read display is used for instructive, advertisement and greeting messages in many languages.

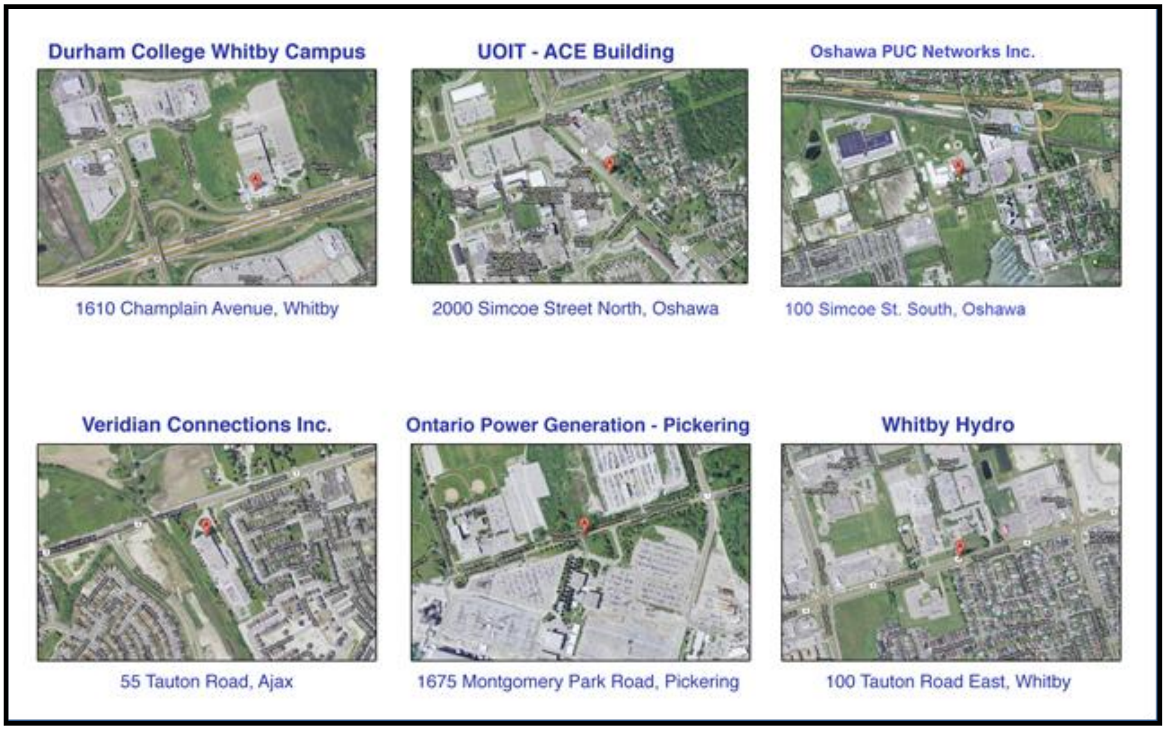
2.1.6 INTEGRATED FEATURES

- Ground fault detection: Integrated ground-fault detection circuitry with auto retry and driver notification is standard.
- Over-current detection: The charger disconnects power to prevent nuisance breaker trips at the service panel. Auto retry and driver notifications are automated.
- Plug-out detection: An algorithm disengages power and notifies the driver when a plug is removed.
- Charging status detection: An algorithm detects complete and incomplete EV charge and notifies the driver.

2.2 LOCATIONS

The following six pilot locations were identified within the Durham Region for the purposes of installation and testing of EV charging stations on the present grid arrangement.

Figure 2: Location for EV Charging Station Installation



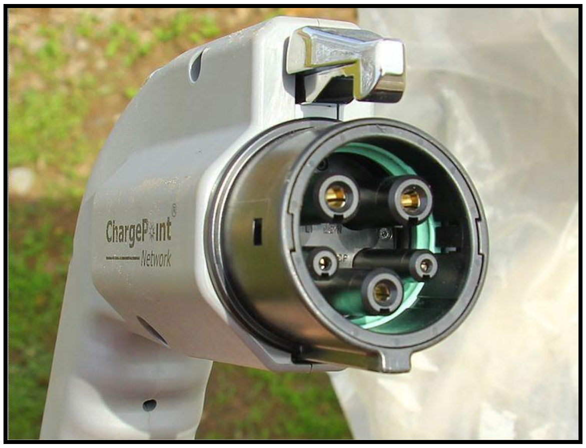
2.3 SAE REQUIREMENTS

The Society of Automotive Engineers (SAE) is responsible to define ground vehicle standards. In the case of the Electric and Hybrid electric vehicle, the objective is to define a common electric vehicle conductive charging system architecture including operational requirements and the functional and dimensional requirements for the vehicle inlet and mating connector.

The following is a partial listing of the various SAE connectors:

1. **J1772:** SAE Electric Vehicle and Plug-in Hybrid Electric Vehicle Conductive Charge Coupler

Figure 3: ChargePoint Conductive Coupler



2. **J2464:** Electric and Hybrid Electric Vehicle Rechargeable Energy storage System (RESS)
3. **J2836:** Use Cases for Communication between Plug-in Vehicles and the Utility Grid/EVSE/customers
4. **J2894:** Power Quality Requirements for Plug-in Vehicle Chargers

2.4 NETWORK CONNECTIVITY

Network connectivity was achieved utilizing the ChargePoint® network service provider and included charging station locations, trip mapping and billing information. Remote billing, maintenance and software upgrades can be conducted seamlessly over the commercial Code Division Multiple Access (CDMA) or General Packet Radio Service (GPRS) cellular data networks with local area network provided by utilizing 2.4 GHz 802.15.4 dynamic mesh. The integrated power metering circuitry provides bi-directional measurement of energy utilization between the vehicle and utility.

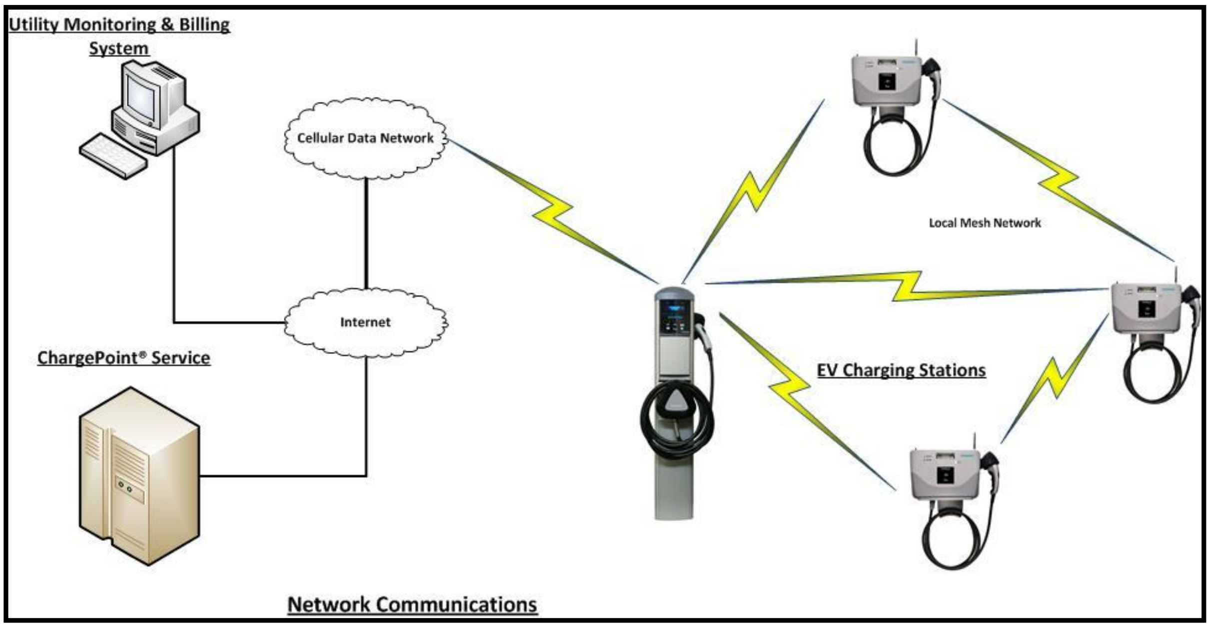
The Smart Grid of the future, while expected to affect all areas of the Electric Power System, from Generation, to Transmission, to Distribution, cannot function without an extensive data communication system. Electric vehicle charging stations are but one element, out of many, that will make up the Smart Grid of the future. The data communication system will have to cover the entire length and breadth of a Utility's serving area to support the devices and applications that will be deployed.

Communication links will therefore need to use all kinds of resources, varying from hard-wired links to fibre optics, private and public wireless, satellite or micro-wave links. In order that these new applications and devices function in such a diverse communication network they must support Internet Protocol (IP).

For the Electric Vehicle Charging Demonstration Project network connectivity is achieved utilising the ChargePoint® network service provider, which is a public cellular service and includes charging station locations, trip mapping and billing information.

Remote billing, maintenance and software upgrades can be conducted seamlessly over the commercial CDMA or GPRS cellular data networks with local area network provided by utilizing 2.4GHz 802.15.4 dynamic mesh. The integrated power metering circuitry will provide bi-directional measurement of energy utilization between the vehicle and utility.

Figure 4: Network Communications



3.0 INSTALLATION DETAILS

3.1 THE ELECTRICAL SAFETY AUTHORITY

Ontario residents and workers are protected from potential electrical hazards under Ontario Regulation 164/99 - the Ontario Electrical Safety Code (OESC). This Code defines the standards for safe electrical products and installations in Ontario, and when followed protects the public, workers, contractors and business owners.

"Ontario's Electricity Act and the Safety and Consumer Statutes Administration Act and Regulations establish the Electrical Safety Authority's (ESA) responsibility for regulating the safe use of electricity and equipment in Ontario, enforcing the Ontario Electrical Safety Code, and appointing Inspectors."

The EV Charging Station is an electrical device; therefore, it must be installed in accordance with ESA guidelines.

3.2 ONTARIO ELECTRICAL SAFETY CODE (2012)

The latest edition (25^{th}) of the OESC is effective as of May 1, 2012. In this code, Section 86 deals specifically with EV Charging Systems. Due to expected increases in EV penetration, there are several new rules and amendments introduced in this edition and they are summarized below:

Rule 8-200 (1) (a) (vi) – Services and Feeders – Single Dwellings
New rule, when determining the minimum ampacity of the service or feeder conductors supplying a single dwelling, any EV charging equipment shall be considered with a demand factor of 100%. The EV charging equipment loads shall not exceed 80% of the rating of the overcurrent device – Rule 8-104 (5). Where the equipment load is not known, the load shall be considered to be 80% of the rating of the overcurrent device.

Rule 8-200 (3) – Services and Feeders – Single Dwellings
This rule clarifies that the portion of the load made up of an EV charging system shall not be considered continuous when calculating service and feeder conductors for single dwellings but should be considered continuous when calculating branch circuit conductors.

Rule 8-202 (3) (d) – Services and Feeders – Apartment and Similar Dwellings

Any EV charging equipment loads must use a demand factor of 100% for when determining the minimum ampacity of service or feeder conductors.

Rule 26-710 (o) – Receptacles for Residential Occupancies
This rule specifies that where required by the National Building Code of Canada, receptacles used for EV charging equipment shall be provided car spaces in any garage or carport serving residential buildings. This rule is to introduce installation criteria for receptacles and dedicated branch circuits for EV charging equipment wherever such infrastructure requirements are mandated by the building code.

Rule 86-100 (refer to Appendix B) – Special Terminology – EV Inlet
The EV inlet is considered to be part of the EV and **NOT** part of the EV charging equipment.

Rule 86-308 (1) –EV as a Power Production Source
An on-board EV supply system is required to be approved if it provides bi-directional power feed.

Rule 86-404 – Height of EV Charging Equipment
This rule specifies that the height of the EV charging equipment shall be located between 450mm and 1.2 m above floor level.

3.3 WIRING INSPECTIONS

For all new construction and renovations, electrical work must be inspected as required by the Ontario Electrical Safety Code. To arrange for an electrical inspection Applications for Inspection form must be submitted to the Electrical Safety Authority.

Figure 5: Technical Specification for EV Charging

Electrical input	Level 1	Level 2
Input power	2.0 kW	7.2 kW
Input voltage	120 VAC	208/240 VAC
Input current	16 A	30 A
Input power connections	Line, Neutral, Earth	Line 1, Line 2, Earth
Required service panel breaker	20A single-pole breaker (non-GFCI type) on dedicated circuit	40A double-pole breaker (non-GFCI type) on dedicated circuit
Service panel GFCI	Do not provide external GFCI as it may conflict with internal (CCID)	
Standby power	5 W typical	

Electrical output*

Output charging power	2.0 kW	7.2 kW
Output voltage	120 VAC	208/240 VAC
Output current	16 A	30 A
Output charging connector	NEMA 5-20 receptacle	SAE J1772™ EV connector on 18' (5.48 m cable)

Functional interfaces

Card reader	ISO 15693, 14443	
Ground fault detection	5 mA CCID with auto retry (15 minute delay, 3 tries)	20 mA CCID with auto retry (15 minute delay, 3 tries)
Plug-out detection	Programmable arm and trip current thresholds	Power terminated per SAE J1772™ specification
Power measurement	2% @ 15 minute intervals	
Local area network	2.4 GHz 802.15.4 dynamic mesh network	
Wide area network	Commercial CDMA or GPRS cellular data network	

Safety and operational ratings

Safety compliance	UL listed for USA and cUL certified for Canada; complies with UL 2594, UL 2231-1, UL 2231-2, UL 1998, UL 991, and NEC Article 625
Surge protection	6 kV @ 3000 A. In geographic areas subject to frequent thunder storms, supplemental surge protection at the service panel is recommended.
EMC compliance	FCC Part 15 Class A
Operating temperature	-22 °F to 122 °F (-30 °C to +50 °C)
Operating humidity	Up to 95% non-condensing
Enclosure	NEMA 3R
Terminal block temperature rating	212 °F (100 °C)
Maximum charging stations per 802.15.4 radio group	100 (each station must be within 150 feet "line of sight" of at least one other station)
Approximate shipping weights	Bollard (8EM1115-1B***) 77 lbs (34 kg) Pole Mount (8EM1115-1C***) 52 lbs (23 kg) Wall Mount (8EM1115-1D***) 55 lbs (25 kg)

***NOTE:** *Both the 120 VAC and the 208/240 VAC charging outputs can operate simultaneously.*

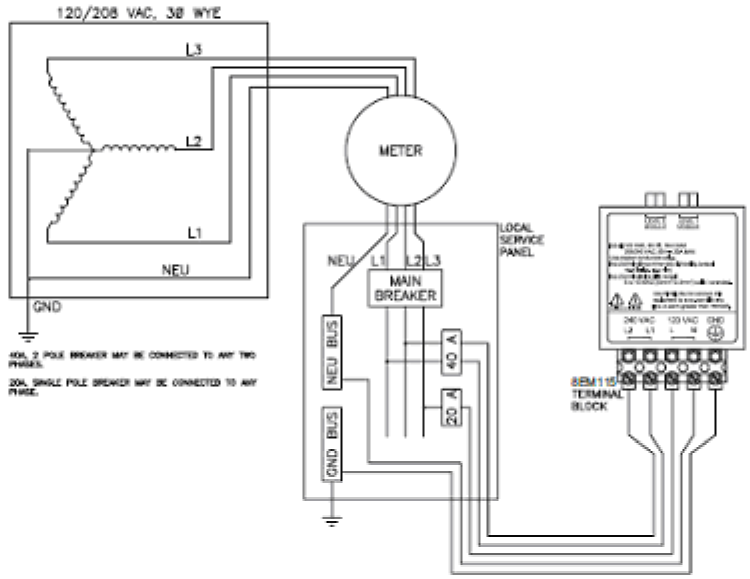
Important: You must connect BOTH the 120 VAC and the 208/240 VAC circuits. The 8EM1110 will not operate if only one of the circuits is connected.

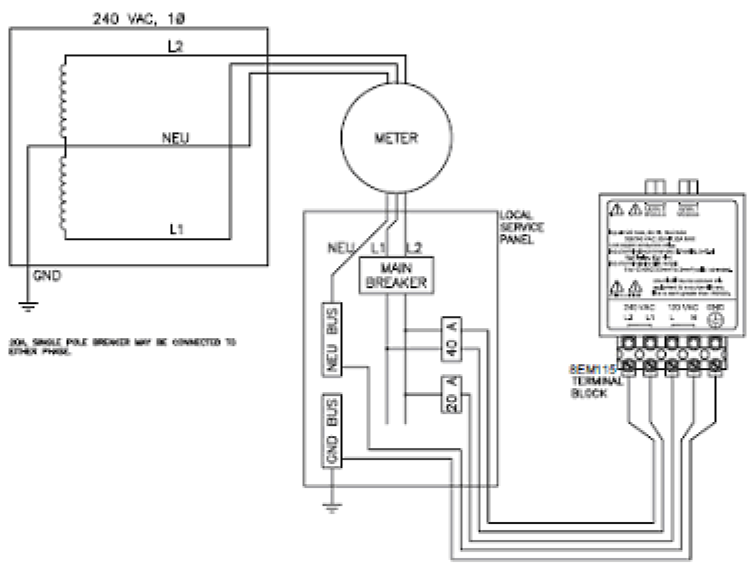
Figure 6: Wiring Information for EV Charging Station

Wiring requirements

The ChargePoint® Charging Station must be installed in accordance with applicable codes and standards, such as the National Electrical Code®, (NEC®) NFPA 70. The branch conductors provided must be sized in accordance with NEC® article 300.

For installation subject to solar radiation (sunlight), the conductor ampacity must be adjusted in accordance with the NEC®, for example, table 310-1b. When exposed to significant solar radiation, the ambient temperature inside the charging station may be substantially higher than the outside ambient, perhaps by as much as 20 ºC - 25 ºC (36 ºF - 45 ºF). The user must adjust the ampacity of the branch circuit wires accordingly and must also select the temperature rating of the wire appropriately.





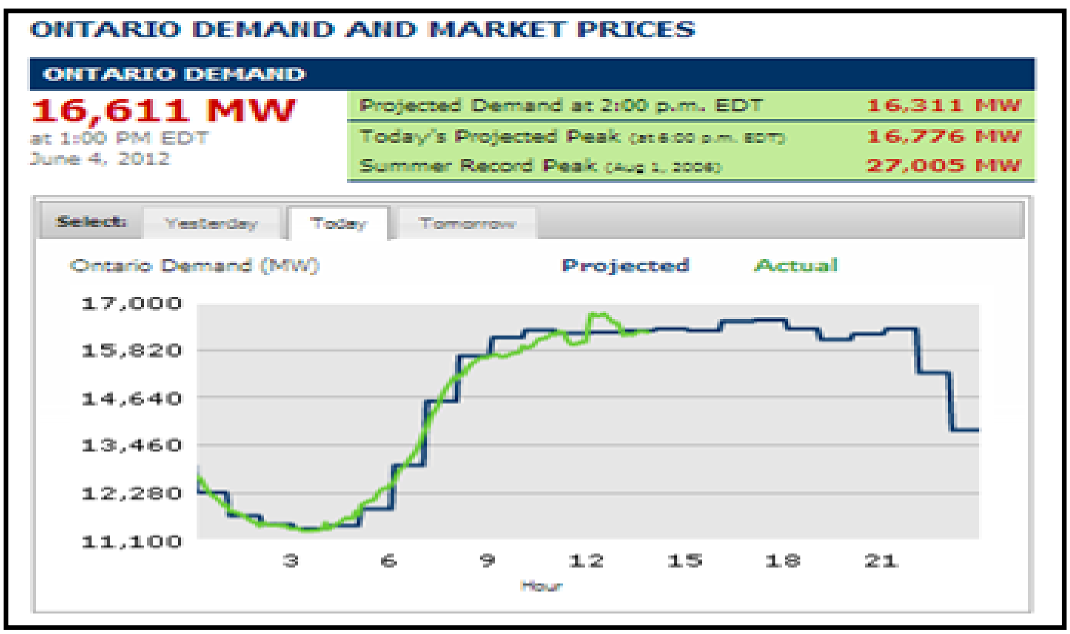
4.0 LOADS AND ENERGY COST

From the Siemens charger specifications, the level 1 charge is 2 kW and the level 2 charge is 7.2 kW.

For planning purposes, a typical gas heated residential home represents a load of 4 kW, therefore, the level 1 EV load is equivalent to ½ of a full home load and a level 2 EV load is equivalent to almost 2 full homes. So adding EV charging may overload existing transformers. Those areas with higher concentrations of EV charging stations may be particularly at risk.

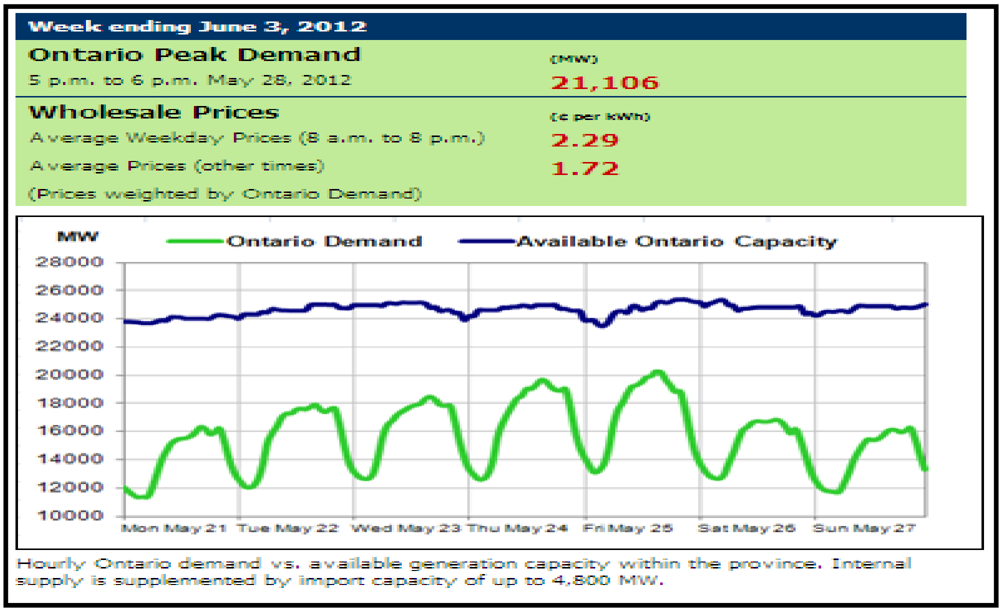
The figure below is a "snapshot" of the provincial demand curve, it is clearly seen that peaks occur between 10:00 AM and 9:00 PM. It is expected that most drivers will return home and plug-in between 4-8 PM, resulting in an increase to the afternoon peak. Adding to the system peak would lower the system Load Factor (LF) and put additional stress on system infrastructure.

Figure 7: Ontario Demand Market Prices



The figure below illustrates the "peaks and valleys" which the provincial grid experiences on a daily basis, if charging habits could be modified so that charging for homeowners commenced after 9:00 PM the effect would be to "fill" in the valleys, the result would be an improved provincial Load Factor (LF) which implies better utilization of the power system.

Figure 8: Ontario Peak Demand



4.1 ELECTRIC CARS

Veridian Connections Inc. donated a vehicle to UOIT for the purpose of testing the load of an EV on the current grid. The information from this research vehicle provides utilities and power suppliers a glimpse of grid management strategies for future development of energy infrastructure programs.

Many of the participants in this pilot demonstration utilized fleet vehicles for EV loads; in particular, the Chevy Volt is one vehicle that has been used. The following is a partial listing of various manufacturers' rechargeable energy storage systems:

Table 1: Battery Operated Vehicles

Vehicle	Battery Type	Rating (kWh)
Chevy Volt	Lithium-ion	16
Nissan Leaf	Lithium-ion	24
Mitsubishi iMiEV	Lithium-ion	16
Toyota Prius	Lithium-ion	4.4

4.1.1 DEFINITION: HYBRID AND EV

An **electric car** is powered by an electric motor instead of a gasoline engine. The electric motor gets energy from a controller, which regulates the amount of power—

based on the driver's use of an accelerator pedal. The EV uses energy stored in its rechargeable batteries, which are recharged by electricity.

A **hybrid car** is fuelled by gasoline and uses a battery and motor to improve efficiency—an electric car is powered exclusively by electricity. Historically, EVs have not been widely adopted because of limited driving range before needing to be recharged, long recharging times, and a lack of commitment by automakers to produce and market electric cars that have all the creature comforts of gas-powered cars. That's changing – As battery technology improves—simultaneously increasing energy storage and reducing cost—major automakers are expected to begin introducing a new generation of electric cars -see Appendix C for a listing of manufacturers' EV's. Also, see Appendix D for an article suggesting future improvements to batteries and battery charging times.

4.1.2 *HYBRID AND EV OPERATIONAL CONDITIONS:*

Two operational modes of function are typically employed for conventional hybrid vehicles

1. (CS) Charge Sustaining – Vehicle will operate using gasoline only, utilizing regenerative braking to recharge the electrical system.
2. (CD) Charge Depleting – The vehicle will utilise stored electric energy to power and operate vehicle. Once the vehicle has depleted the energy available it will switch to (CS) mode of operation.

For electric vehicles operation:

1. Only electricity is consumed which requires recharging at the destination; providing stations are available.

4.2 STATIONARY BATTERIES

Due to a shortage of EV at the commencement of the pilot project, it was decided that a battery system would be purchased and used to simulate an EV load. Batteries were supplied by eCamion, however, as the project progressed, enough EV's were available to satisfy the needs of the data collection and the battery was not used.

4.3 Vehicle Energy Costs – Electric versus Gas

One of the barriers to EV market penetration is capital cost. Offsetting this barrier is the cost savings in fuel/energy required to operate the EV.

The following table represents the determination of energy costs associated with an EV based on the following assumptions:

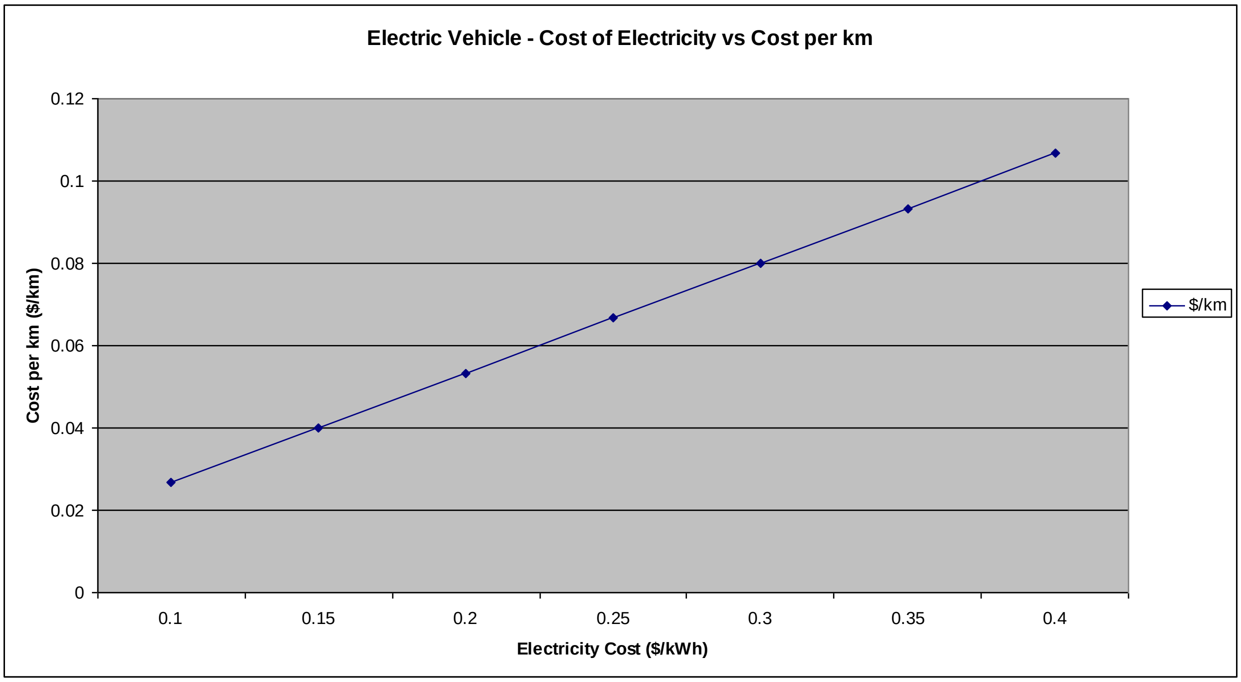
- Cost of electricity = $0.10/kWh
- Load = 16 kWh
- Range = 60 km

Results:

- Cost to charge = $1.60
- Cost per km = $0.0267/km

Figure 9: Electric Vehicle Energy Costs

Energy Cost ($/kWh)	Load (kWh)	Range (km)	Power Usage (kWh/km)	Cost to Charge ($)	Usage (km/yr)	Annual Fuel Cost	
						$/yr	$/km
0.1	16	60	0.267	1.6	20000	534	0.0267



The following table represents the determination of energy costs associated with a gasoline vehicle based on the following assumptions:

- Cost of fuel = $1.25/l
- Fuel usage = 6 l/100km

Results:

- Cost per km = $0.075/km

Figure 10: Gas Vehicle Energy Costs

Fuel Cost ($/l)	Usage (km/yr)	Fuel Usage (l/100km)	Annual Fuel Cost ($/yr)	$/km
1.25	20000	6	1500	0.075

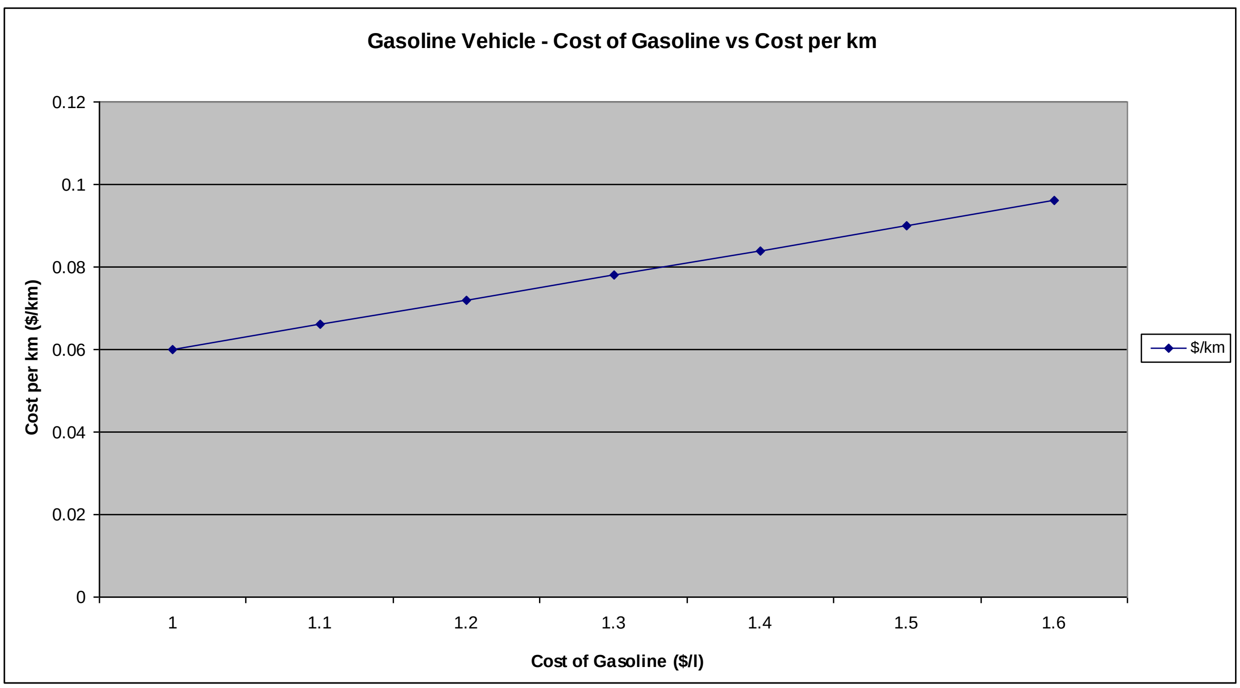


Table 2: Summary – Battery Operated Vehicle vs. Gas Vehicle

Battery Operated	Gasoline
No tail pipe emissions	Greenhouse gases/pollution
100 km range +/-	500 km range +/-
Hours to recharge (Level 1 & Level 2)	Minutes to refuel
$0.027 / km @ $0.10/kWh	$0.075 / km @ $1.25/l and 6 l/100km

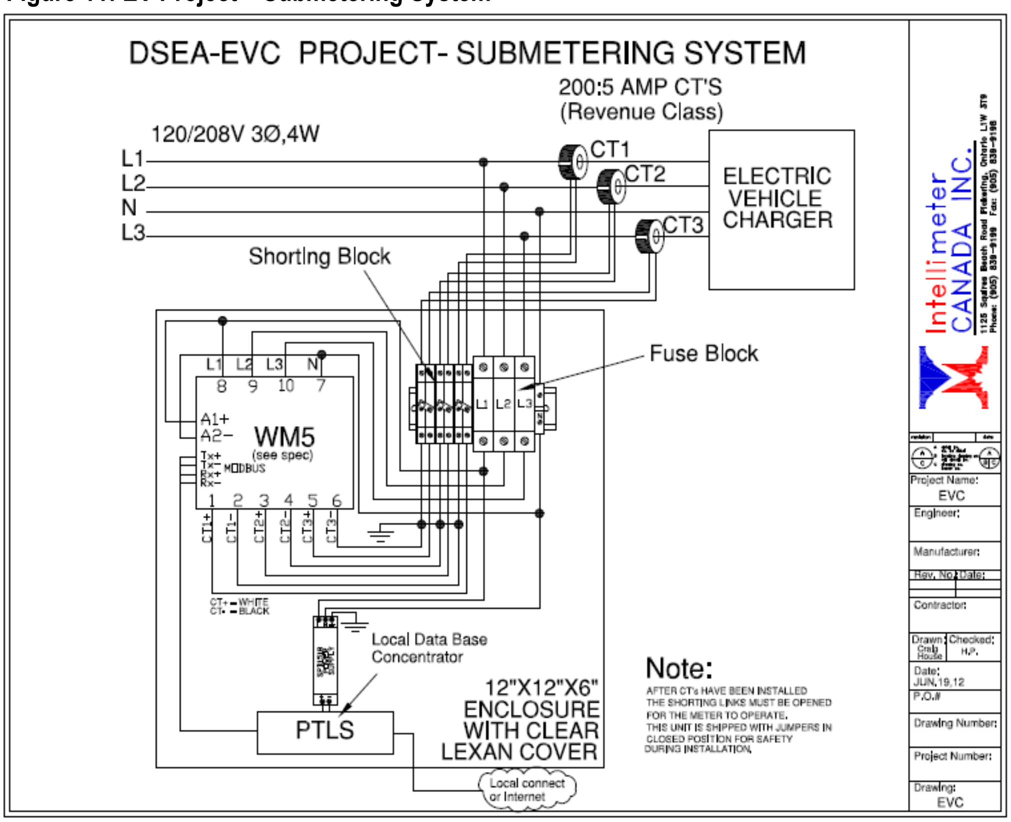
5.0 MONITORING AND DATA COLLECTION

5.1 METHODOLOGY

Intellimeter Canada Inc. provides revenue class electric metering systems and is accredited through Measurement Canada. For this project, the WM-5 power analyzer was used to monitor and capture the charging interval data during charging cycles of the various Electric Vehicles at different locations.

The metering system used was made as a portable unit and was tested on a certified console for accuracy prior to placing into service. The unit was deployed to various subject locations to capture the charge profile and characteristics of the charge cycle. This data included volts, amps, kWh, harmonics and many more analytic measurable as out lined in the meter specifications within this report. The data was transferred from the portable unit between each deployment to ensure the subject locations and the associated vehicles remained traceable. A copy of the data was provided to UOIT to use as the basis for the modeling process found in this report.

Figure 11: EV Project – Submetering System



5.2 INTELLIMETER FIELD DATA

The following tables are a small sampling of the data collected from the charging sites for this project. The Intellimeter WM-5 was installed to analyze and record the electrical energy at the charging stations. The average duration per site was approximately 2 weeks to capture a substantial cross section of electric vehicle charges. The metering and monitoring system provided by Intellimeter was set to read the system every minute and record 52 registry values such as Volts Amps, Power Factor (PF), Total Harmonic Distortion (THD), etc. The system collected over 1,000,000 lines of data from each site to provide a substantial amount of data for actuary modeling.

Figure 12: Raw Data – Location Whitby Hydro

				Average During Charge							
Date	Time	Sample Period	Location	Voltage (Volts)	Current (Amp)	Power (Watts)	VA	VAR	Power Factor	THD Total VL1-N	THD Total VL2-N
27/04/2012	14:07 - 14:48	41 minutes	Whitby	209.0939534	10.86128577	2154.775363	2159.960897	-126.5766532	-0.977372561	2.248885399	1.945342854
30/04/2012	11:02 - 12:24	82 minutes	Whitby	206.9763479	13.73379522	2827.744851	2830.050351	-108.5084365	-0.999001642	2.165175826	1.912619112
07/05/2012	13:31 - 16:59	208 minutes	Whitby	205.3898804	15.12281423	3095.776223	3097.446403	-101.2193343	-0.999456095	2.276887791	2.023096737

				Grand Total of Charge		
Date	Time	Sample Period	Location	kWh	Total kVARh+	Total kVARh-
27/04/2012	14:07 - 14:48	41 minutes	Whitby	1.135	0.302	0.369
30/04/2012	11:02 - 12:24	82 minutes	Whitby	3.827	1.051	1.198
07/05/2012	13:31 - 16:59	208 minutes	Whitby	10.684	2.96	3.309

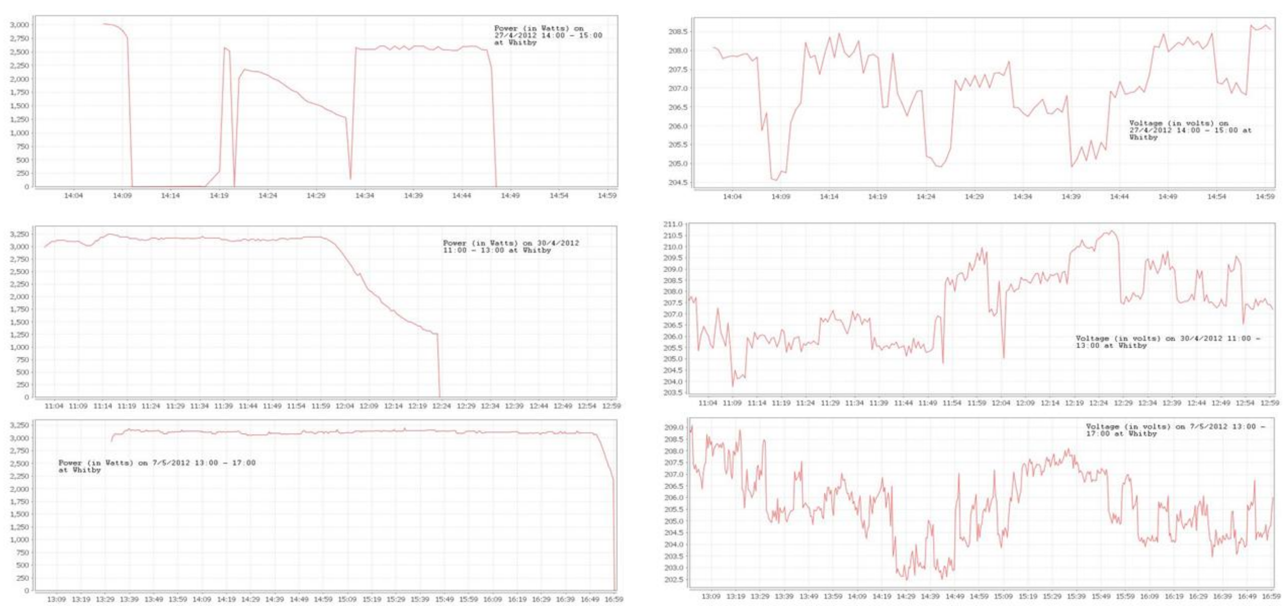
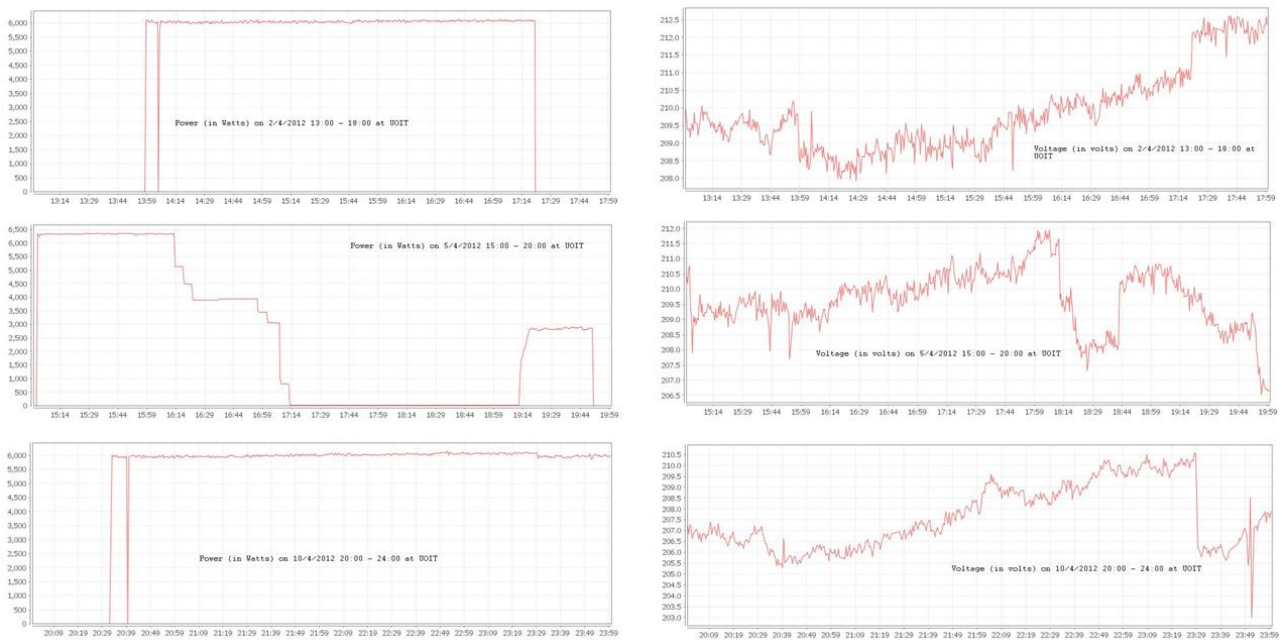


Figure 13: Raw Data – Location UOIT

				Average During Charge							
Date	Time	Sample Period	Location	Voltage (Volts)	Current (Amp)	Power (Watts)	VA	VAR	Power Factor	THD Total VL1-N	THD Total VL2-N
02/04/2012	13:57 - 17:21	204 minutes	UOIT	209.4822419	28.83679955	6021.640098	6025.54188	215.0754548	0.990947142	2.442928379	2.307551435
05/04/2012	15:01 - 19:51	290 minutes	UOIT	209.7290537	13.05325314	2685.658118	2726.733319	-146.5602666	-0.669408468	2.310743551	1.792495733
10/04/2012	20:32 - 24:00	208 minutes	UOIT	207.7851189	28.80022791	5967.947702	5972.154984	222.1647277	0.985999443	2.163983859	1.5845633
				Grand Total of Charge							
Date	Time	Sample Period	Location	kWh	Total kVARh+	Total kVARh-					
02/04/2012	13:57 - 17:21	204 minutes	UOIT	20.329	6.321	5.594					
05/04/2012	15:01 - 19:51	290 minutes	UOIT	12.978	3.497	4.201					
10/04/2012	20:32 - 24:00	208 minutes	UOIT	20.68	6.356	5.583					



6.0 DATA ANALYSIS

DATA ANALYSIS

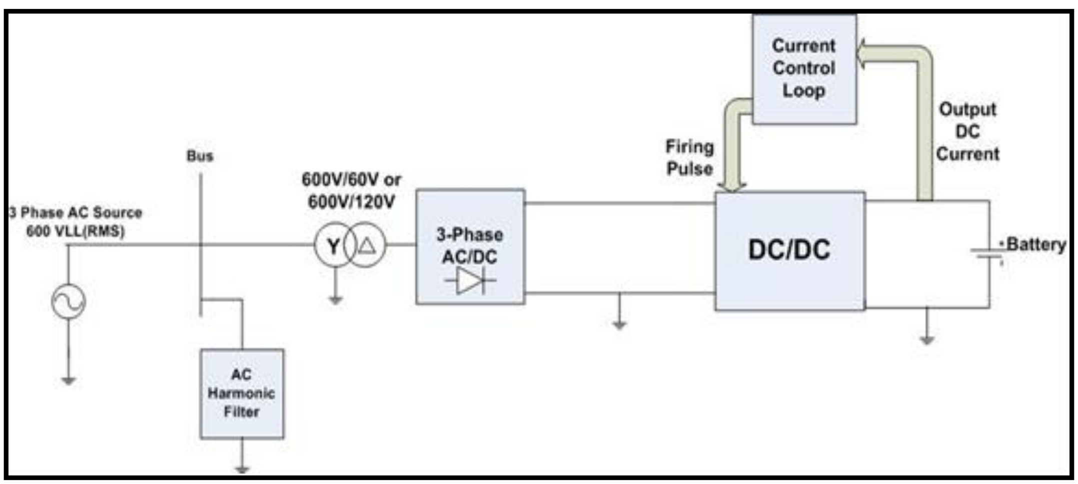
Data samples from the various sites were collected and analyzed for EV Charging Station Demonstration Project. Due to the monitoring system limitations, both in terms of bandwidth and sampling times, the data only provided very limited analytical opportunity such as electricity consumed. Other methods for analysis are presently being investigated, but are unlikely to provide any useful conclusions to be drawn.

6.1 SIMULATIONS

The University of Ontario Institute of Technology (UOIT) developed an EMTP software simulation model of a generic charging unit to monitor the potential load impacts of EV technology on the present grid. The data generated from this model will allow utilities to forecast the impact of the charging stations on the grid.

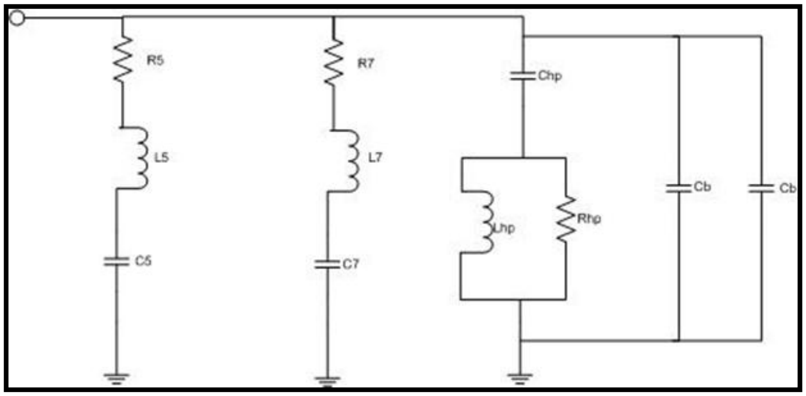
The schematic of the modeled system is shown in Figure 11 below. The model consists of a 3 phase grid connection bus at 600 V rms.

Figure 14: Schematic of the modeled system for battery charging



The AC bus has AC harmonic filters (Figure 12) connected to the bus for characteristic harmonic reduction and reactive power support. The AC filters comprise arms tuned to the 5th and 7th harmonics, and high pass filter tuned to the 12th harmonic. The AC bus is also connected to a diode rectifier through a Y-D transformer.

Figure 15: AC Harmonic Filter and Reactive Power Capacitor banks



The DC voltage from the rectifier is fed to a controlled DC-DC buck converter to supply DC power to the vehicle battery at a constant current. A control loop is used to vary the firing pulses to the DC-DC buck converter which switches and controls the output voltage which is matched to the battery voltage level. Two types of control circuits were employed to control the charging current.

The data for the system is provided in table below.

Table 3: Data for Modeled System

Parameters	Rating
AC Input Voltage	600 V
Frequency	60 Hz
Source Inductance	26.5 mH
Transformer Power Rating	15 kVA
Transformer Primary Voltage	600 V
Transformer Secondary Voltage	60 V or 120 V
AC Filter Rating	2 kVA
Rectifier Bridge Rating	10 kW
DC Charging Currents	10A, 20A and 40A
DC Output Voltage	24 V or 48 V

6.2 LOAD FORECASTING

Sufficient analytical results could not be extracted from the data collected.

6.3 IMPACTS ON THE GRID

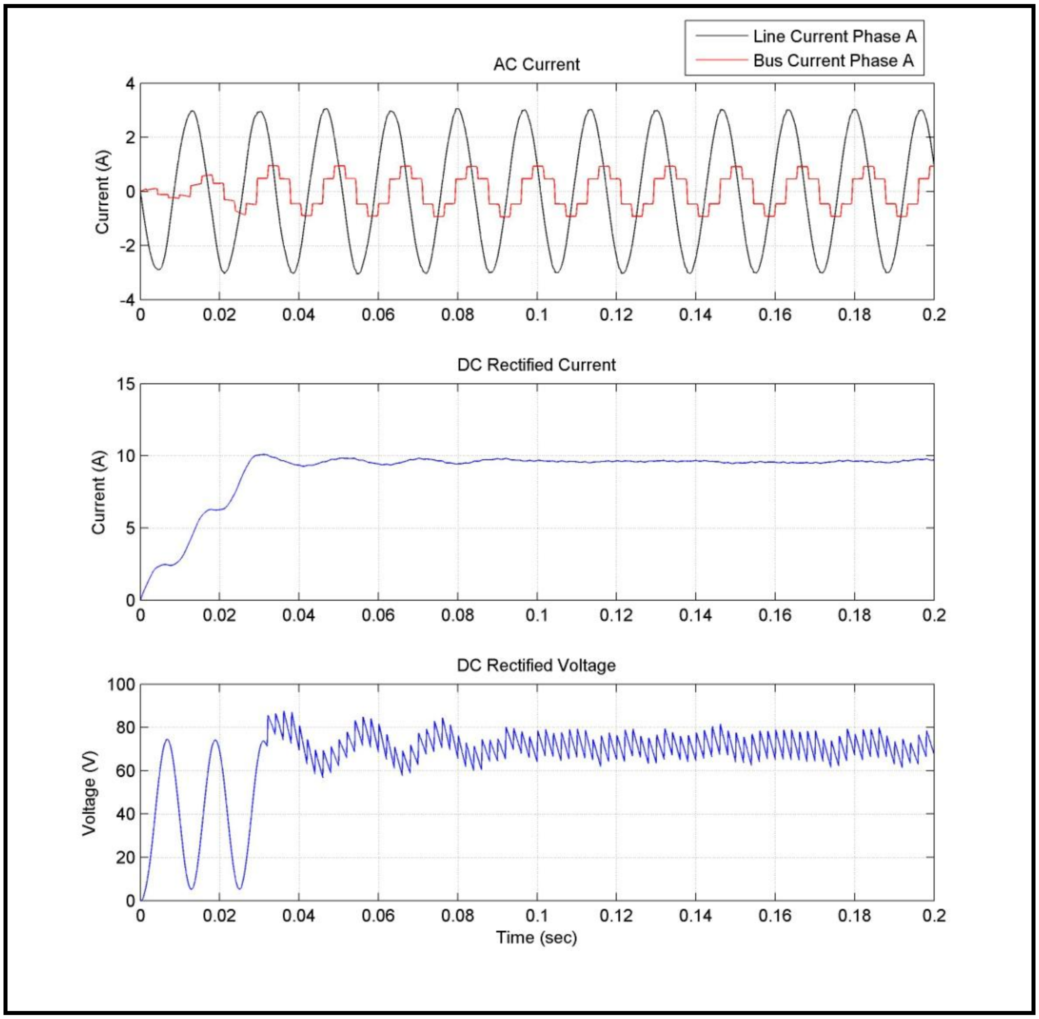
The results of the simulation are shown in Figure 13 below. The current in the line and the current fed to the converter are shown in Fig. 13 (top trace). The rectifier current draws trapezoidal waveform with 5, 7, 11, 13, i.e. (2n+/-1) characteristic harmonics. The current drawn from the AC system is sinusoidal due to the AC filters employed. The lack of such AC filters will directly feed the harmonics into the grid source.

The impact of a few charging stations is unlikely to impact on the grid in a dramatic way. However, if a large number of such charging stations are deployed in the future, then there is going to be an impact on the grid. The anticipated impact will be a result of the relative short circuit ratio of the grid presented at the Point of Common Coupling.

The bottom two traces of Fig.13 show the DC-DC converter current and voltage respectively. The DC current is relatively smooth but the DC voltage shows a high level of the fixed switching frequency of 500 Hz due to the DC-DC converter. This switching frequency could be raised depending on the converter employed, but it is usually in the range of a few kilo Hertz, which is in the critical telephone circuits range. An alternative converter with variable switching frequency was also tried and resulted in a full range of frequencies being generated. These frequencies may cause some concern with telephone circuits near to the battery charger.

Another kind of impact on the grid may result if the battery charger utilizes a soft start or sudden start control circuit. Again, there was no data available from the readings obtained to ascertain if this technique was employed or not.

Figure 16: Simulation Results



7.0 BILLING AND SETTLEMENT

7.1 Capture Revenue with Flexible Payment Options

Pricing Options:
The ability to change charge station pricing by time, session, or kWh basis is available. In addition, by combining pricing with custom access control, you can vary pricing for preferred employees, customers or residents and take advantage of Time of Use (TOU) energy prices by varying station pricing by time of day. The following is a partial listing of the pricing options:

- Pricing by the hour encourages drivers to move their cars when they are fully charged.
- Pricing by the session is available if minimum or maximum charge times are required.
- Pricing by kWh covers costs very precisely (where pricing by kWh is allowed).
- The ability to set a maximum price accommodates/attracts drivers who need to leave their car for an extended period, such as overnight one or more nights.
- The ability to charge a precise fee based on actual usage provides the peace of mind drivers want (since they often don't know ahead of time how long they will stay) and the operational flexibility needed.
- The ability to selectively apply a single pricing plan to any number of stations allows pricing changes in one place and have it automatically take effect at multiple stations, while retaining the ability to price each station differently if required.
- Preferential pricing provides free or reduced rate charging for special individuals or groups (loyalty program members, execs, tenants, monthly permit holders, etc.) while still collecting the regular pay-for-use fee from the general public. It also provides loyalty programs that

include charging services, or incorporate charging services into existing affinity programs.

- Support for multiple preferential pricing plans allows for different pricing for different people and groups (such as a tiered loyalty program where members in each tier pay a different fee)
- The ability to apply a single preferential price plan to any number of stations creates ease of maintenance as individuals only maintain one plan. If any members are added or deleted, or change the preferential price, change needs to happen at only one place and it applies to all stations.

7.2 PROCESS PAYMENT AND TRANSFER FUNDS

Once pricing is set, the ChargePoint Network processes ChargePass™ and credit cards automatically transfer the funds from the driver to the designated bank account. The operator can centrally monitor and report transaction data by individual or by groups of stations and optionally export transaction data to the operators accounting systems to automate measuring the return on investment.

- Automated payment processing and funds transfer avoids the burden of new and ongoing personnel overhead to support charging operations.
- With granular usage data by driver that is transferred in real-time, the operator can also accurately bill back departments for charging station usage.

8.0 BUSINESS CASE SCENARIOS

8.1 BUSINESS CASE

The business case for personal use vs. commercial use as it pertains to both vehicles and charging is markedly different.

From a utility standpoint the preferred option is to have charging occur at night during off peak hours, when a surplus of base load electricity is available and to minimize loading on the delivery system – i.e. wires and transformers.

A qualitative analysis of usage patterns yields the following:

1. Personal - Commuting to work
   a. People who live and work in the region – typically the range will permit charging at home at night.
   b. People who commute to public transit node e.g. GO train station - typically the range will permit charging at home at night.
   c. People who commute distances that exceed the range of a single charge – would require charging facilities either at work or in public domain.

2. Personal – Recreational
   a. About the region - typically a range of 100-200 km should suffice, permitting charging at home at night.
   b. Longer range would typically require charging network outside the Region and therefore is outside scope of project.

3. Business/commercial:
   a. Providing charging for fleet vehicles. Assume that fleet EV users will look after their own needs and that the electricity used will simply become part of their consumption and that they are charged according through conventional/existing means.
   b. Providing charging for employee (private) vehicles at work. Charging for employees prompts issue of charging for power.
   c. Public charging. This type of charging would typically be during peak and so smart grid could not be optimized. Further this type of use could exacerbate peak demands.

8.2 Electric Vehicle Charging System Installation Options (Business Case)

Personal – at home[1]

1. Option #1 - 120 volt – assuming that homes have suitable circuit in proximity to the parking space – no incremental cost.
2. Option #2 - 240 volt – assuming purchase price of charger and installation at $1500.00[2]

[1] Does not include condos and rentals.
[2] Assumes basic installation (circuit/capacity available in panel, basic run of cable), costs will rise dramatically if service requires upgrading or for example the basement is finished.

Charging can save $1000/year at $1.25 per litre gas.

Commercial – Public Charging

Assumptions:

- $5000 for EV Charger (with RFID) and installation.
- 5 days a week charging.
- Two (2) charges per day.
- Electricity costs are $1.60 per charge.
- Life span of an EV Charger (even at 3 cycles/day) is in the order of decades.
- Business model cost recovery of 5 years
- Maintenance and upgrades (software) costs 5% of replacement cost/year.

8.3 Estimated Annual Costs to Operate:

- Electricity - At 5 days per week = 210 days x 2 charges/day x$1.60/charge = $672
- Capital $5000/5 years = $1000
- Maintenance (at 5% of replacement cost/year) = $250
- Estimated total cost/year **= $1922**
- At 420 charges/year the break even cost/charge would be approximately $4.58/charge.

- Profit a $1/charge
- Estimated total cost/charge $5.55

8.4 BUSINESS CASE SUMMARY

Cost to driver to charge publically using above assumptions is about $5.55/day.

If a driver were to use solely public chargers and charged 5 days/week the annual costs would be approximately = $5.55/day * 5 day/wk * 52 wk/yr = $1443.

If 'fuel' savings are in the order of $1000/year public charging would effectively eliminate most of this saving.

The following is a future qualitative analysis of EV vehicles adaption vs the various parameters:

Figure 17: Qualitative Analysis of Future

Parameter – and direction of change	**Likely Impact on Adoption of EVs**
Price of electricity rises substantially	Decrease
Price of gas rises substantially	Increase
Incentives for electric vehicles (preferred delivery Times, lower license fees (taxis))	Increase
Carbon Tax	Increase
Policy – ability of private entities to 'retail' electricity	Increase
Removal of existing rebates	Decrease

9.0 CONCLUSIONS

Charging at home, off peak likely appeals to majority of private vehicle users from a cost standpoint and supports the off peak rationale which is desirable for distribution utilities and generators.

The business case for public charging would appear less desirable due to cost, and the potential to aggravate peak demand. A series of variables could either promote or discourage adoption of Electric Vehicles. Such factors include; if the price of electricity rises substantially or EV rebates are eliminated the adoption could adversely affected, if the price of fuel rises substantially, or further incentives or carbon taxes are introduced the adoption may be favoured.

The Electric Vehicle Charging Station Demonstration Project is a stepping stone for further studies on:

1. Effects that charging EVs will have on residential transformer loading.
2. Effects that charging EVs will have on electric system voltage and current balance.
3. EVs as a means of energy storage and their impact on the grid.

Appendix A: Project Partners

1. DSEA: i. Ursula Hatherly - Member Manager/Project Co-ordinator Email: uhatherly@dsea.ca ii. Martin Croteau - Executive Director Email: mcroteau@sparkcentre.org
2. Durham College: i. Chris Gillis, P.Eng - Manager Incubator Centre Email: Chris.Gillis@durhamcollege.ca ii. Ralph Aprile – V.P Facilities Email: Ralph.Aprile@durhamcollege.ca
3. Intellimeter Canada Inc.: i. Jeff Kistner – President Email: jkistner@intellimeter.on.ca
4. Ontario Power Generation: i Todd Hall – Director Sustainable Development todd.hall@opg.com
5. Oshawa PUC Networks Inc. : i. Denise A. Flores, P.Eng – VP, Engineering and Operations Email: dflores@opuc.on.ca ii. Jayesh Shah – Director of Asset Management Initiatives Email: jshah@opuc.on.ca

6. UOIT: i. Greg L. Rohrauer, Ph.D., P.Eng., C.E.T. - Assistant Professor, Academic Director Email: Greg.Rohrauer@uoit.ca ii. Vijay Sood, Ph.D, FEIC, FIEEE, P.Eng. - Associate Professor OPG-NSERC Design Engineering Co-Chair Email : Vijay.Sood@uoit.ca ii. Michael Owen, Ph.D – Associate Provost, Research Email : Michael.Owen@uoit.ca
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9. Town of Whitby i. Sheila McGrory - Manager of Economic Development Email: mcgrorys@whitby.ca
10. Veridian Connections Inc. i. Terry Britton – Manager Distribution Services Email: tbritton@veridian.on.ca ii. Michael Angemeer – President & CEO Email: mangemeer@veridian.on.ca

11. Whitby Hydro Energy Service Corporation i. Kevin Whitehead, P.Eng – VP of Engineering & Business Services Email: KWhitehead@whitbyhydro.on.ca ii. John Barratt – Manager of Engineering Email: jbarratt@whitbyhydro.on.ca
12. WireIE Holdings International Inc a. Robert Cressatti – Vice President of Solutions Engineering Email: robert.cressatti@wireie.com

Appendix B: OESC 2012 Amended Rule 2-000

Amended Rule 2-000

Amend Rule 2-000

2-000 Scope ***(See Appendix B)***
This Code does not apply to
(a) electrical equipment and electrical installations used exclusively in the generation, transmission, or distribution of electrical power or energy intended for sale or distribution to the public, where
(i) the distributor is licensed to own or operate the distribution system under Part V of the Ontario Energy Board Act*, 1998;*
(ii) the transmitter is licensed to own or operate the transmission system under Part V of the Ontario Energy Board Act, 1998; or
(iii) the generator is licensed to own or operate the generation system or is licensed to provide ancillary services for sale through the IESO-administered markets or directly to another person, under Part V of the Ontario Energy Board Act, 1998;
(b) electrical equipment and electrical installations in communication systems from the transformer or other current limiting device used at the junction of the communication system with the electric circuit supplying the communication system;
(c) electrical equipment and electrical installations in the cars, car-houses, passenger stations or freight stations used in the operation of an electric railway or electric street railway and supplied with electric current from the railway power-circuit;
(d) electrical equipment and electrical installations in railway locomotives, railway cars, signalling systems, communication systems, wayside train monitoring systems, and track facilities including the branch circuit supplying such electrical equipment or electrical installations when such electrical equipment or electrical installation is used in the operation of a railway;
(e) electrical equipment and electrical installations in an aircraft;
(f) electrical equipment and electrical installations in a mine as defined in the Mining Act*, excluding any dwelling house or other building not connected with, or required for, mining operations or purposes or used for the treatment of ore or mineral;*
(g) electrical equipment and electrical installations on a vessel of non-Canadian registry or on a vessel that is required to be certified in accordance with the Canada Shipping Act *except for such equipment and installations required to connect the electrical supply from the onshore electrical supply facility to the service box on the boat and including the service box; or*
(h) electrical equipment forming an integral part of a self-propelled vehicle that is required to be certified in accordance with the Motor Vehicle Safety Act *except for such equipment supplying electrical power from an electrical installation to the vehicle and those portions of a vehicle capable of receiving electrical power from an electrical installation.*

Add new Appendix B Note for Rule 2-000(h) to read:

Rule 2-000(h)

For electrical vehicles; this Code applies to electrical vehicle supply equipment and requires it to be approved and installed in accordance with applicable Code requirements. This Code does not apply to the inlet or on-board charging equipment as defined by Rule 86-100 that does not provide bi-directional power feed, as specified by Rule 86-308. The on-board charging equipment is considered to be part of the vehicle and not part of the electrical vehicle supply equipment.

Appendix C: New and Upcoming Electric Cars[1]

BMW Megacity

BMW is working on a small electric car that could launch in 2012. The Megacity is a low-slung three-door four-seat hatchback coupe. The car is smaller than the Honda Fit, and will have a projected range of 100 miles. The BMW Megacity, which could be sold either as a BMW or Mini, is not much more than a concept at this stage, but pressure on BMW to meet California's zero emissions vehicle requirements might bring the car to life—albeit in small numbers.

BYD E6

If China's BYD can deliver on its big promises for the E6 all-electric crossover, then it could take the US by storm. (Investment guru Warren Buffet is betting that BYD will come through.) Unlike the small city-oriented electric runabouts on slate from established carmakers, the E6 is a five-passenger wagon capable of carting a typical American family. Moreover, the E6 has a range of 200 to 250 miles and boasts a 0 to 60 mph time of less than 10 seconds. Top speed is 100 mph. The vehicle can be fully charged in about 10 hours by plugging into a standard household outlet. BYD says that it takes only 10 minutes to charge to 50 percent capacity and 15 minutes to the 80 percent level. BYD has been in the battery business only since 1995, and started building cars in 2003. Considering that the company maintains an R&D department with 8,000 engineers, it's not surprising that the initials BYD stand for "Build Your Dreams."

Chevy Volt

Technically a plug-in hybrid rather than an electric car, the Chevy Volt's technology has leapfrogged standard hybrids like the Toyota Prius. This well-equipped, five-door, four-seat hatchback operates as an electric car for its first 35 or so miles after a full charge and then uses gas to extend its range. It burns no gasoline during the first 40 miles after a charge, drawing energy from a lithium ion battery pack. When the battery is depleted, a 1.4-liter engine kicks in to power a generator that sustains the battery charge enough to give the car another 260 miles of range.

Coda (Electric Sedan)

Southern California automaker Coda Automotive announced plans to bring a new electric car to the US from China in 2010. The all-electric sedan is based on an existing gas-powered four-door car, known as the Hafei Saibao 3, built in Harbin, China. Re-engineered with a lithium ion battery, the Coda sedan promises a driving range of 100 miles. The MSRP for the Coda sedan will be around $44,000.

Ford Focus Electric

The Ford Focus EV, due out in late 2011, is the first electric car designed for the generic aisle of the dealership. Ford's plans for the Focus EV are not aimed at buzz and sizzle. Instead, the company is focused on addressing the biggest obstacle between EVs and the mainstream: cost. By choosing an existing platform—the Focus—and using technology developed by auto supplier Magna, Ford will save the expense associated with developing a unique design. The Ford Focus EV is targeted to have a range of 100 miles between charges, courtesy of a 23 kWh battery pack.

Ford Transit Connect Electric

With the introduction of the Ford Transit Connect Electric, unveiled at Chicago Auto Show, Ford may have produced the first green halo truck. When you combine car-like driving dynamics, cargo capacity and accessibility with the built-in marketing opportunities for small businesses to emblazon the large exterior panels with green slogans such as "Zero-Emissions" and "100 percent electric," it makes for a compelling package. The vehicle has a 75 mile per hour top speed and can drive up to 80 miles on a charge—perfectly fine for the needs of a local delivery cycle.

Mercedes BlueZero

In late 2008, Mercedes-Benz unveiled its BlueZero concept vehicles—the core idea is to build electric, plug-in hybrid, and fuel-cell cars on a single platform. Daimler had previously announced that its next generation FCV fuel cell cars will be built on a subcompact (B-class) chassis in 2010. Migrating to the BlueZero would only be a minor adjustment. Daimler's future electric cars could also shift to the BlueZero—because the guts of its electric cars already fit in the smaller Smart and A-Class. Sharing platforms and technology architectures could allow Daimler to telescope development and production timelines, and save money on rolling out new electric models. At this stage, it's still a concept.

Mini E

The limited edition Mini E car is based on the Mini Cooper platform. The car's 380-volt battery is comprised of 5,088 individual cells, and can be recharged using a standard 110-volt electrical outlet. The battery pack has a maximum capacity of 35 kilowatt hours. BMW will offer a specialized high-amp wall-mounted device that will allow a full replenishment of the battery in less than three hours. The Mini E will have a cruising range of 150 miles. Approximately 500 cars are slated for production and lease to select customers in Southern California and the New York area. Pricing, as well as production beyond the first 500 units, is not yet determined.

Mitsubishi iMiEV

Mitsubishi began delivering the all-electric iMiev to Japanese customers in 2009. Production numbers are slowly ramping up from the current target of a few thousand per year. The small EV uses a single 47 kW motor and 16 kWh lithium ion batteries—to yield about 75 miles of range and a top speed of 80 miles per hour. The vehicle is a four-seater with a real but cramped back seat.

Nissan LEAF

Nissan is calling its new electric car—the Nissan Leaf—the "world's first affordable, zero-emission car." And they could be right. Unveiled on Aug. 2, 2009, the Leaf is a medium-size all-electric hatchback that seats five adults and has a range of 100 miles. At just under $33,000, minus tax incentives, the LEAF is certainly accessible to mainstream buyers. The Nissan Leaf's closest comparable future all-electric car is the Ford Focus Electric. The distinguishing characteristic between the two vehicles could be design—pitting the established look of the Ford Focus against the purpose-built Nissan Leaf, which went on sale in late 2010. As of Feb. 2011, most of the first set of customers, who placed advance orders, are still waiting on delivery.

Pininfarina Blue Car

Legendary Italian sports car designer Pininfarina will begin production of its small all-electric four-seat five-door Blue Car in 2010. The Blue Car is powered by a 50 kW electric motor getting energy from a lithium polymer battery pack with 150 miles of range. The company began accepting reservations from European customers in spring 2009. The lease will be about $500 per month. The body of the car is designed as an elastic shell resting forcefully on the four wheels, providing more room than the average city car. Techno-goodies include solar panels on the roof, and the ability to use a smart phone to monitor battery state-of-charge, and to start AC or heat from a distance. Pininfarina will start slow, only in Europe, and aim to ramp up production up to 60,000 units per year by 2015.

Renault Fluence

Patrick Pelata, executive vice president, said that the all-electric Renault Fluence will launch in 2011, starting with at least 20,000 units in the first year. (The gas-powered Fluence debuts in 2009.) The company will produce a smaller compact electric car in the following year. No more details at this time, although its sister company Nissan will introduce its yet-to-be-named electric-only model also in 2012. That's probably not a coincidence.

Smart ED

Despite considerable media buzz for Daimler's Smart ForTwo, microcars have not taken American roads by storm. Perhaps consumers may be more forgiving of the lack of size and power if the Smart is offered with an electric drive. The first models will likely go to Europe in about 2010. Availability in the US is uncertain. The car will provide 70 miles of range and 70 miles per hour on the freeway. Recharge time from 30 to 80 percent capacity is about three and a half hours. The gas version of the Smart ForTwo has earned low marks for handling, especially at higher speeds.

Subaru R1E

The Achilles Heel of electric cars has been the limited range they can travel between charges. The Subaru R1e could help change that. The diminutive two-seater, about 20 inches longer than a Smart ForTwo, has a top speed of 65 miles per hour and a range of 50 miles. More importantly, the time to recharge the 346-volt lithium ion battery pack has been reduced to about 15 minutes. Here's the hitch: To get the faster charging time, you need a special stationary charger. Using the onboard standard charger puts the electricity refueling time back to about eight hours.

Toyota FT-EV

Toyota introduced the FT-EV electric concept at the 2009 Detroit Auto Show, hinting that it might offer an urban all-electric commuter vehicle in the next few years. The FT-EV concept shares its platform with the company's Japanese and European minicar, the Toyota iQ. The iQ is larger than the quintessential minicar, the Smart Fortwo, but not by much. Its wheelbase is a little more than five inches longer, and on the whole, the car is only about a foot longer than the smart—11.4 inches to be exact. The electric version on display at the Detroit Auto Show, the Toyota FT-EV concept, offers driving range of 50 miles, according to Toyota. The company is expected to launch 10 new hybrid gas-electric models globally by 2012, but has not made firm commitments to bring a full battery-electric car to market.

Tesla Model S

What makes the Model S so cool? First of all, the visual design is gorgeous. Second, it seats five—or seven if you count the two side-facing rear seats for small children. There are killer features, like the 17-inch touch screen that provides all of the vehicle's interface components such as climate control and entertainment, but also offers 3G or wireless connectivity. But most importantly, the Model S is way more affordable than the company's $109,000 Tesla Roadster. The current price target for the Tesla Model S is $57,900 (minus a $7,500 federal tax credit)—still not in range for most mainstream buyers but moving in the right direction. The Model S is planned for release in late 2011.

Reference: 1 http://www.hybridcars.com/electric-car

Appendix D: Hydro-Quebec Research Boots Electric-Car Dream

June 08, 2012 Peter Gorrie for the Toronto star

VARENNES, QUE.—Engineers at Hydro-Québec's research institute in this Montreal suburb say they can recharge a lithium-ion battery cell in just one minute.

That speed is the current state-of-the-art for solving one of the big problems with electric vehicles — how to cut the time it takes to re-juice a depleted battery.

The best fast-chargers now promise to do that job in about 30 minutes. With a 240-volt charger — the most common type — its hours.

But before you rush to your nearest EV showroom, you should know the breakthrough involves recharging just a single 18650 cell, the small, tube-shaped battery that's used in many laptops and other electronic gadgets, and, in a pack of nearly 6,700, powers the Tesla Roadster electric sports car.

Still, it's a major step in the slow-moving effort to produce batteries that can help make EVs appeal to the mass market.

The goal, says Karim Zaghib, who heads the Hydro institute's battery research team, is a five-minute charge for almost any battery pack; a rate that would get drivers back on the road in about the same time as filling a gas tank.

That level of performance is reasonably close, Zaghib says. But he won't provide details: The institute and its partner in this research, the U.S. Department of Energy, have applied for patents for the technology and they'll reveal nothing until that's complete, likely by the end of the year.

Skeptics who argue it's physically impossible to push enough electricity into a battery to achieve a five-minute charge — several readers have sent me detailed calculations to "prove" that point — are just trying to pry a few secrets loose, Zaghib says with a laugh.
This development of super-fast charging is notable enough. What's more remarkable is that it's just part of the ground-breaking research being conducted at the institute — work that places provincially owned Hydro-Québec among the global leaders in developing battery technology for electric vehicles.

Around the world, many government and corporate labs are pushing to develop the next-generation battery — the one that would make its inventors rich by giving EVs the same performance, convenience and cost as internal combustion cars. "Breakthroughs" are routinely announced, although most come with the caution that sales to consumers are years away.

No other utility in North America is doing anything like the Quebec work — certainly not Ontario Power Generation, where, a spokesperson says, “research and development is no longer part of (its) core mandate.”

Hydro-Québec has been involved in battery research for more than three decades and got into lithium-ion in 1995. It “wanted to accelerate the penetration of EVs and plug-ins as soon as possible,” Zaghib says. “We want to be recognized for helping to accelerate EVs.”

The utility has electricity to spare — 98 per cent of it from massive hydroelectric generating stations — and would benefit from increased demand. Its current capacity could support 1 million EVs, or one-third of all cars on Quebec’s roads, it says.
Part of its pitch is based on the fact that, although dams on the province’s northern rivers have had dramatic impact on the James Bay environment, waterpower is considered a pollution-free, renewable energy source.

EV batteries are made up of cells, each containing two electrodes. One, the cathode (usually a metal compound), is positive. The other, the anode (usually graphite), is negative. Between them is a liquid called the electrolyte, as well as a separator (a bit of plastic material that prevents the electrodes from touching so they don’t short-circuit).
When a typical EV battery is fully charged, each anode is full of lithium ions. As the driver hits the accelerator, ions flow through the electrolyte to the cathode, creating an electric current. When most have made that journey, the battery must be recharged, which pulls the ions back to the anode, ready to move again when power is demanded.
Current batteries produce adequate power. But, compared with gasoline, they store very little energy, so most travel, at best, about 160 kilometres between charges. They’re also very expensive.

Hydro’s institute is trying to devise better compounds for all the cell components, as well as new methods of applying them, to improve performance at a much-reduced cost.
It’s also working on a silicon-based anode that would dramatically increase energy storage, and just beginning research into lithium air, the ultimate, but extremely difficult, technology that promises huge increases in range.

APPENDIX E: GLOSSERY

CD	Charge Depleting
CDMA	Code Division Multiple Access
CS	Charge Sustaining
DSEA	Durham Strategic Energy Alliance
EDA	Electrical Distributors Association
EMPT	Electromagnetic Pulse Technology
ESA	Electrical Safety Authority
EV	Electric Vehicles
GPRS	General Packet Ratio Service
LDC	Local Distribution Companies
LF	Load Factor
OESC	Ontario Electrical Safety Code
OPG	Ontario Power Generation
RFID	Radio-Frequency Identification
SAE	Society of Automotive Engineers
TOU	Time of Use
UOIT	University of Ontario Institute of Technology