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City of Vancouver EV Infrastructure Strategy Report

December 2016

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Abstract

The role of the local government in supporting the growth and maintenance of a strong plug-in electric vehicle market in Vancouver is evaluated in this report. This report identifies areas of action in which a local government, such as Vancouver, can impact their region based on a thorough understanding of the current plug-in vehicle market, international demonstration projects, and research efforts. Specifically, workplace and public charging is needed to reinforce and fulfill the gaps from home-based charging in dense urban regions. Local government can encourage investments in workplace and public charging by providing clear regional guidelines for installers and customers, providing appropriate incentives to businesses, allowing for an innovative marketplace in the vehicle charging industry, and collaborating with the regional utility to identify specific opportunities for optimization and encouragement of utility rates and vehicle-grid interactions.

Abbreviations

BEV	Battery Electric Vehicle
BMS	Battery Management System
CA	California
CEC	California Energy Commission
CPUC	California Public Utilities Commission
DOE	United States Department of Energy
DSM	Demand Side Management
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
EVSE	Electrical Vehicle Supply Equipment
GHG	Greenhouse Gas Emissions
GVWR	Gross Vehicle Weight Rating
HOV	High Occupancy Vehicle (or carpool) lanes
ICE	Internal Combustion Engine
MOU	Memorandum of Understanding
NHTSA	National Highway Transportation and Safety Administration
OEM	Original Equipment Manufacturer (Automotive companies)
PEV	Plug-in Electric Vehicle, including both BEVs and PHEVs
PHEV	Plug-in Hybrid Electric Vehicle
PPP	Public Private Partnership
SAE	Society of Automotive Engineers (governing vehicle standards)
SCE	Southern California Edison
SOC	State of Charge
TOU	Time of Use (used in electricity rates)
QC	Quick Charging (also sometimes referred to as Fast Charging)

Introduction

Developing a robust market for plug-in electric vehicles (PEVs), including both plug-in hybrid electric vehicles (PHEVs) and battery-electric vehicles (BEVs) is critical to transitioning our transportation systems to a cleaner, low carbon future. Lower emissions vehicles will have measurable impacts on local air quality, global emissions levels, and citizens' health. While the role of public infrastructure in aiding the development of the PEV market is still unknown, it is one of the areas in which the local and regional government can play a role. The goal is not just growth of PEV sales, but maximizing the utilization of the PEVs in the region – thereby decreasing use of fossil fuels and emissions, which depends on a reliable and functional charging network. Throughout this report, specific actions and recommendations are italicized for clarity.

A recent poll suggests that the large majority of Canadians and British Columbians, 76 and 71 percent respectively, would like to own a car that is not powered by gasoline, including electric vehicles. The same poll further suggests that 81 percent of Canadians and 80 percent of British Columbians think that electric vehicles are the “way of the future” (Ipsos, 2015). With regard to the environmental impacts of displacing petroleum with electricity for transportation, 91% of British Columbians believe, according to the poll, that electric vehicles would bring about great benefits. These numbers would seem to suggest that Canada in general, and British Columbia in particular offer promising conditions for the market acceptance of plug-in electric vehicles. However, 66 percent of British Columbians and 67 percent of Canadians surveyed indicated that while they would like to own an eco-friendly car, electric powered cars are “too much hassle”. This last finding may be one important reason why the market uptake of plug-in electric vehicles in British Columbia (and Canada in general) is still slow. In 2015, there were just 6,661 plug-in vehicles sold in Canada, 0.35% of the new vehicle market, though that was an increase over the 0.27% of sales in 2014 (EV-Sales).

The Role of Charging Infrastructure in the Developing PEV Market

The recent National Academies Council on electric vehicles reviewed consumer surveys that suggest that public access charging stations, so far predominantly level 2, have not had a strong impact on plug-in vehicle sales. Instead, some of these surveys suggest that charging infrastructure may have a stronger impact on the *use* of plug-in vehicles (Transportation Research Board and National Research Council, 2015). In other words, consumers who already own plug-in vehicles become aware of the existence and geographical locations of charging spots, which leads to more public charging and more electric miles. These studies have not evaluated whether those miles replaced walking/biking or public transit use or just ICE vehicle use. UC Davis is currently conducting an empirical study of the effectiveness of various state strategies on the market uptake of plug-in vehicles, and preliminary results suggest that the impact of public access infrastructure may have not been as strong as expected. Simon Fraser University arrived at consistent conclusions in a recent study, namely that charging infrastructure has not shown a very significant effect on the market uptake of plug-in vehicles (Bailey et al, 2015).

All these findings should be looked at with an understanding of the context. Plug-in vehicles are still in an early market stage, and markets and related consumer behavior and learning continue to evolve. Much of the investment in charging infrastructure was done during the very early years of the market launch of these vehicles initiated with the EV Project (launched in select cities in the US in 2010), when very little was known about best practices for strategic deployment of this infrastructure. The early stage can be characterized as one of experimentation, where ideas are tested to learn about best practices. It is possible that investments in infrastructure were inefficient initially, failing to identify the best locations for installations, or not being able to deploy stations at desired locations. The most common factors that affected installing Electric Vehicle Supply Equipment (EVSE) was the willingness of the property or business owner to host the EVSE, installation costs, and parking location relative to electricity source rather than the desirability

of the location or expected demand.

We also hypothesize that the relationship between availability of public access infrastructure and plug-in vehicle adoption may be more indirect and complex. Our studies consistently show that public awareness of electric vehicles is low (Kurani, 2016) and that peer-to-peer communication is a key driver of awareness and likely of plug-in vehicle adoption (Axsen, 2010). Innovation scholars and practitioners have known about these peer-to-peer dynamics for decades, usually with the name of “contagion” (as the models used to study diffusion of innovations borrowed from those used in the study of epidemics). In this context, the role of public access charging infrastructure may be first to help existing owners of plug-in vehicles have a good consumer experience with the product. Once that happens, these consumers will feel more inclined to recommend plug-in vehicles in their social networks, which in turn can induce more plug-in vehicle adoption. *This speaks to the potential value of investing in charging infrastructure in settings where social interaction is likely—for example, the workplace.* One important message is to integrate effective planning as well as program evaluation into infrastructure investments, to ensure that earlier learning is incorporated and to document lessons learned that can inform future investments.

The value chain possibilities for electric vehicle charging infrastructure are more complex than those currently seen for conventional pump fuels. It is fair to state early in this report that the search for sustainable business models for the supply of stand-alone public access charging equipment is still open. It is helpful, however, to mention two elements that will inform our discussions. First, the fact that businesses and other organizations are installing charging stations at a cost, suggests that a business model exists, or at least that it is believed to exist. Second, conventional fuel stations make a significant portion of their profits from the sales of convenience store items rather than purely liquid fuels (National Association for Convenience and Fuel Retailing) due to the low profit margins on fuel sales. It is equally likely that EV infrastructure will also be dependent on associated sales

rather than purely electricity sales for the same reason, with the added constraint of a low cost, home-charging option for most PEV drivers.

Technology Background

This section includes a description of the electrical requirements for the installation of charging infrastructure, both for level 2 and DC Fast Charging, a review of the retail price of typical level 2 and DC fast charge equipment, and a description of electrical variables during charging, including how current and power vary during the charging event as a function of time and other variables (e.g. state of charge). All of these factors will affect the utilization, pricing, and business case for installation. Later in this chapter, we include some purchase and installation cost information from the early US market as a reference. Infrastructure type, installation costs, and dwell time will have a direct impact on the return on investment that an owner and operator can expect.

Charging Equipment – Type and Difference

The Electric Vehicle Supply Equipment (EVSE) or Electric Vehicle Charging Station is a device to transfer electricity from the electric grid and distribute electricity to plug-in electric vehicles. Electric vehicle charging is the process of converting AC electricity from the AC electric grid to DC electricity and storing DC electricity in DC batteries of electric vehicles. The power electronics used to convert AC to DC and to control battery charging is a “charger”. Two basic types of charging stations: AC charging and DC Fast charging have been defined according to where the charger is positioned. The difference is where the AC/DC conversion and the charging control is done. The diagram in Figure 1 illustrates where the charger is positioned.

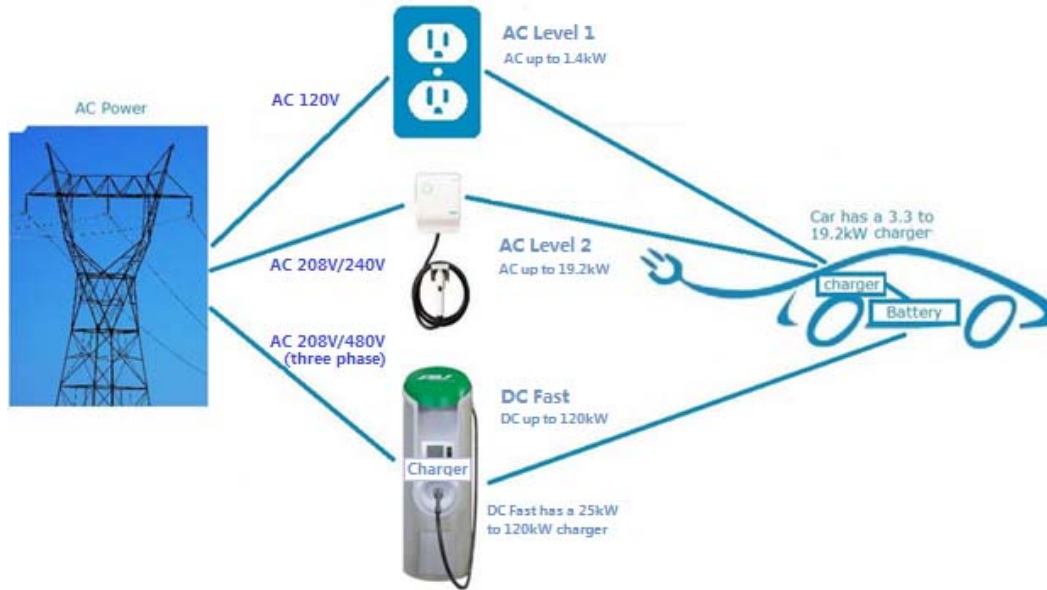





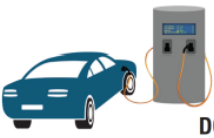




Figure 1. AC and DC Charging Paths (modified, source: pluginamerica.org)

All charging systems take AC power from the grid and convert it to DC power at a suitable voltage for charging the battery. AC Level 1 and AC Level 2 charging are low power charging and are implemented on the vehicle onboard charger. AC Level 1 and Level 2 charging stations merely deliver the AC power to the vehicle. DC Fast Level 1 and Level 2 Charging requires very high power and very large and very expensive power electronics. The AC/DC conversion and the power conditioning and control are exercised in the charger within the charging station. Table 1 summarizes the charging power, supply power requirement, and where charging happens for each charging level. For all types of charging stations, the onboard battery management system (BMS) integrated with the battery provides the charger the required constant current / constant voltage charging profiles.

Table 1. Power boundary between different charging types and levels [source: Bohn, 2013]

Charging Level	Setting	Supply Power	Representative Example	Where Charging Occurs
 AC Level 1	Residential/ Parking Lot 5 mi/hour @ 1.7 kW	120vac/20A (16A continuous)		RESIDENTIAL  1/3 of charging
 AC Level 2 (minimum)	Residential/ Commercial 10 mi/hour @ 3.4 kW	208/240vac/20A (16A continuous)		2/3 of charging
AC Level 2 (maximum)	Commercial (up to) 60 mi/hour @ 19.2 kW	208/240vac/100A (80A continuous)		
 DC Level 1	Commercial up to 500v @ 80Adc (up to) 120 mi/hour @ 40 kW	208vac/480vac 3-phase (input current proportional to output power; ~20A-200A AC)		COMMERCIAL  1/3 of charging
DC Level 2	Commercial up to 500v @ 200Adc (up to) 300 mi/hour @ 100 kW	208vac/480vac 3-phase (input current proportional to output power; ~20A-400A AC)		

AC Level 1 charging uses a standard 120 V plug, should be used on a dedicated circuit, though that is often not the case for standard home use case and existing household wiring. This charger is included with the purchase of a PEV, and is often referred to as the “convenience charger” and carried on-board and can be used in the case of emergencies. Many EV lessees do not install a level 2 charger at home, especially if they have access to workplace charging, and will instead rely on their convenience charger and existing electrical system. While this can lead to tripped breakers if multiple devices are in use on the same circuit, in updated homes with 20A rated, and no other devices, it can be an economical solution for those not dedicated to installing a charger and driving an EV in the long term. Any property with electricity can be a potential fueling point for the PEVs with a portable charging unit. The portable charging unit comes standard with the vehicle, and can only plug into conventional 120 V outlets found at home and businesses. Since the adoption of a standard connector – SAE J1772, every new PEV can be charged using any AC Level 2 charging equipment with the standard connector. For DC Fast charging,

there are three fast charging standards in various stages of adoption, CHAdeMO, Tesla Supercharger, and SAE J1772 Combo or CCS (combined coupler standard). CHAdeMO – Japan Electric Vehicle Standard, is the most established after a major push by Nissan for installing chargers. The CCS Fast Chargers are currently being installed by ABB and Chargepoint, and serve the American and German automakers who have agreed to implement that standard, but were later to market with vehicles, and chargers. Another available in the market is the Tesla Supercharger, but for now it is only a proprietary device, dedicated to the Model S and Model X. These three DC Fast charging interfaces are not physically compatible. Some EVs have two separate connectors to accommodate different charging standards. Other EV owners need to find the DC Fast charging station that's compatible with their EVs.

Wireless Charging

Wireless charging is a young technology that can be deployed in either dynamic or static charging applications, where energy is transferred wirelessly through a magnetic field, with a coil in the road connected to the power grid, and a receiver on the bottom of the vehicle. Currently, some companies such as PROOV are deploying static wireless charging for quick recharging at bus stops, where this could allow the busses to have smaller on-board battery packs. In addition, this charging could be used by multiple buses, on multiple routes, through strategic placement at transfer stops. There are many demonstrations of this technology, one example is operating in Den Bosch, Netherlands with 120kW wireless charging since 2012, shown in Figure 2. It is still a relatively expensive installation compared to standard charging, but may remove some aspects of operator error, and allow for reduced vehicle cost in the long term. Some analysis, for example by Dr. Micah Fuller was conducted evaluating the potential for dynamic (in-road) wireless charging for high-traffic freeways found that a high investment cost is needed, but that in the long term could be a more cost effective approach to extending range than increasing battery capacity (Fuller, 2016).



Figure 2: 120 kW Wireless Charging in Den Bosch, Netherlands.

The other application for wireless charging that may be viable in the nearer-term would be to assist handicapped users in adopting EVs, especially for home charging, since the multiple suppliers of wireless charging systems are not necessarily compatible yet. These systems are more expensive than standard level II home charging systems, so subsidies for their installation may help handicapped drivers adopt EVs.

If increasing EV adoption is the goal, and system expense is a secondary concern wireless charging can overcome lack of charging where users are either unmotivated or uncomfortable with the charging process, such as fleet/assigned vehicle applications, and car-sharing applications.

Wireless charging will be most transformative when there are automated vehicles or at least automated parking. Charging efficiency corresponds to alignment, which is achievable by automatic control. More importantly self-driving cars can charge themselves, allowing for very efficient use of a charging spaces and for self-driving cars to drive themselves to a charger which may be near, but not at one's destination, helping to solve the "last-mile" problem.

Available EVSE - Power and Cost

Even though the PEV market grows slowly, the charging station market is taking on rapid growth. The costs of a charging station vary widely depending on power levels, number of outputs, and if it's networked through one of the customer facing systems. Most charging stations do not support the full range of AC Level 2 charging or DC Fast charging. Table 2 lists major EVSE products available on the market, and the range of their power level and prices.

Usually AC Level 1 EVSE operates at 15 A/1.8 kW. Most PEVs come with an AC Level 1 EVSE cordset, so no additional charging equipment is required. Based on the vehicle onboard charger and circuit capacity, most of AC Level 2 charging stations operate at 30 A – 32 A, delivering 7.2kW – 7.6 kW of electric power, costing anywhere between \$450 - \$5000. The majority of current DC Fast charging occurs with either a CHAdeMo or SAE Combo interface and can provide 50 kW charging at 125 A with the price of \$19,000 – \$40,000. The numbers mentioned above and shown in the table below are purchase price only for the EVSE, and do not include electrical supply and installation costs.

Table 2. Major EVSE Make and Power Level (New West Technologies for US DOE, 2015)

Level	Make / Model	Max Amps & Power	Purchase Price
Level 1	ChargePoint CT2100 Series	10 A – 20 A	\$300 -
	ClipperCreek PCS-15, ACS	1.2 kW - 2.4 kW	\$1,500
	Eaton 120VAC Universal Receptacle		
	EV-Charger America EV2000	Most operate at 12	
	EVExtend Commercial Level 1	A – 16 A	
	Leviton Evr-Green 120		
	Shorepower WU-120, SC2-120		
	Telefonix L1 PowerPost		

Level 2	Aerovironment EVSE-RS	16 A - 75 A	\$400 -
	Bosch Power Max	3.6 kW - 20 kW	\$6,500
	ChargePoint CT2000, CT500, CT2100, CT4000 Series	Most provide 30 A -	
	ClipperCreek LCS Series	32 A, 7.2 kW - 7.6	
	BDT GNS, BBR Series	kW	
	Delta AC and Pedestal Mount		
	Eaton Pow-R-Station		
	Ecotality Blink		
	EV-Charge America EV2100, EV2200 Series		
	Evatran level 2		
	General Electric WattStation, DuraStation		
	GoSmart ChargeSpot RF		
	Green Garage Associates Juice Bar		
	GRIDbot UP-100J		
	Legrand Level 2		
	Leviton Evr-Green 160, 320, Level 2 Fleet, CT Level 2		
	Milbank EV Pedestal		
	OpConnect EVCS		
	ParkPod		
	Plug-in Electric Power (PEP) Level 2		
	Schneider Electric EVlink Outdoor, Square D Indoor		
	SemaConnect ChargePro 620		
	Siemens Smart Grid EVSE, VersiCharge		
	SPX Power Xpress		
	Telefonix L2 PowerPost EVSE		
	Volta Charging EVSE		
	DC Fast	ABB Terra 51 Fast Charger	60A-550A
Aerovironment Fleet Fast Line, DC Fast Charge		20kW-60kW	\$40,000
Aker Wade Level III Fast Charger			
Andromeda Power ORCA-Mobile		Most are 125A	
Delta EV DC Quick Charger		50kW	
Eaton Pow-R-Station DC Quick Charger			
Ecotality Blink DC Fast Charger			
Efacec QC50			
Epyon Power Terra 50.X System, 50.1 Charge Station			
EVTEC MobileFastCharger, PublicFastCharger			
Fuji FRCH50B-2-01			
Nichicon Quick Charger			
Nissan NSQC-44 Series			
Schneider Electric Fast Charger			
Tesla Motors Supercharger			

Next-Gen Fast	Expected charging for Porsche Mission-E (Fastned)	Up to 300kW	Unknown
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Plug-In Electric Vehicles – Power and Energy Requirements

Charging speed is not only governed by the power level of the charging equipment, but also limited by the size of the onboard charger and the capacity of the battery pack. The 2011 and 2012 model-year plug-in electric vehicles such as Nissan Leaf and Chevy Volt have a 3.3 kW onboard AC charger; by 2013, Leaf had offered the 6.6kW charging as an option. Honda Fit and Ford Focus EVs support charging at 6.6 kW. Tesla Model S comes standard with a 10 kW onboard AC charger or an optional dual AC charger of 20 kW. In the current market, most automakers bring compact PEVs with EPA-rated ranges of 120 -130 km, which have a battery capacity of 20-24 kWh. The Tesla Model S has either a 60 kWh or 85 kWh battery pack, which provides an estimated range of 270 km and 354 km, respectively.

The battery pack includes the battery management system (BMS) that integrates the battery and battery cooling system. The BMS monitors the key battery operating parameters of voltage, current and temperature, calculates the battery state of charge (SOC), and controls the charging rate. Usually, the battery is first charged at a constant current and then a constant voltage. The BMS provides the required current to the charger. Figures 2 through 6 show several daily charging power profiles measured from a workplace 6.6 kW AC Level 2 charger, with charging electricity consumption range of 6-60 kWh per charging event. These different charging profiles are just 4 examples measured at a single charger at UC Davis. Different EV manufacturers use various types of battery chargers based on the battery chemistry and the method to control the charging rate. All the charging starts with a constant current charging until the voltage reaches a set value. Then, some onboard chargers stop charging immediately, while some change to a constant voltage control and continue charging at tapered power to ensure the battery is fully charged. Figure 7Figure 4 illustrates the typical monthly usage of a workplace Level 2 charging station. These profiles help identify the variation of charging power

demand across hours and days and may help host organizations plan for the charging demand and utilization rules ahead of installation.

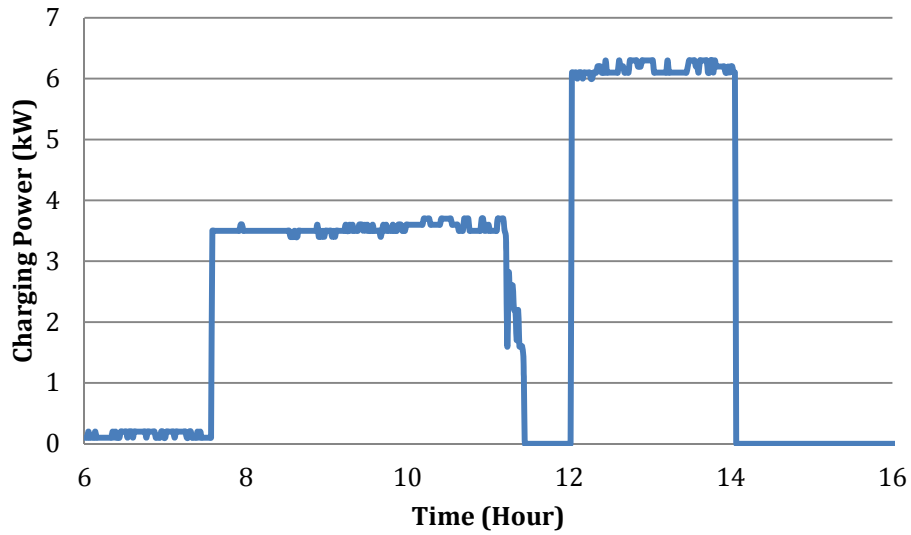


Figure 3: Daily charging load profile of a GE charger at West Village (Two vehicle charging at 3.5 and 6 kW, each withdrawing 12-13 kWh)

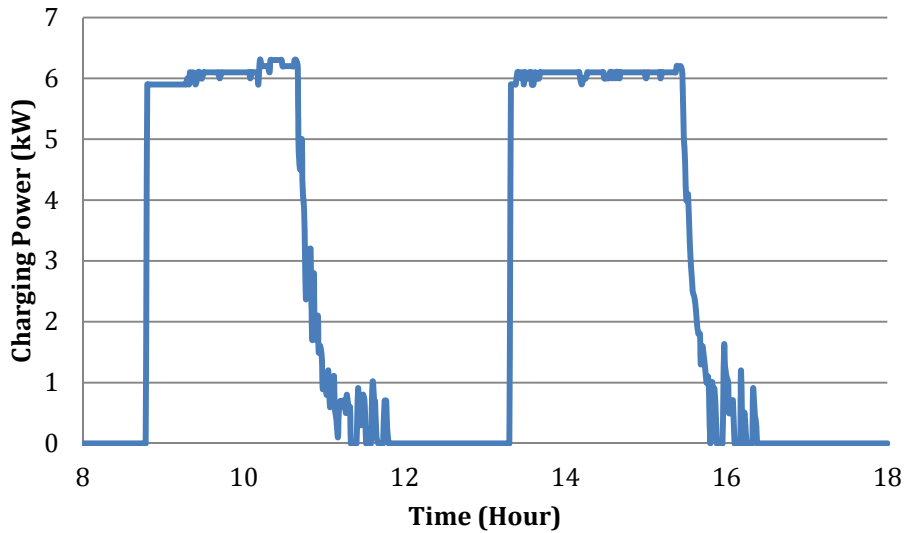


Figure 4: Daily charging load profile of a GE charger at West Village (Two charging at 6 kW, each withdrawing 12-13 kWh)

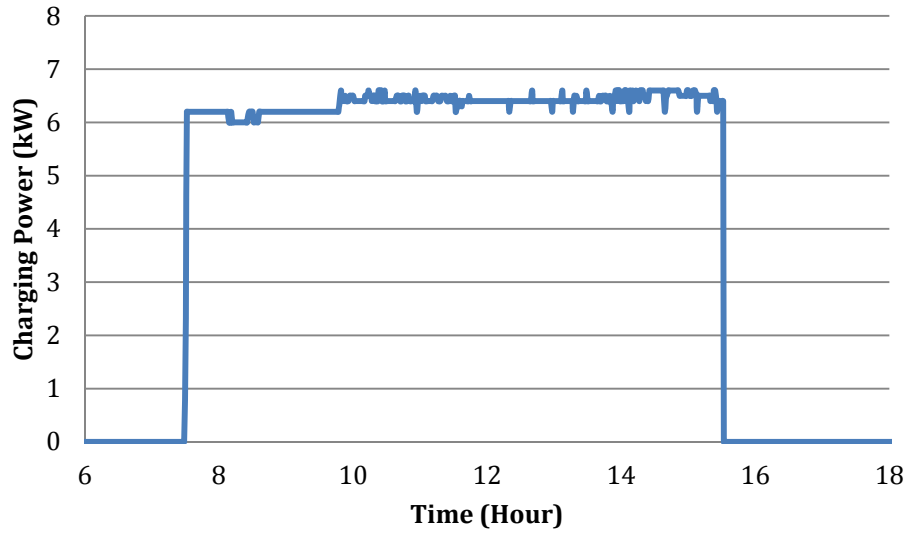


Figure 5: Daily charging load profile of a GE charger at West Village (One possible Tesla charging at 6.6 kW, withdrawing 50 kWh electricity)

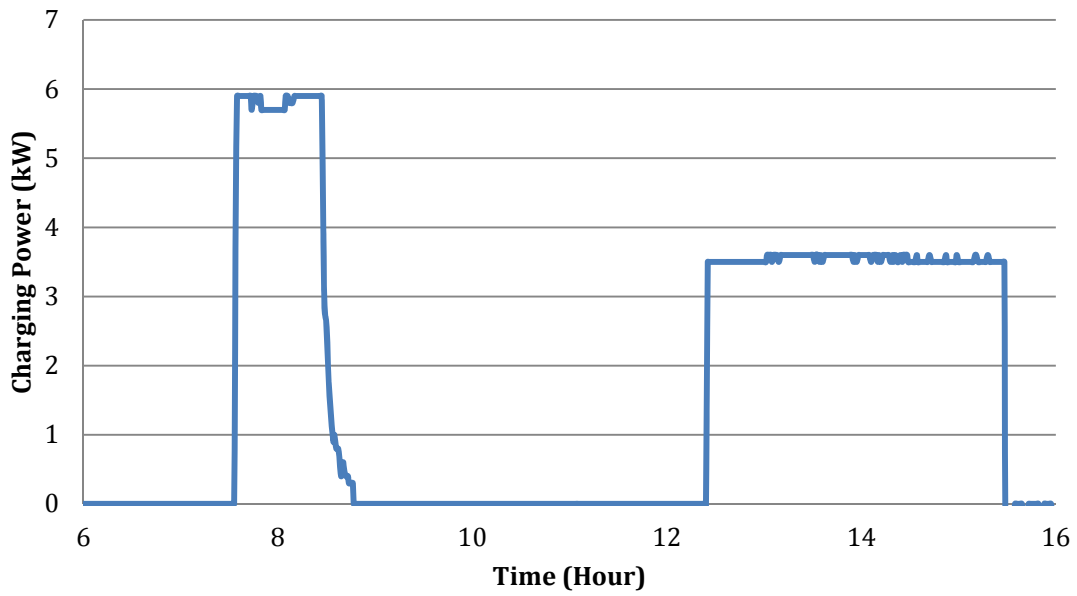


Figure 6: Daily charging load profile of a GE charger at West Village (Two vehicle charging at 6 kW and 3.5 kW, withdrawing 5 kWh and 10 kWh, respectively)

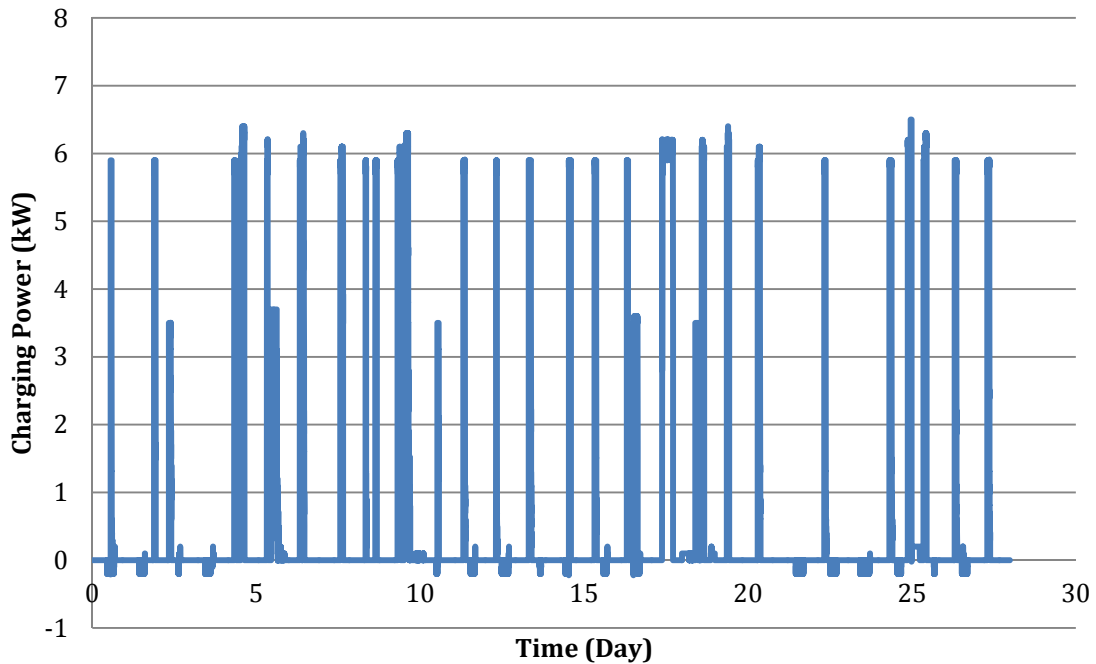


Figure 7: Example of a Workplace Charging Station Utilization over a one-month period (February 2015)

EVSE Installation – Cost and Siting

In general, installing an EVSE involves five significant steps:

1. Assess the installation site for the EVSE,
2. Obtain electrical wiring permits,
3. Coordinate with local utility company for electricity metering,
4. Installation of the EVSE and the electric panel upgrade, if necessary, by a licensed electrician or EVSE supply company
5. Operate the EVSE.

The specifics of each of these steps will vary significantly by site, and installation type – whether private, public (on-road, or parking lot) or semi-private (for example workplaces). The costs of installing charging stations include equipment, installation, operating and maintenance costs. In this section, EVSE installation data gathered over the past five years is presented as a point of reference for the Vancouver region.

Installation costs vary widely according to circumstances such as the availability and capacity of the utility supply. The average labor, materials, permit, trenching and repair, concrete work costs for installing a new charging station are summarized in Table 3 as of 2013. The parking and electricity payment management costs are not included in Table 3. The expected lifetime of the charging stations is 10 years or 10,000 cycles, and include manufacturer warranties of 1-3 years, though some analyses use EVSE system lifetimes of up to 20 years (Silver Spring Networks, 2010).

Table 3. Installation Costs in US dollars for Publicly Available EVSE/Charge Stations as of Sept. 2013 (EnergyStar, 2013)

	Publicly Available Charge Station Level 2 (Qty 2)	Publicly Available Charge Station DC Fast (Qty 2)
Labor	\$4,670	\$7,020
Materials (EVSE, panels, breakers, signage, etc.)	\$6,840	\$56,863
Permit	\$85	\$85
Trenching and Repair	\$4,500	\$1,500
Concrete Work	N/A	\$1,500
Total	\$16,095	\$66,968

A new report from the US Department of Energy in Nov. 2015, looked at average installation costs, as well as provided the range of installations costs per unit (Figure 8), and the average installation cost by regions that were part of the EV Project (Figure 9). These should help provide some context for the City of Vancouver to consider when planning for EVSE installations.

Ballpark EVSE Unit and Installation Costs

EVSE Type	EVSE Unit* Cost Range (single port)	Average Installation Cost (per unit)	Installation Cost Range (per unit)
Level 1	\$300-\$1500	not available	\$0-\$3,000** Source: Industry Interviews
Level 2	\$400-\$6,500	~\$3,000 EV Project (INL 20 15b)	\$600-\$12,700 EV Project (INL 20 15b)
DCFC	\$10,000-\$40,000	~\$21,000 EV Project (INL 20 15d)	\$4,000-\$51,000 EV Project (INL 20 15d) and (OUC 2014)

Table 4. Ballpark costs for EVSE units and installation.

*EVSE unit costs are based on units commercially available in 2015.

**The \$0 installation cost assumes the site host is offering an outlet for PEV users to plug in their Level 1 EVSE cordsets and that the outlet already has a dedicated circuit.

Figure 8: Installation costs as of Nov. 2015 (New West Technologies for US DOE, 2015)

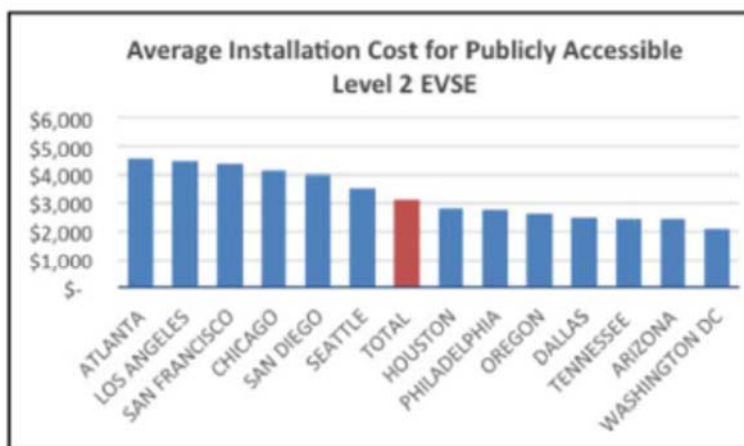


Figure 6. Average installation cost for publicly accessible Level 2 EVSE by EV Project market. Graph from INL (INL 20 15b).

Figure 9: Average Installation costs for Specific Regions from the EV Project (New West Technologies for US DOE, 2015)

Publicly available EV charging stations are AC Level 2 and DC Fast charging stations. Siting of AC Level 2 charging stations differs from DC Fast charging because of substantial difference in charging duration. Most DC Fast charging events last approximately 10 – 30 minutes, while AC Level 2 charging events last for 1-3 hours. Therefore, public charging stations should be planned near destinations where activities appropriately fit the waiting period. DC Fast charging stations should be

located along major highways and also close to regional destinations where 480 V electric grids are available. Shopping centers, restaurants, workplaces, parks, and theaters, etc. are good sites for installing AC Level 2 charging stations (Mayfield, 2012).

Commercial charging stations are often networked via the internet. Networked charging stations allow PEV users to manage their charging and reserve stations online, and also give charging system operators ability to multiplex distribution power to multiple EV charging. The degree of intelligence of the networked charging stations can have a significant impact on operating cost.

EV Charging Options by Location

The PH&EV Research Center at UC Davis has investigated four primary charging situations and three pricing scenarios (Nicholas and Tal, 2013). The charging situations are primarily organized according to their location - home, work, public, and fast charging, and are further detailed below. The pricing scenarios are free, less than or equal to home charging, and more than home charging.

1. Home charging – Primarily level 1 or level 2, used by the residents of a home or their guests. In single-family homes this is often in the garage or covered carport, and there is no competition for the parking spot or access to the EVSE. In multi-unit dwellings (MUDs) there may be assigned spots, or there may be competition for both priority parking and access to the EVSE.
2. Workplace charging – Level 1 or level 2 for employees of a specific company. The availability of charging at work may enable employees with longer commutes to still drive using only electricity when charging is available at the workplace. Free workplace charging can lead to shifting from home to workplace, and can lead to a greater number of chargers needed to prevent congestion versus a scenario that is priced.
3. Public Charging – Primarily level 2 charging that is placed in shared use or

single business public parking lots or garages, for purposes other than workplace. Providing access to an EVSE may encourage visits or longer stays at specific businesses. The EVSE is owned and maintained by the garage or business and decides on the fee structure, if any. Public charging, as in the case of a downtown parking garage, may serve as both workplace charging to employees of nearby businesses, and public charging for customers of nearby businesses.

4. Fast (Quick) Charging – Also called DC Fast Charging (and mistakenly referred to as Level 3), Fast Charging provides significant range to the vehicle in a short amount of time. This can be used en route to a destination, but can be a substitute at a destination when level 2 is unavailable. Additionally, some use will result from those who normally charge at home but forget to charge or have unusually high travel needs on occasion. Customers prefer Fast Charging locations that also provide other amenities. Due to the high current, this requires electrical service upgrades at most locations, and would be the highest cost per kWh to the customer.

Home Charging

Early scenario modeling of the role of charging in meeting current travel demand shows that home charging meets ~71% of current VMT for a Battery Electric Vehicle with 80 miles (129 km) of electric driving range (BEV80) annually for California drivers. While the details of Vancouver travelers may alter this finding somewhat, the ratio of miles provided by home charging vs. public vs. DC fast charging is likely to be similar. In Vancouver, daily travel demand may be lower, for example, but availability of home charging may also be lower.

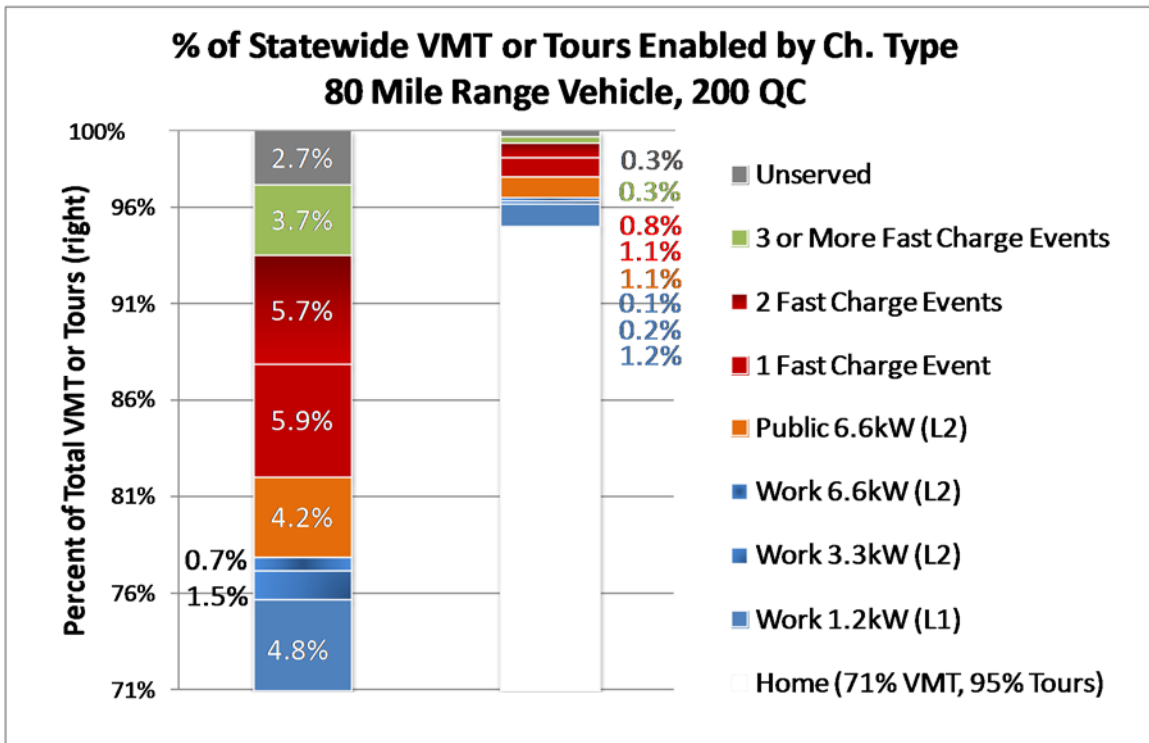


Figure 10: Breakdown of miles gained versus frequency of potential charging need (Nicholas et al, DC Fast Charging in the Context of Bigger Batteries, 2013)

In this scenario, the assumption is that everyone in the state of California drove a BEV 80 for one day and charged at every work stop if they needed it to complete their travel, and included 200 Quick Chargers (QC) distributed throughout California. This is a paid scenario. 71% of driving could be done with only home charging assuming drivers are comfortable with arriving home with at least 8 km left (changing this to 16 km reduces the “home-only” kilometres to less than 71%). Level 1 at work enables an additional 4.8% of travel while faster level 2 is needed for an additional 2.2% of driving. For those who did not work or needed additional charging before or after work level 2 at stops longer than 1.5 hours added an additional 4.2% of kilometres. Fast charging (or Quick Charging), while less likely to be used, has a potential to add 6%-12% additional kilometres when all level 2 has been exhausted. Although, this graph shows the technical potential of providing up to an additional 29% of km for lower range BEVs, these charging events only occur on 5% of tours per day. A tour is a round trip from home back to home. This

scenario gives a sense of the relative role each type of charging can play for a BEV, however, a discussion of each category is useful to give further context.

For home charging we see a trend towards level 1 even in some homes with the popular Nissan Leaf as shown in figure A.

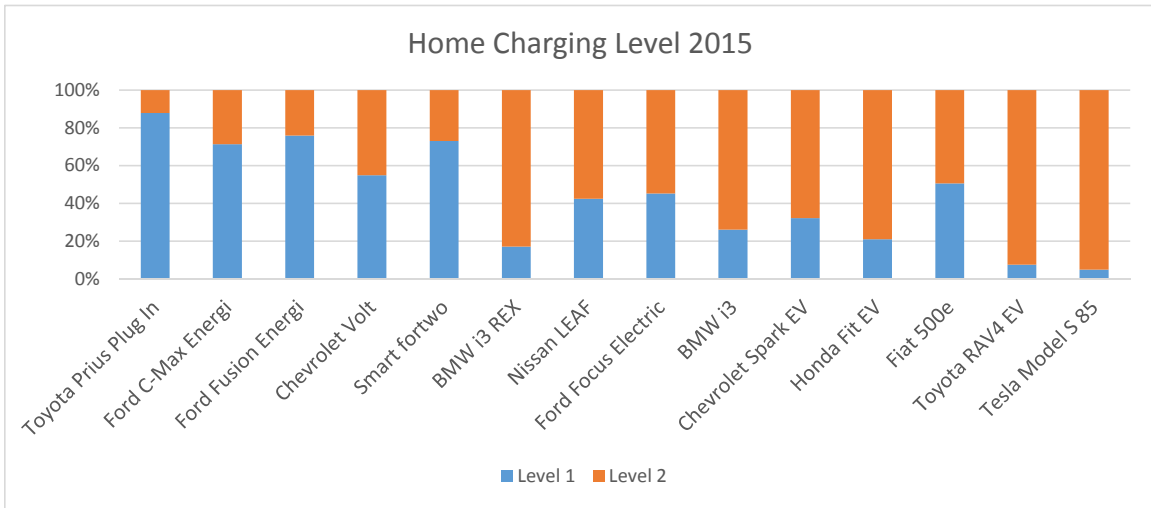


Figure 11: A UC Davis 2015 California survey of ~5000 households

The vehicles are ordered by electric vehicle range (low to high from left to right) and we see a general trend for PHEVs to have level 1 at home and BEVs to have more level 2 at home. However, we see a significant number of people managing initially with only level 1 and only later switching to level 2 with other household upgrades. Leased vehicles are also more likely to only have level 1 at home perhaps signaling less commitment to the technology

Workplace Charging

Additional research at UC Davis’ Plug-In Hybrid & Electric Vehicle Research (PH&EV) Center investigated the role of charging at workplaces, and specifically, the impact of paying for charging at work. Based on a survey of about two thousand CA PEV users, we found that of current PEV drivers with workplace charging, 78% reported that workplace charging was free to use. There are benefits of free workplace charging for both the employer and employees. For the employers, this

includes simplified EVSE installation and operations/administration costs (no service provider needed, since no revenue is collected), avoiding the impression of pettiness in charging for electricity used, and an improved “green image” for the company, (something that provides a tangible benefit to employees).

The biggest detriment may be that it switches home charging to workplace charging for those who don’t need it, therefore not increasing electric vehicle kilometres traveled (eVKT) compared to a priced charging scenario. This can lead to congestion at the chargers, and particularly for BEV drivers who may rely on access to workplace charging, a subsequent decrease in dependability. For all PEV drivers, the demand drops as the price for charging goes up from free to the same as home to double the price of home charging. However, BEV drivers, compared to PHEV drivers are much more willing to pay double the cost of home charging on an infrequent basis – in other words, they are willing to pay a high price when they really need the electricity.

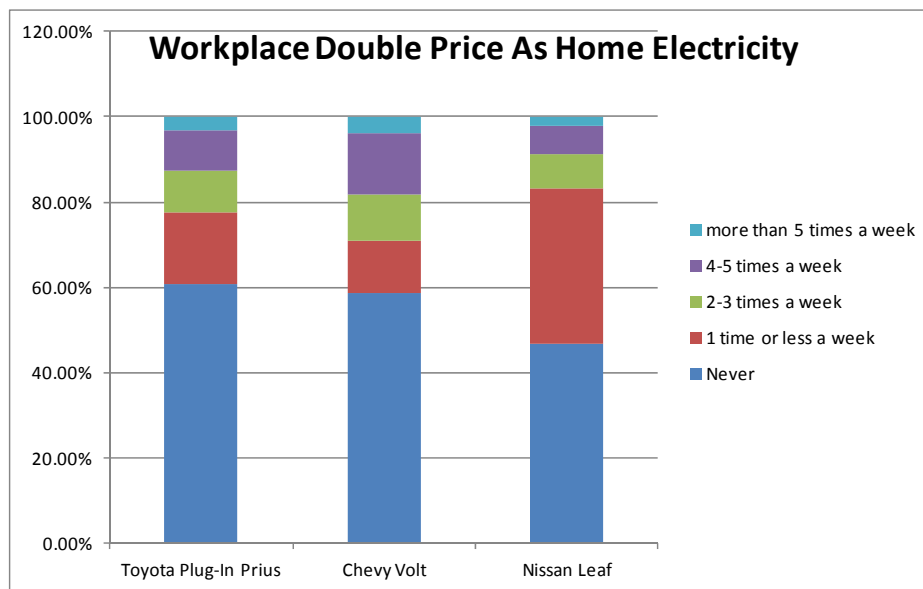


Figure 12: Potential Demand for Workplace Charging by Vehicle Type when the cost is double that of home electricity (Nicholas and Tal, 2013, Charging for Charging at Work)

A multi-state survey conducted by UCD researchers at the end of 2014 led to the conclusions that 30% of PEV drivers have some level of congestion at their workplace, but that paid chargers are 1.7 times less likely to experience congestion. Our survey results showed that at least 53% of people who did not need workplace charging charged anyway when they had access to free, uncongested charging (Nicholas, SACOG Seminar 2015). This led to the conclusion that moderate fees (slightly higher than home electricity prices, but less per mile than the cost of gasoline) for workplace charging will provide access to chargers for those who need it – either due to long commutes or a lack of home charging – with minimal congestion caused by unnecessary use of free charging. Figure 13 compares the break-even cost per mile of different PHEVs and a Nissan Leaf.

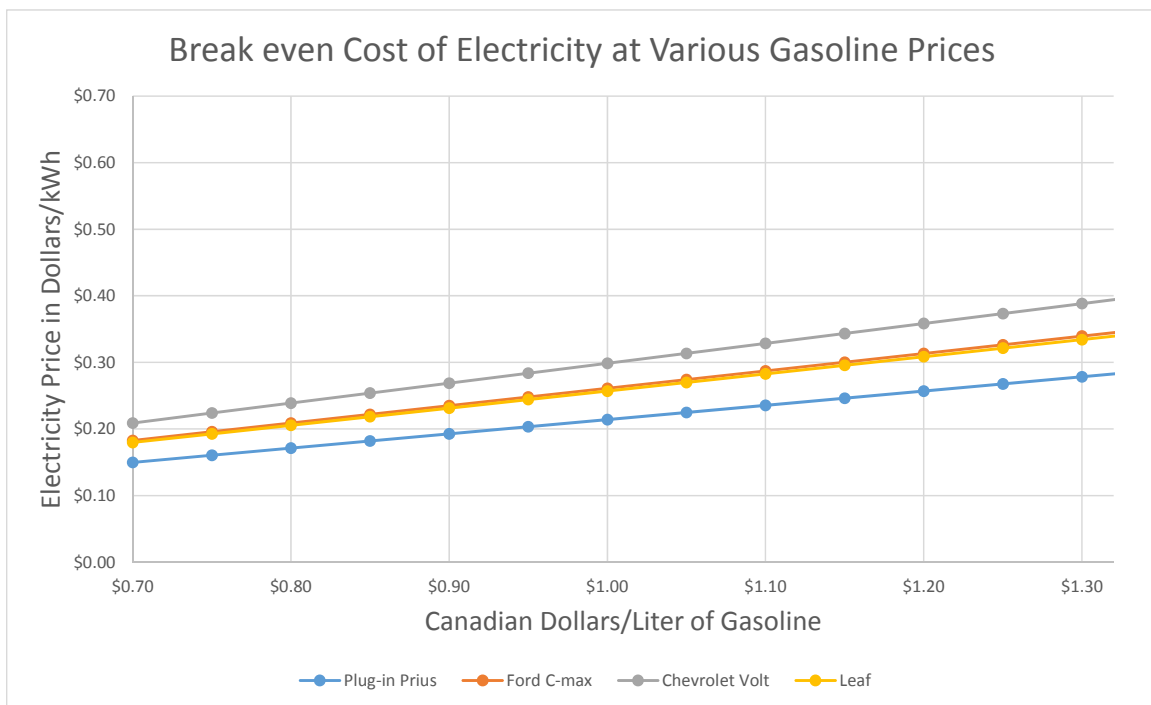


Figure 13: Break even cost of electricity at various gasoline prices

Figure 13 shows that workplace electricity can be no more expensive than \$1.00 CAD/liter or \$0.25/kWh and should be above current home electricity prices to maximize the use of infrastructure, without causing unnecessary congestion at public charging locations.

Based on this survey, and the assumption that a charger can charge two vehicles per day, we estimate that between 8 and 12 chargers are needed per 100 plug-in vehicles in the workplace. 20 Chargers should be sufficient if chargers serve less than two vehicles per day due to timing and parking coordination constraints. With free charging that number climbs to 40 chargers assuming two vehicles per charger each day. 25-30 chargers are needed per 100 plug in vehicle with a price equal to home. This assumes a mix of PHEVs and BEVs. As the range climbs to 200 miles for a BEV, you would need 27 if free, 16 if equal to home, and 2 chargers if more than home electricity price. In this case range is a substitute for charging infrastructure.

Public Charging

Level 2 public charging may provide an added benefit to help bring customers, who may have gone to a competitor, or to incentivize customers to shop for longer in order to maximize their use of retail charging, though in many retail locations the distance from home is not very far. Public charging for 30 minutes would provide about 4 miles of range at 3.3kW or 8 miles of range at 6.6kW. PH&EV Center analysis of California's Department of Transportation (Caltrans) data concludes that public charging at retail locations is complementary to workplace charging, and has an additive effect in terms of electric kilometres enabled, but does not subtract from the need for either home or work charging (research in progress presented by Michael Nicholas at EV Roadmap 8, July 29-30, 2015).

All public charging is not equal and need can be estimated by distance from home and dwell time as shown in Figure 14 and Figure 15.

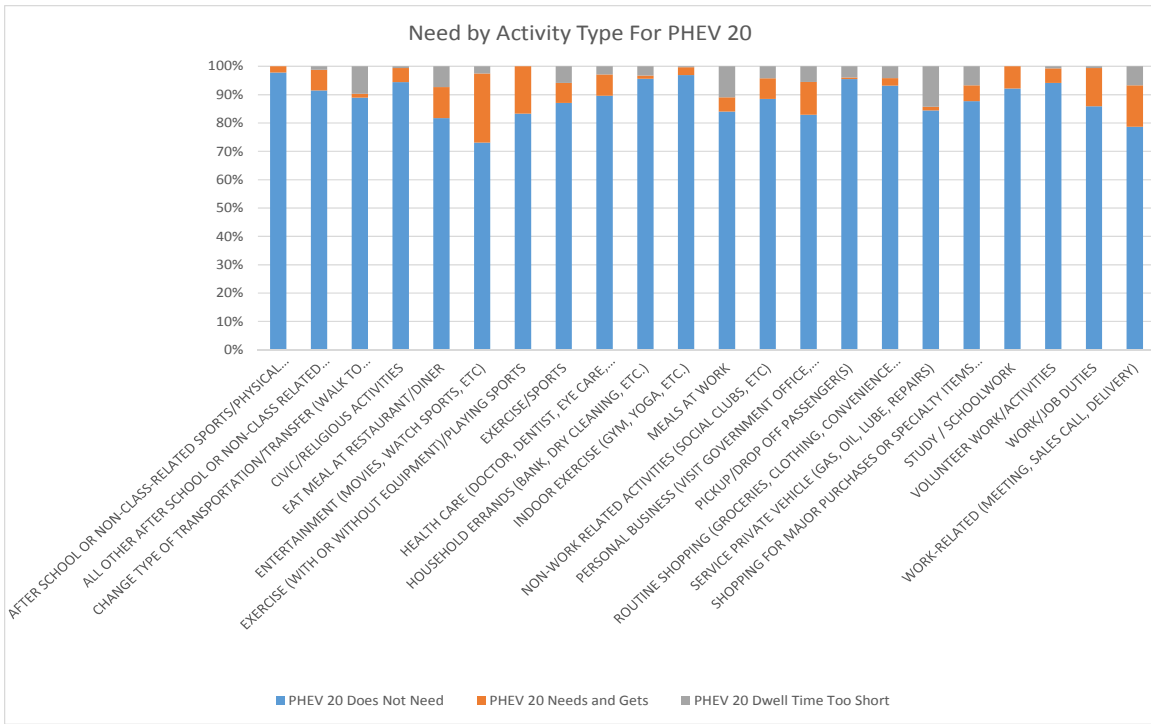


Figure 14: Need for charging for PHEV 20s (20 mi or 32 km of electric driving range)

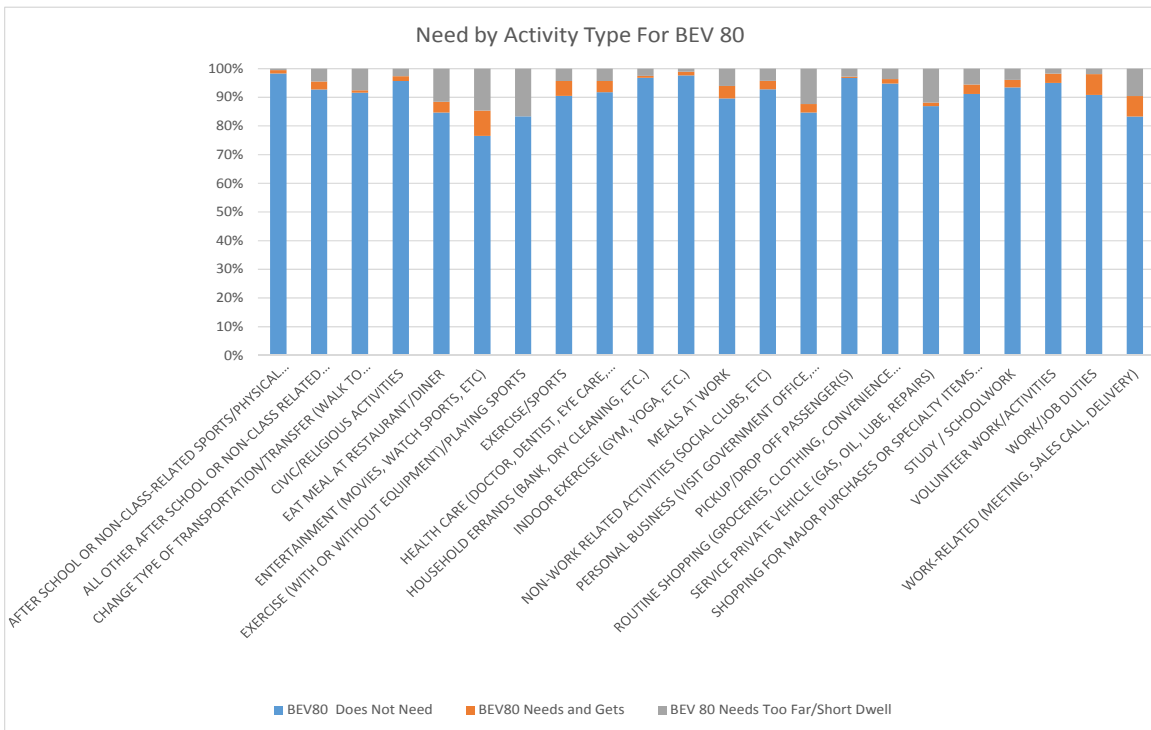


Figure 15: Need for charging for BEV 80s (80 miles of 129 km range)

Figure 14 shows the need for PHEV charging where the distance is more than 16 km (10 miles) from home and the dwell or parking time is enough to return the user home on electricity or the dwell time is sufficient to get at least 16 km of range additional. Many trips do not meet these criteria. All round trips in blue are too short to require charging. All trips in grey are far enough away, but dwell time is too short. Linked trips (a series of trips that link without a return to home between them) will change this estimation, but the relationships should be representative. For example, sporting events have long distances to reach them and have long dwell time. These are good places for chargers.

There are a few potential business models for operating public charging. Parking garages owned by the city/local government, may offer free charging with paid parking for PEV drivers as an incentive to increase adoption. In some cases, like the city of Sacramento, electricity is free, and the parking spot is discounted for PEV drivers. In privately owned parking garages or multi-tenant retail locations, the owner purchases the EVSE, but operation and billing is subcontracted out to a network operator. Finally, in some cases with standalone retailers (or anchor stores in multitenant locations), the retailers own the chargers and offer the use for free, some offer up to 2 hours of free electricity, after which the user pays a set rate per hour or per kWh. The options for infrastructure owners and operators is discussed further in the “Basic Models of Infrastructure Ownership” section below.

Fast Charging

DC fast charging provides approximately 80% state of charge (SOC) to a current electric vehicle in approximately 20 minutes. This makes fast charging better suited to connecting neighboring regions by providing charging en route or at either end of a longer driving tour. A less obvious, but equally important function of fast charging is acting as a back up to congested level 1 or level 2 chargers, and as a community resource for those without home and/or work charging. Using both real-world

travel data and survey answers, UC Davis researchers have investigated the role of DC fast charging extensively.

As shown in Figure 10 above, fast charging (one or two events per day) can allow for approximately 10% more miles traveled on electricity in the case of an 80 mile (129 km) range BEV under current California usage patterns. The reason we look at the role of fast charging under this restriction is based on survey responses from current BEV drivers. 100% are willing to fast charge once per day on occasional long tours, this drops to 49% who would be willing to stop twice on an occasional long tour, and even more significantly, only 12.5% of current BEV drivers would be willing to stop three times in a single tour. As the range of BEVs increases with coming vehicle models, home and workplace charging will still be the most significant source of electricity for the vehicles, but fast charging will allow for the rare long range tours to be accomplished using an electric vehicle and reduces the number of miles that are seen as unlikely to be served or unserved for shorter range vehicles with a moderate charging network (Nicholas et al 2013, CA Statewide Charging).

The Impact of Demand Charges on Fast Charging Costs

Utilities must meet the demand for both power (kW) and energy (kWh) on their grid. While typical residential and commercial loads ramp up and down slowly over the course of a day, in terms of their power demand, fast charging inserts a sudden brief spike in demand. To manage high peak power demand, utilities employ demand charges that are based on the peak monthly demand that a customer requires. While the load profile of Fast Chargers is not likely to be a problem for utilities in terms of load, they are still subject to demand charges, and their load factor is lower than typical commercial users. Thus, while the energy (kWh) costs may be slightly lower, the fixed power demand charge would be the same whether it is divided over one charging event per month or 300 charging events per month.

The Electric Power Research Institute (EPRI) performed a simple analysis of the potential electricity cost per charge, for a 50kW charger providing 20 kWh per charge, from an example CA utility using two sample rates, one of which included demand-based charges. Their results showed that for winter fast charging, a cost of approximately \$5 per charge could be achieved with 15-25 charges per month on an energy-only rate, but would require 100-150 charges per month to reach the same cost during the winter on an electricity rate with demand charges. Interestingly, on an energy-only rate during the summer, even with 300 charges per month, the expenses would still not drop to \$5 per charge. On an energy + demand rate, after 250 charges per month the costs would drop below \$5 per month (EPRI, 2014).

This analysis demonstrates the need for additional critical thinking on appropriate, or tailored electricity rates for the unique operating profiles of Fast Chargers, which can help lead to both economical costs for consumers and operations for the owner and utilities, especially early in the market when utilization of fast chargers is still low.

The Business of Charging

In this chapter, we will present the various business models that have been successfully and not-so-successfully implemented in the nascent EV charging market, as well as potential future opportunities to build a successful business case around public charging. Specifically, some early concepts, such as video or audio advertising at the EVSE may no longer be viable, since the smart phone has become ubiquitous and diverts the attention of drivers while they wait for their vehicle to charge. However, there are other potential revenues around the data gathered from the devices, and improved grid integration to provide some demand-side load management, which still need to be explored. Finally, we present the workplace

charging investment model, which is implemented as a component of a complete human resources benefits package to retain and recruit employees.

Infrastructure Operation Business Models

We discuss briefly three EVSE operating models: EVSE network operators, EVSE infrastructure owner & operator, and financial lease construction.

EVSE Network Operators including current companies ChargePoint, Semaconnect, and Liberty Plugins, generate revenue by selling hardware (in the case of ChargePoint), as well as through network fees paid by site hosts to manage the billing and access to the EVSE. In this case, the host pays for the electricity use, and the network operator manages billing of customers – the “back-end” of the EVSE network system. For network operators, the host decides on the pricing terms, and can have free, time-limited free, or fee-based electricity. Network operators may be interested in expanding their networks in order to have the most comprehensive charging coverage to offer their customers. This offers them a competitive advantage over other EVSE network providers, which can help them recruit new customers. They expand their networks in one of two ways, and earn revenue based on host sites paying them to manage the access and billing of customers.

In the first case, the network can pay sites to place their charger. This approach may be used when external (governmental) funding is available to install EVSEs, or for sites that may be seen as “critical” sites for customer satisfaction.

In the second case, the EVSE host purchases the EVSE and then pays the network operator either a set monthly fee or a percentage of revenue generated by use of their charger.

ChargePoint network operates exclusively their own chargers which they sell to host locations. ChargePoint may be contracted for maintenance of the chargers, but is not responsible for keeping them operational once they have been sold. In

contrast to ChargePoint, Liberty PlugIns can operate the customer billing/networking for many different EVSE manufacturers.

Infrastructure owner/operator companies (EVGo, Car Charging Group (formerly Blink network owned by Ecotality), and Tesla): Under this model, a company supplies and owns the infrastructure and the back-end networking and billing capabilities, and determines the fees for use. This model has been compared to that of mobile telecommunications companies, which invest in infrastructure and then charge clients for the use of that infrastructure via their mobile devices. Obviously, the success of the telecommunications industry does not imply that the same model can successfully be used for electric vehicle charging infrastructure. Companies adopting this model in its most general form typically have relatively large capital expenses, and fixed costs dominate variable costs, and thus return on investment (ROI) is strongly dependent on higher user throughput (i.e. infrastructure utilization). The primary source of income is the monthly subscription fees that users pay to the infrastructure company, regardless of whether they use electricity in a given month. The infrastructure company then charges a reduced rate for charging for monthly subscribers compared to the general public, or all their charging may be included in the “premium tiers” of membership.

In the case of Tesla, they request bids from prospective host locations in a competitive process. The host site then has the benefit of the charger at their place of business at a cost they deem acceptable, since Tesla does not charge the customers for use of the electricity. In this case, the cost of installation and operation would be part of the competitive bid that a host proposes. This may include the host site providing an “install-ready” location, premier parking location, or free electricity.

In the financial lease construction business model (used by Blink), organizations simply enter a lease agreement with a supplier by which the charging equipment is installed in the organization’s facilities and used (say by employees or customers) for a fee (typically monthly or annual). This was not a popular option for host sites

due to the terms being offered, which included the host site preparing the site for installation, paying for the electricity, and renting the use of the charger on an on-going basis. This may have been economically feasible with large government support for installing infrastructure, but is unlikely to be a viable business plan in the long term.

While Langezaal and Bouman (2011) project the emergence of corporate investment on charging infrastructure by offering access to such infrastructure for a monthly fee, similar to the case of mobile telecommunication, we do not see this being the case, particularly in the early stage of EV market development. For one, cell towers and charging stations differ in the user throughput they can accommodate. EVSE offer “physical” access to one user at a time, while cell towers offer “airwave” access to multiple users simultaneously. While one cell tower is sufficient to provide connectivity for its area of coverage into the broader network, one single charging station cannot guarantee coverage to all prospective users in a given area. Corporations pursuing a monthly-fee model would need to plan on significant investments to ensure adequate service to end users, and a competitive scenario involving multiple corporations will lead to overlapping investments. Subscription-based models are attractive for early stage markets because they help with revenue benchmarking, though for this particular market end users would need to subscribe to multiple suppliers in order to ensure access to charging services. EVGo has tried the subscription model with varying levels of success.

Revenue flows vs. value proposition

A study prepared for the State of Washington says that “At a minimum, a promising EV charging project must show that the charging station owner-operator will receive direct and indirect revenues that are sufficiently greater than the total project cost to generate profit” (C2ES, 2015, p. 36). We want to expand beyond this argument and offer three broad considerations:

- a- We believe that a stand-alone EVSE project will not be able to pass this financial test early in the PEV market development, further development of the market will eventually lead to a high enough number of paying customers.
- b- We believe that direct (net present value) revenues cannot offset the (net present value of the) project cost, particularly when the financial projections account for uncertainty in demand;
- c- We believe that when the EVSE industry will pass this test no public intervention will be needed similar to the gas station industry today.

For example, on a \$5,000 installation, paid back over 10 years, a business would need to recover \$1.37 per day. As a consequence, we propose that EVSE investments ought not to be assessed on the basis of conventional revenues flows, but rather on the basis of value proposition.

We define the charging station as the combination of the charging equipment, embedded/related information technology (as applicable), and the space assigned for the vehicle while charging. We consider direct revenues as the revenues arising from the duration of the use of the charging station. Different from these are indirect revenues, which we here define as those revenues arising from the availability of the station.

Charging services as a stand-alone business will be economically challenging. Like liquid fuel sales, electricity fuel sales will likely have a small profit margin, and require high utilization of the investment. Unlike liquid fuels, many PEV drivers, especially in the early market, will have a home refueling option (Axsen and Goldberg, 2016) that largely satisfies their daily driving needs. In a multi-state study of current PEV owners conducted in late 2014, 57% of respondents reported only plugging in their car at home within the last 30 days prior to completing the study, leaving less than half of the PEV buying population that either occasionally uses or relies upon away from home charging to meet their travel needs (EPRI, 2016). This is a very different utilization rate than our current liquid fueling system.

The capital and operating costs of the equipment and installation exceed the possible discounted revenues from the use of the equipment projected over its lifetime, even at maximum economic utilization rate. We define economic utilization rate as the ratio between the actual utilization of the equipment to the (realistic) revenue-maximizing utilization. The latter is generally rendered when the equipment is continuously used, although the maximum feasible realistic revenue under a continuous-operation scenario will depend on the billing system (e.g. it would be different for a system that charges per kilowatt-hour compared to one that charges for the access to the equipment). A simple financial analysis confirming this conclusion was included in (C2ES, 2015).

If the price of electricity is, for example, \$0.15 per kWh, then the electricity cost of topping an onboard battery could well be in the order of \$1.5. Let us first recognize that consumers understand prices differently depending on the context. For example, consumers may assess the “goodness” of a \$1.5 deal by comparing to what they would pay charging at home, or they could assess it compared to what they would have spent on a comparable amount of liquid fuel. The former is more likely the case among PEV users, while the latter may be more likely among *prospective* PEV owners.

The distinction is important for business and policy decisions. If the residential electricity rate is the mental reference for prospective users of public-access charging infrastructure, then programs or policies that affect the difference between rates for public and residential charging can lead users toward one of the alternatives. For example, a preferred electricity rate for PEV residential charging would diminish the business case for public-access infrastructure. Similarly, policies to support the widespread deployment of solar generation capacity will tend to deflate prices during daylight hours thus, potentially, place public charging rates at a competitive advantage vis-à-vis residential charging. While we expect PEV owners to be better educated on electricity rates and pricing, the recent EPRI-UC Davis multi-state survey of PEV drivers showed that there were still 16% of respondents

who did not know what electrical rate structure they had for their home. On the other hand, 21% had moved to a Time-of use or specific EV rate for their vehicle or vehicle and home electricity use, and 8.1% of respondents had changed their rate in some way after purchasing their PEV, indicating that some education and awareness of rates had occurred (EPRI, 2016).

Considering the frame of reference of *prospective* PEV owners is also important to understand business models for charging infrastructure. To the extent that access to charging infrastructure at advantageous rates (compared to gasoline) helps with PEV market uptake, it makes business and policy sense to think about the value of infrastructure in conjunction with the value of new plug-in vehicle sales. This, of course, is the perspective that governments have taken over the last few years— financing infrastructure as an investment to incent market adoption of plug-in vehicles. It is also the strategy that governments are trying to transition from, into models that are not dependent on government subsidies. For corporate entities with a vested interest in the market development for plug-in vehicles, on the other hand, investments in infrastructure are a natural component of their strategy. This, it should be highlighted, is more the case for companies committed to selling battery electric vehicles. Nissan and Tesla have demonstrated this with investments in charging equipment, particularly high-power equipment (50kW and higher), to support longer-distance travel. In the case of Nissan, they have installed DC charging at many of their Nissan dealerships in areas with significant Leaf sales. Tesla has installed 602 Supercharger stations throughout the US, Canada and Europe, operating 3,519 Superchargers (www.teslamotors.com/supercharger Feb. 2016). Corporations with a stronger focus on plug-in hybrid electric vehicle offerings will not face a strong incentive to invest in infrastructure because their customers value, but do not actually depend on, access to charging.

From a public-private partnership perspective, understanding corporate motivations is important. Governments interested in the development of charging networks and/or corridors will typically find willing partners in PEV-oriented

companies. They could also think about creative ways to invite PHEV-oriented companies to join such partnerships. For example, state and municipal incentives for PEVs (e.g. sales tax exemptions) could be tied in some form to the level of engagement by the car companies in the process of planning and deployment of charging infrastructure.

In the early days of PEV market deployment (2009-2012), it was commonly thought that businesses would be interested in leveraging charging infrastructure to a) attract customers and b) market themselves as green and innovative. After an investment of a few thousand dollars to install the equipment, businesses would be in a position to offer free charging (possibly along with parking validation), absorbing the small operations costs and packaging them as “complimentary”, on hopes that users would spend more time and money with them. The need to wait for the battery to recharge could act as an incentive for customers to stay at the store longer than they otherwise would.

In this early market however, there were a few hurdles for host businesses to overcome. The largest hurdle is that the hosts are unfamiliar with the costs, risks and benefits of installing and operating a charging station these include:

- Liability associated with EVSE operation,
- Reliability of the EVSE, including the potential for upset customers
- Maintenance costs, parts and labor for hardware failures, and ongoing network fees
- Electricity costs, specifically the potential for triggering steep demand charges,
- Potential “image boost” to the host company
- Additional customer expenditures while charging, (ie. Increase in average transaction amount for customers who charge while they shop) customers may make additional unplanned visits to a store, spend additional time at a store, or choose one store over a competitor who doesn’t offer charging)

- Legal requirements governing disabled persons' access to charging in parking spots
- Technology turnover, ie. whether the EVSEs currently available will meet the needs of PEVs produced in 5-10 years
- For workplace charging, the benefit, or perceived value for employees of having workplace charging available.
- Average payback time for investment costs

This lack of resources and experience is enough to scare off many business owners. The second reason is that there are relatively few PEV owners, to attract in these early years. *One strategy that cities or regions could employ in trying to encourage companies to install and host EVSEs would be to create an informational resource that addresses these unknowns based on the past five years of experience. This resource could include specific local utility information, local experienced electricians, information on the local requirements for installation and inspection, and more general information on costs, reliability and non-financial benefits.* Specifically, additional research evaluating the potential increase in revenues for stores or shopping centers by customers who charge while they shop, and perceived value of workplace charging as an employee benefit, could be instrumental in encouraging retail and workplace locations to install EVSEs.

IT and Data: An important part of the value underlying EV charging infrastructure.

Information Technology (IT) defines the intelligence of the charging infrastructure and how it integrates into a network and into a broader system of electricity supply and demand. The latent value of IT in the creation of future successful business models for infrastructure cannot be overemphasized. Indeed, the hardware involved in providing charging services is “off the shelf” technology and a business that was predominantly built around the equipment would have essentially no barriers to entry. Unfortunately, while the EVSE technology is available, the demand for charging is still limited. Consumers are also unwilling to pay very high prices for

electricity, especially compared to either gasoline or home electricity, as discussed previously. In regions with high gasoline prices and low electricity prices, like Vancouver, charger access can be priced to allow for a small net revenue. In places with low gas prices, charging cannot be priced high enough to allow for a near-term revenue stream, without turning away customers.

↑ Gas prices + ↓ electric prices = small net revenue

↓ Gas prices + ↑ electric prices = no short term revenue

Gas prices + electric prices + potential IT revenue = ↑ potential net revenue

The potential business case, and competitive frontier, likely lies on the development of technologies that govern the operation of the infrastructure and the processing of massive amount of real-time data. However, charging operations and data processing can be done either at the equipment or at the vehicle. In fact, because charging control is (or can be) ultimately under the onboard charger, an IT-based business case for charging infrastructure may be undermined if the automakers choose to act on this.

Control of charging operations is a complex undertaking and could be designed and implemented with multiple end goals. Upstream stakeholders, predominantly electric utilities, will be interested in charging control algorithms that contribute to the value chain of the delivery of electricity, delivery of grid stability and higher margins. As tempting as this route can be, it is critical to keep the end user at the forefront because the social goal is ultimately to support PEV market uptake and utilization (i.e. electric kilometres traveled). PEV users will want to know that their charging and mobility needs will be met. On the downstream side, control of charging operations can be implemented to maximize margins on the charging service and/or to maximize end user satisfaction (e.g. by coordinating charging throughput with instantaneous electricity rates or by integrating electricity from clean generation sources). For downstream control, the front end of the IT solution

takes center stage, as the user is provided with information, interactivity and control options.

In the early stage of the industry, IT applications related to charging infrastructure were centered on basic elements such as billing, mapping, and navigation. Applications to inform EV users about the location of charging points emerged quickly as the immediate idea contributing to the value chain. Companies added value by providing information about, or based on, the location of charging points (e.g. PlugShare). There is a possible inverse value added: The charging point generating revenue from making information available to the IT company. To the extent of our knowledge, this reverse value direction has not been tested. One form that this could take is charging station owners could capitalize on data generated by equipment at their location. Sales of user dwell-time data to car manufacturers, businesses, or advertisers could lead to additional revenue for the EVSE owner or operator. Sample travel (origin-destination) data has been used to model potential demand for charging and assist with charge station planning in research applications, with explicit permission from participants. The automakers may have more travel data available, though this data is heavily guarded for privacy reasons within each automaker and is unlikely to be shared. EVSE companies would have data from each location in their network, but not the complete picture of user travel around charging events, though even their limited information could provide valuable insights to host locations and researchers.

One additional potential source of revenue, that to our knowledge has not yet been implemented, is charging an additional fee for users to want to reserve a charging station to be available at a specific time and for a set charging duration. A “reservation” fee would offset the cost of implementing a reservation system and any potential lost revenue for a spontaneous charging event, but a reservation would likely be a relatively low-cost system to implement.

Grid Integration

In the current stage of market development, the IT focus has expanded onto applications for grid integration. The application storyline, in this case, is about the value of charge control or modulation to a) mitigate load peaking from simultaneous charging of plug-in vehicles in large numbers within a given distribution line or more broadly within the interconnection, and b) absorb generation peaks, such as those resulting from large scale non-dispatchable capacity (e.g. wind and solar).

We emphasize again that it is not clear that economic players upstream from the charging connector can assert jurisdiction over the control of charging. This is a space that can be claimed by the auto manufacturers and third-party Software as a Service (SaaS companies). Charge control from smart charging equipment can take the form of telling the onboard charger how much power is available to take at a given moment. On the other hand, the onboard charger ultimately decides how much of that available power it will take at any given time. Thus, smart charging equipment can control maximum power draw but cannot control actual power draw. Conversely, the onboard charge can control actual power draw up to the maximum specified by the charging station. From a value perspective, charging equipment operators can help mitigate EV load peaking, while onboard charger controller (third-party or automaker) can help absorb power generation peaks through charging control and scheduling which can then lead to lower installation or panel upgrading costs.

Table 4: Table of Grid System Management Techniques and potential benefits.

System Management Technique	Function	Benefits
Load Management or Demand-Side Management (DSM)	The process of controlling the demand for power rather than the production of electricity. Can be implemented as pre-scheduled or interrupted charging for PEVs.	Allows for grid to meet reduced demand rather than requiring additional production to be brought online.

Load Sharing	Distributing power across more than one vehicle simultaneously through a microprocessor-controlled EVSE. Can be distributed based on vehicle SOC, order of connecting to the grid, and system capacity.	Allows for multiple vehicles to be plugged in and charged in parallel or series. Useful for applications where vehicles will be plugged in for longer periods of time, such as workplaces or airports.
Load Shedding	The systematic reduction of system Demand by temporarily decreasing the Supply of Energy to Loads in response to transmission system or area capacity shortages, system instability, or voltage control considerations. (CalISO)	Real-time signals to cut load can result in a more stable grid, with temporary reductions in demand when necessary.
Smart Charging	Vehicle charging can be started and stopped based on time of use, real-time demand and battery state of charge through an intelligent control strategy or wireless signals.	Smart charging can integrate all or some of the above system management techniques, as well as vehicle input, and allow for easier integration of vehicles and renewables to the electricity grid.

Beyond the current stage of the market, we expect innovative IT applications to enter the value chain. These could be geared toward enhancing the overall economics of EV ownership or integrating the individual vehicle into networks of transactive energy. We will not speculate here about the future, but we venture to say that the pathway of IT applications will involve some form of aggregation, or integration of the charging points into organic networks. This is consistent with our earlier assertion that business models around a stand-alone charging location are not competitive in the long run.

Early EVSE suppliers considered providing video, audio and static advertising on the EVSEs that users would view while charging. While the rapid adoption of smartphones has largely eliminated the “captive audience” that EVSEs may have

been able to capitalize on, static advertising or “EVSE sponsorship” may still play a role in funding chargers.

Workplace Charging Investment Models

The participation of employers in the supply of charging infrastructure may have significant implications for the market uptake of plug-in vehicles. Employers may be motivated to invest in charging equipment at the workplace for a variety of reasons, most importantly employee satisfaction and retention. In this instance, the business case is linked to the overall human resources strategy of the host organization. The decision to install charging equipment may depend on a variety of factors, including cost of equipment, cost of installation, size of the organization, financials of the organization, characteristics of the employee pool, support from company leadership, etc.

Employers may adopt different models for the use of charging equipment, which would broadly fall into two categories: free of charge or charge for a fee. The pros and cons of each model were discussed by Nicholas and Tal (2013), and more succinctly in a video at <http://zeroemissionmap.ucdavis.edu/category/multimedia/>. Free charging at work leads to more workplace charging, but not necessarily more electric miles traveled, and requires four times as many chargers to be installed. However, availability of workplace charging may help to grow the PEV market by provided that as an additional perk to potential PEV buyers or allowing customers without easy or low-cost access to home charging to have a reliable daily charging location.

Programs like the one instituted by the State of Massachusetts could be even more effective in spurring PEV adoption if the existence of the program was communicated to prospective vehicle buyers before they make their choice of vehicle. New vehicle dealers could play an important role in such communication. However, the marginal value of advertising the program at the dealership may be small because, as recent research suggests, most PEV buyers may walk in the

dealership already strongly inclined to buy a PEV (Cahill, webinar June 4, 2015) (<http://zeroemissionmap.ucdavis.edu/wp-content/uploads/2015/06/EC-slides.pdf>) *A better strategy would be to work directly with employers who may be inclined to invest in charging infrastructure, and let them advertise the program among employees.*

One example of a program encouraging installation of workplace charging is the Massachusetts Electric Vehicle Incentive Program (MassEVIP), which is an open grant program administered by the Massachusetts Department of Environmental Protection, which provides incentives to employers for the acquisition of Level 1 and Level 2 electric vehicle charging stations, and launched in April, 2013 (Mass EVIP documents). This program will provide employers with 15 or more employees 50% of the funding (up to \$25,000) for hardware costs for employers installing Level 1 and 2 charging, and is offered on a first-come, first-served basis. (<http://www.mass.gov/eea/agencies/massdep/air/grants/workplace-charging.html>)

Depending on the model that the employer adopts for the use of the charging stations, the economic benefits to end-user employees can be significant. A report on workplaces with charging published by the California Plug-in Electric Vehicle Collaborative (PEVC, 2013) found that employers that have installed charging stations to serve employees have seen increased numbers of employees with plug-in vehicles. The state of California has adopted a number of programs to encourage infrastructure deployment by businesses. On the easier end of the scale there is the CoolCalifornia Climate Leader and Small Business Awards program, which gives awards to 15 businesses every year in recognition for their initiatives to cut energy consumption and demonstrate measurable greenhouse gas emissions reductions, EV charging stations count toward these initiatives. These award winners document their cost savings, return on investments, and other benefits received from taking specific actions. This award provides prestige and visibility for small businesses, and

can be a good promotional tool for them (CoolCalifornia). A similar program of recognizing forward-thinking companies could be implemented at low cost and could lead to a local business culture of energy conscientious companies. Incorporating EV charging in the evaluation criteria can simultaneously help build a local charging network.

A more elaborate program is the [Electric Vehicle Charging Station Financing Program](#), instituted by the California Pollution Control Financing Authority (CPCFA). This program is funded by the state, but instead of giving funding directly to business owners, the funding is used to reduce the burden and risk of business loans for all costs included in the installation of charging infrastructure at the workplace. The state pays 20% (30% for multi-unit dwellings or disadvantaged communities) of the principal balance into a loss reserve account at the time of loan approval. After the borrower pays back the loan (or 48 months, whichever occurs first), they are eligible for a rebate equal to half the deposit to the loss reserve account. This program mitigates the risk to lenders and also mitigates the financial burden on non-defaulting borrowers. The EVCS Financing Program is a pilot project with initial funding of \$2,000,000, from the California Energy Commission, which launched in mid-2015, and is administered by the California Pollution Control Financing Authority (CPCFA). It will be evaluated by the California Energy Commission and the California Pollution Control Financing Authority after the initial funding is exhausted. A program brochure is included in Appendix 1.

The value of workplace charging to support EV markets needs to be better studied, but there is mounting anecdotal evidence that this value may be significant. There is also a theoretical rationale that lends credibility to this evidence, which we discuss later. However, workplace programs are not always easy to implement. Employers face challenges, two of which we highlight here: employee reticence to use plug-in vehicles in the fleet, and the unknowns related to installing charging infrastructure. The State of Washington has developed a guidance document that answers questions facing employers and employees in regard to plug-in vehicles and

charging infrastructure (Miller-Crowley, Moulton and Jensen, 2014). The document is clearly written and organized, and begins with a focus on the key determinant for fleet operators, the total cost of ownership: “The bottom line, based upon the total cost of ownership, is public fleet managers should think of battery electric vehicles as their default choice for sedan replacement, only moving on to plug-in hybrid or hybrid vehicles after they’ve determined that a battery electric vehicle is not practical for their typical daily use”. It provides information, guidelines, and additional resources to decision makers organized around to vehicle, charging equipment, and operations options.

Public Private Partnerships

The potential of public-private partnership (PPP) approaches to help the growth of infrastructure that supports new technologies has been demonstrated. The State of Washington, having a well-established PPP office in the state Department of Transportation, is well positioned to explore these approaches. Corporate-sponsored installations are the simplest PPP model explored to date. In Washington, the US-2 EV corridor offers a more advanced example of a PPP approach, where public funding was complemented with private investments in an integrated corridor development. The West Coast Electric Highway is a network of EV chargers linking Washington, Oregon, and California on Interstate-5. It is led by governmental agencies in each state, but implementation and operation is by private EVSE companies (West Coast Green Highway). Similar strategies can be used to incent EVSE installations along other corridors, including commute corridors. In urban areas, public fast chargers that are co-located at or near apartments can provide service to both visitors and residents. This solution may allow charger owner/operators to maximize their revenue by providing a steady stream of customers throughout the day and night. Yet another PPP approach involves the adoption of regulatory incentives in return for infrastructure investments. For example, an infrastructure installer may be given a break on taxes, or electricity rates in order to incentivize installation without providing a cash incentive. This

requires a justification based on the broader carbon benefits and eventual reduction in electricity rates and for all ratepayers or residents. In specific instances early in the market this could help jumpstart the PEV market which could lead to benefits for all ratepayers.

One example of PPP is the State of Massachusetts's MassEVIP program as discussed above. This program offers employers with 15 or more employees to partner with the state in sharing the cost of installing charging equipment. Under the program, the state covers half of the cost of level 1 or level 2 equipment and the host organization covers the other half as well as the cost of installation. The host organization retains the freedom to select the type and brand of equipment. The state integrated this program with its vehicle rebate program by telling about the existence of this program to every person who claims the rebate. This motivates PEV adopters to approach their employers and request that they install charging equipment in partnership with the state.

Case study: Overview of charging infrastructure development in France

The EU Parliament established in March 2014 a goal of installing 800,000 public access charging stations across Europe by 2020, with individual targets set for each Member State (Evolution, 2014).

Some projects supporting electric mobility in the region are in progress. One example is the European Project Long-distance Electric Clean Transport Road Infrastructure Corridor (ELECTRIC) with private public investment of 8.4 million euro (effort is part of European Union's Trans-European Transport Networks) in infrastructure policy aimed at connecting EU member states between east and west, north and south (ABB).

France invested 60 million Euros between 2009 and 2012 to install 1,250 public charging points in about 20 large urban areas (Leurent, Fabien et al., 2011). The electric utility Electricité de France (EDF) established an extensive network of

public charging stations in France. The most significant development occurred in cities with more intensive EV adoption like Paris and La Rochelle. There are currently 9,400 charging points installed throughout France and government projections expect this number to climb to 40,000 by 2020 (Lesechos, 2015).

French decision makers recognize that a dense charging station network alone does not ensure that motorists have access to charging because of the variety of sockets, communications standards and payment methods. In March 2015, France established the Association for Roaming Electric Vehicle Charging (Afirev), with the goal to ensure that electric car drivers can travel and charge seamlessly across the territory regardless of the operator of the charging station (e.g. EDF, Mallore, Vinci, Bouygue, etc.)

To support electric mobility, the city of Paris created the Autolib car sharing scheme in 2011, currently operating over 2,000 electric cars, and around 4,000 charging stations around the city and surrounding region. This is an annual subscription based program allowing members to rent the vehicles from one rental station and return them to any other rental station for varying 30-minute rental rates (depending on the membership type). It is reported that on a typical day, electric cars in the Autolib system serve about 10,000 trips. Autolib also offers charging services to private vehicle owners with a special subscription, and free use of the Autolib charging stations was included in Renault EV sales as of early 2014. These multiple revenue streams appear likely to create a successful business case. The French group Bollere announced an investment of 150 million euros to deploy 16,000 public access charging stations throughout France, to build a charging network. In this plan, the maximum distance between a charging point and the next will be 41 kilometers (25 miles). Now the government of France, led by the Ministry of Finance and the Ministry of Environment, is considering a package of tax incentives to support Bollere's initiative, in addition to expanding the rebate offered for electric drive vehicle purchases, from 6,000 to 10,000 euros (Bollere.com). In June, 2013 Autolib joined with Indianapolis, Indiana to form BlueIndy, which

opened to the public in September 2015, and a similar program was launched in London in March 2015 using the existing network of chargers there.

Theoretically, this network will be integrated with a separate infrastructure project co-sponsored by the Trans-European Transport Network Executive Agency (TEN-T EA, now the Innovation and Networks Executive Agency, INEA under the European Commission). This program was established by the European Commission to support the construction and upgrading of various transportation infrastructures in the EU and includes projects in all transport modes – air, rail, road, maritime, and logistics and intelligent transportation systems. This project was designed as consisting of three phases. In the first phase, 5 million euros are invested to install and test 200 interoperable and multi-standard fast chargers on the highways of France by the end of 2015. The second phase will build upon the experience of the first one, to develop recommendations regarding interoperability, to support the integration of charging and hydrogen refueling networks across France and Europe. The third and final phase will be concerned with the discovery and validation of innovative business models for sustainable charging networks. We highlight the integration of the investment for this project into a broader framework that is oriented toward experimentation and learning. Such approaches represent a great improvement relative to investments that stop at the deployment of the equipment. Projects to install fast-charging networks in France, Ireland and the UK (2011-2012), Denmark, the Netherlands, Sweden and Germany (2013) aim to not only help develop local infrastructure, but also improve drivers' acceptance of EVs and improve connectivity and compatibility throughout the European Union member states. In these projects, the European Commission funds approximately 50% of total project costs while the member countries or private partners fund the remaining amount (European Commission).

Successful European experiences have integrated the deployment of the equipment into broader longer-term plans that include the sustained reliability of the equipment as well as experimentation and open learning. We believe these should

be pillars of any infrastructure investment, to support good user experience, product legitimization, testing of new ideas, innovation and ultimately financial sustainability.

There are two complementary programs (“EcoCities” and “Ville de demain”) and funds for the implementation of infrastructure for EVs from the Ministry of Ecology and Sustainable Development and Energy, which allocated 50 million euros to support the installation of public chargers for EVs in cities with over 200,000 inhabitants (Ministère, 2015). In 2016, a new program “Programme Advenir” allows for financing of private charging points through energy savings certificates. This program is focused on shared charging on company property, private areas that would be accessible to the public (such as store parking lots), and private charging on collective housing properties (<http://www.developpement-durable.gouv.fr/Le-renforcement-de-l.html>).

Successful projects have also included consumer education programs: Such programs included information in areas like benefits of using plug-in vehicles, best practices for the use of plug-in vehicles and charging infrastructure (e.g. eco-driving to save energy and using lower rates to charge the battery) and familiarity with the technology. In the United States, for example, San Diego Gas & Electric created a website and handouts that were distributed to regional car dealerships with information on their local EV utility rates, and links to information on local, state, and federal incentives. This removes the burden of information from the dealer for potential buyers (<http://www.sdge.com/electric-vehicles>).

Legitimation of the EV Market

Consistent with studies of technology innovation, the rate of growth of plug-in vehicle markets increases the more they are perceived as a mainstream technology. In innovation studies, this is often referred to as *legitimation*. One way for the public sector to encourage legitimation of plug-in vehicles is to provide charging

infrastructure an institutional framework comparable to other elements of the electric grid and electrical appliances. The needed components of such institutional framework are familiar to most stakeholders working on vehicle electrification, but may be unexpected to those who are new to the industry. They include certification, permitting, inspection, electrical codes, building codes, development regulations, compliance with requirements for disabled person access, consistent and highly visible signage, and a variety of rules and norms that often vary across government jurisdictions, such as building efficiency standards, appropriate demand charges, right of way in the public space, and others. The role of government is extended for installations in public-sector facilities, including procurement guidelines and funding. The development, implementation and enforcement of such institutional framework, and the development of a regionally-specific guide to the appropriate regulations, would send a clear legitimization signal to sectors of the economy, equivalent to reducing the cost and risk of doing business involving charging infrastructure.

To illustrate the notion of a legitimizing institutional framework, consider the case of building codes. Some initiatives to revise state building codes to include basic requirements for charging infrastructure, such as laying out conduit in parking spaces, have been met with concerns about the impact of such requirements on building costs. A legitimizing institutional framework provides for building codes that give equitable treatment to plug-in vehicles, treating them as other loads that meet basic needs of the occupants of the building. Much like power generation increasingly comes from distributed sources, vehicle refueling will increasingly be a distributed activity. In the world of vehicle electrification, parking facilities are the new fuel station. This is a paradigm change that governments need to accept and reflect in legitimized rules and norms. Including regulations in building codes, creating streamlined permitting processes for installation of EVSEs, establishing consistent signage and rules for publicly accessed charging will also help, and can be done at a local level.

We refer above to public parking facilities in a broad sense, which includes all non-residential publically available charging. This includes on-street parking, public-access garages, customer dedicated parking, shared public/workplace parking, and miscellaneous parking (e.g. recreational spaces, rest areas, and such). The installation of equipment in some of these settings, for example those in the public right of way for on-street parking, may be financially impractical for most users. The Netherlands has dealt with this issue, and the biggest hurdles are that the costs are borne by a single owner/user, who is then required to offer the use of the charger publically. They also had delays due to uncertainties around permitting and installation requirements. In this case, offering partial funding for owners who want to install on-street charging that will be publically available, as well as clear requirements and processes can alleviate the burden on the initial owner. Another option would be if the initial owner fully funded installation, but the city took over maintenance. Finally, the charger could be locked so that it is not publically available, despite being on-street. However the challenge is approached, the set of rules for installation, maintenance, and use should be clear for such cases. A recent study explores the question of charging infrastructure for garage orphans (electric vehicle owners or prospective owners who do not have access to off-street parking) (Nelson Nygaard, 2014). The city of San Francisco will soon be embarking on a study to evaluate the potential for adding level one charging at existing streetlamps, since they are street-side and already have electricity available, which could help reduce costs and add charging access for city dwellers. Another solution is support for fast charging locations that can serve as a back-up to congested level two and public and multi-unit dwelling parking locations.

The integration of the electric vehicle with the building offers opportunities for improved economics on the deployment of charging infrastructure. In contrast, the lack of integration may present deterrents for infrastructure deployments and ultimately for the growth of the electric vehicle market.

Models Based on EV-Building Integration

In the United States, about six percent of direct carbon emissions in 2013 came from commercial buildings. Direct emissions in commercial buildings originate in the burning of fossil fuels for heating and cooking (55.3%), waste management (34.5%), and leaks (10.2%). Electricity generation, represented 31.3% of total direct carbon emissions. About 20 percent of total energy consumption in 2014 was attributable to commercial buildings. While in British Columbia stationary energy loads (such as buildings) represent a smaller fraction of total carbon emissions because of the Province's heavy reliance on hydropower, energy benchmarking of commercial buildings with transportation provisions could offer opportunities for this sector to participate in carbon mitigation efforts.

One specific opportunity that we identified for EV-building integration is including the energy and greenhouse gas (GHG) impacts from travel demand generated by commercial buildings into benchmarking methodologies. Studies suggest that energy benchmarking of commercial building is resulting in energy use reductions (Palmer and Walls, 2012, U.S. EPA, 2012). Part of the logic is that benchmarking provides information that is otherwise unavailable to building owners and energy managers and enables/encourages them to adopt targeted strategies to reduce energy use. Integrating building with vehicle will encourage strategies to reduce emissions from transportation. The cities of Austin, Boston, Chicago, the District of Columbia, Minneapolis, New York City, Philadelphia, San Francisco, and Seattle have enacted building energy benchmarking legislation. As building energy benchmarking continues to expand throughout America (and perhaps to British Columbia) there is need to ensure that the program policies are structured to support clean technologies. In some regions, a technology-neutral system for evaluating and scoring transportation emissions is used, though some countries and regions can select a preferred technology based on existing natural resources, such as clean electricity in British Columbia. *Redefining the building envelope to include related travel by PEVs or conventional vehicles may be challenging, but a potentially*

powerful approach.

We do not present here a detailed analysis of this opportunity, but believe that there are opportunities for further exploration and pilots, with the participation of stakeholders in the region. *The starting point could be on accounting practices that encourage building energy managers and commercial property owners to reduce energy and carbon emissions from the travel demand generated by their buildings, such as employee commute and customers' visits.* Such accounting systems would induce building energy managers and commercial property owners to develop strategies to reduce energy use and emissions from transportation. For the purposes of this particular report, *the focus could be on strategies to encourage energy savings and emissions abatement by displacing fossil fuels with electricity fuel for transportation. Probably the most obvious element of such strategies is the installation of electric vehicle supply equipment (EVSE), although it should be complemented with other elements.*

We would note, a revision of energy and emissions accounting protocols that provide property owners with incentives to invest in such infrastructure, would also have legitimation positive externalities, helping familiarize the public with EV technology and in turn support market adoption and e-miles displacement of fossil miles. In the US, these building energy use and emissions standards are set on a federal and state building code level, and forecasted prior to construction. Buildings that go above the minimum may qualify for a LEED certification (Leadership in Energy and Environmental Design, developed by the US Green Building Council, USGBC), We also note the importance of balancing strategies that support EV adoption so that they don't result in inadvertent consequences (such as higher emissions from substituting charging of EVs for bicycle trips or creating new electricity peaks). These accounting processes and green building certifications are set at a federal, rather than city or province level, but should be encouraged to consider the changing transportation system, particularly EV charging.

A deeper exploration of the building-EV integration concepts that we laid out above

could address the following areas:

- City and provincial motivations for adopting an energy benchmarking program and integrating emissions from transportation into the benchmarking of commercial building
- A comparative assessment of energy consumption and carbon emissions arising from travel attraction to commercial buildings and other sources in the building
- Opportunities to integrate such strategies into city/province umbrella strategies, such as the City of Vancouver's Electric Vehicle Strategy (currently under development), Vancouver Building Code updates and long range (2050) emissions reduction planning
- Comparative assessment of the capitalization of EVSE in buildings and alternative strategies to improve energy efficiency and environmental friendliness of commercial buildings
- From the perspective of the building owner, investments in charging infrastructure in the building will increase electricity bills. Policy and business strategies that would likely need to provide means to internalize these additional costs. Quantifying the benefit through either increased revenue from customers, or as a part of the benefits package used to recruit and retain employees could help justify the investment.
- Engage stakeholders to discuss implications of EV-building integration programs for a) other transportation programs such commute trip reduction, b) regional energy planning (e.g. grid reliability), c) regional economy, and d) environmental justice (e.g. mobile emissions reductions).

The Possible Role of Electric Utilities

The role of electric utilities in encouraging EV adoption should be to keep the fuel costs for electricity lower than that of gasoline vehicles, while allowing users to maintain the lifestyle to which they are accustomed. The right combination of rates

and meters will allow the household to operate as usual, while easily switching from a gasoline fuel source to electricity as a fuel. To this end, the role of rate structures within utilities is to create a variable rate in order to manage the charging demand by users. Rates create the price signal that customers can react to.

While total electricity consumption in the United States has been stabilizing over the last decade or so, the trend in Canada shows decreasing energy use per capita. The reasons for these trends are likely similar, including slower economic growth and the implementation of energy efficiency programs. However, BC Hydro may soon be experiencing an increase in demand due to the electrification of transportation and heating systems.

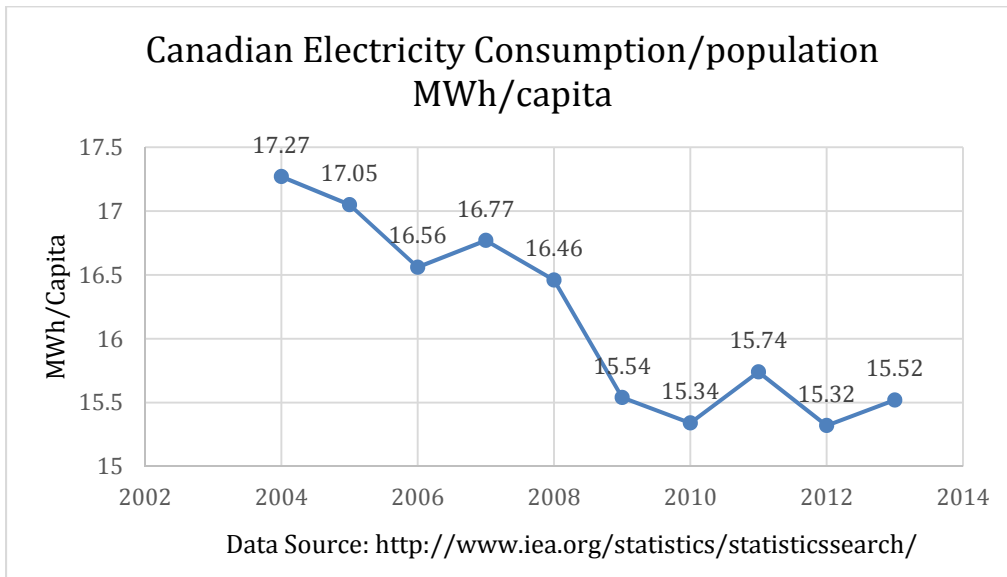


Figure 16: Electricity Consumption per capita for Canada, 2004 - 2013

BC Hydro is mandated to be 93% renewable, and in 2015 served 98% renewable. A possible shift in the mandate to 100% renewable power is under consideration, and the region is currently debating the short and long-term feasibility of a mandate for 100%. BC Hydro is forecasting significant (10-15%, even with massive efficiency measures) load growth due to increasing electrification for private and public transportation and building thermal management. This means a growing role for on-site renewables – like rooftop solar – in order to meet the expected increase in

demand and increased requirement for renewables.

For some utilities, these trends have resulted in a surplus of generation capacity. As many utilities profits come from higher sales of electricity, the reutilization of stranded assets in the industry would provide new revenue streams—in this respect, the load growth that would result from the large-scale deployment of plug-in vehicles is attractive to the industry. Informal conversations with utility representatives suggest that the industry sees a possible opportunity, but that a business case is not yet clearly seen by all utilities. Some of them see a business case for charging infrastructure that focuses around home charging, where about 70-80 percent of the vehicle charging occurs. This business case however relies on a critical mass of plug-in vehicles in the market that is significantly larger than the current one. We have not been able to obtain utility estimates of the critical mass of plug-in vehicles that would make infrastructure deployments lucrative to utilities. Anecdotally, some utilities see a marginal increase in load even at a 5 percent market penetration of plug-in vehicles. Our preliminary assessment is twofold: a) the industry is paying attention to possible opportunities that can result from the market success of plug-in vehicles but better modeling may be needed; and b) whether and the extent to which electric utilities can justify investments to support plug-in vehicle markets may depend on a range of local variables.

To encourage higher electric vehicle market adoption, addressing consumer concerns about vehicle range limitations will be critical. An important question is the extent to which deployments of public access DC Fast or level 2 charging can be an effective strategy to address range concerns. If this infrastructure could significantly augment the market appeal of plug-in vehicles and ultimately increase revenue for utilities, then investments in infrastructure may be warranted. Moving from the conceptual level to quantifications is a complex exercise. The industry is interested in quantitative estimates of plug-in vehicle adoption resulting from additional charging spots. Studies currently underway at UC Davis estimate 2-8% more PEV sales due to availability of workplace charging, but further research is

needed, especially on the impact of awareness of public charging on future PEV sales.

In the remainder of this section, we summarize the proposals of the three larger electric utilities in California to support deployment of charging infrastructure financed with increases in electricity rates. We also explore possible ways in which electric utilities could create financial mechanisms to support infrastructure investments, with a focus on BC Hydro, the electric utility that serves the City of Vancouver.

Proposals from Utilities Conducting Pilot Programs

The proposals developed by the three larger electric utilities in California do not present innovative ideas related to the financing of charging infrastructure, and could be generally characterized as subsidies. Regardless, the financing of charging infrastructure through increased electricity rates has been receiving increasing attention, and we believe it is pertinent to include a summary of these proposals as one alternative financing pathway. The California Public Utility Commission, which oversees the utilities granted approval to Southern California Edison and San Diego Gas & Electric to proceed with the phase 1 or pilot portions of their proposals in early 2016. These investments are paid for with revenue from utility rates and increased utility rates, justified by the fact that the lower emissions from cleaner electric driving provides a benefit in terms of local air quality for all customers.

Pacific Gas & Electric

The proposal submitted by Pacific Gas & Electric includes the following elements:

- Deploy, own and maintain approximately 25,000 Level 2 (L2) EV charging stations;
- Deploy, own and maintain approximately 100 DC Fast Chargers (DCFC);
- Target public facilities, workplaces and multi-unit dwellings;
- Offer education and outreach materials to drive EV adoption;

- Target approximately 10 percent of the charging infrastructure for disadvantaged communities; and
- Use time-variant pricing.

Including capital investments, operation and maintenance, education and outreach and other expenses, the program would have revenue requirements capped at \$653,846,000, or about \$26,000 per charging station. By the year 2020, about 25% of the proposed 25,000 Level 2 charging stations and 100 DC Fast Chargers would have been deployed, primarily in workplaces.

Southern California Edison

On Jan 14, 2016, Southern California Edison (SCE) received approval from the California Public Utilities Commission (CPUC) for their “Charge Ready” Pilot program. SCE’s proposal was broken down into a Phase 1 pilot and Phase 2. At the conclusion of the pilot, they will seek permission from the CPUC to proceed with expanding the program to a total of nearly 30,000 charging stations in the Southern California territory serviced by SCE (Edison International Newsroom). More details of their two-phase plan is provided below.

- Deploy infrastructure to support up to 30,000 EV charging stations in their service area;
- Target deployment in areas with long-time dwell sites as well as installing at least 10% of the chargers in disadvantaged communities;
- Two-phase program;
 - Phase 1: 12-month pilot to initiate infrastructure deployments with up to 1,500 charging stations to “test several key assumptions underlying its approach” and start a market education campaign “that will target potential car buyers in SCE’s service territory to expand their awareness about EVs and the benefits of fueling from the electric grid,”

- Phase 2: Completion of the installations of “up to 30,000 qualified EV charging stations” and broadening of education efforts.

Including capital investments, operation and maintenance, education and outreach and other expenses, the program would have revenue requirements capped at \$653,846,000. The pilot in phase 1 would require \$18 million and \$4 million in capital and O&M expenditures, respectively, while phase 2 would require \$324.5 million and \$8.25 million respectively for capital and O&M expenditures. This represents a revenue requirement of about \$355 million, or about \$12,000 per charging station (assuming the maximum number of 30,000 stations is deployed). Southern California Edison proposes to recover these costs through increases in electricity rates.

San Diego Gas & Electric

On January 28, 2016, San Diego Gas & Electric received approval from the CPUC for their Electric Vehicle Grid-Integration pilot project, allowing them to own and install thousands of EVSEs in their territory (SDG&E Newsroom). Their plan is outlined below:

- Deploy 3,500 EV charging stations in their service area
- Target deployment in workplace and multi-unit dwellings, the plan is to install 10 chargers at each of 350 businesses and multi-family communities;
- At least 10% of the chargers will be installed in disadvantaged communities
- Implement special EV rates that encourage off-peak charging and allow for maximizing renewable energy integration and minimizing the need for new fossil-fuel power plants;

The pilot program would have revenue requirements \$59 million and \$44 million for capital and O&M investments, respectively, representing a cost of about \$19,000 per station.

Eversource (East Coast Utility)

Eversource, the utility serving Massachusetts, Connecticut and New Hampshire, is launching an electric vehicle pilot program, which may allow PEV buyers to purchase a Level 2 charging station at a reduced cost. The research from this pilot program will also help Eversource design an effective time of use (TOU) rate for PEV customers (Eversource, 2016).

Possible approaches for BC Hydro

We start with an inspection of BC Hydro’s rate structures. The utility has adopted a step pricing rate structure for electricity consumption, summarized in Table 5.

Table 5. Summary of BC Hydro’s electricity consumption rate structure

Rate group	Step 1		Step 2	
	Threshold	Rate	Threshold	Rate
Residential	1,350 kWh/60 days (22,1918 kWh/day average)	\$0.0797	More than 1,350 kWh/60 days (22,1918 kWh/day average)	\$0.1195
Small General Service customers		\$0.1073/kWh		
Medium General Service customers	First 14,800 kWh of baseline	\$0.0989/kWh	Up to 20% over baseline	\$0.0990/kWh
	Remaining of baseline	\$0.0690/kWh	Up to 20% under baseline	-\$0.0990/kWh

Since the early days of systematic deployments of DC Fast charging infrastructure (Department of Energy’s EV Project and State of Washington Electric Highway), demand charges were viewed as an important obstacle. Demand charges are an important component of the pricing of the service provided by electric utilities and waiving it altogether for charging infrastructure seemed impractical. At the same time, demand charges seemed to greatly curtail any hopes to find sustainable business models for the provision of DC Fast charging infrastructure.

In Table 6 we summarize the demand charge structure in the BC Hydro territory.

Table 6. Summary of BC Hydro’s demand charge structure

Maximum power bracket	Demand charge
0 – 35 kW	\$0
35 – 150 kW	\$5.50 per kW
Over 150 kW	\$10.55 per kW

To the extent that BC Hydro has capacity surplus, the increase in consumption from vehicle electrification would generate additional revenue streams from the utilization of existing assets and potentially a reduction in the per-kilowatt cost of generation. It is then in the economic interest of BC Hydro and the region to support market uptake of plug-in vehicles. This may be in contrast with the conservation goals of the region, which have resulted in the tiered pricing system for electricity consumption and demand. *One possible model that supports both economic and conservation goals might include small changes to the demand charge structure. It would first be beneficial if the City of Vancouver and/or the Province of British Columbia instituted rules recognizing and assessing the conservation benefits for vehicle electrification, arising from the displacement of fossil fuel consumption. Such rules would limit institutional barriers to charging infrastructure deployment (and the support of vehicle electrification more generally).*

Experience from pilots conducted in the past suggests that customer consumption does respond to demand charges. The range of estimates of this response is very wide (Hledik, 2014) and certainly dependent on the structure of the charge. The main two incentives that demand charges create are load shifting and lower use. A review of experiments and studies on the impacts of demand charges is beyond the scope of this report, but we point out that demand charges have received attention in the literature for decades (see for example, Berg and Savvides, 1983 and Caves, Christensen and Herriges, 1984). The viability and effects of demand charges is better assessed on a case-by-case basis. Customer response to demand charges is likely dependent on structural characteristics of the local economy and other local factors affecting electricity use patterns.

It is worth highlighting that response to demand charges are likely different for

residential charging and public access charging. Residential customers may have more flexibility to respond with load shifting by charging overnight, while public access charging often responds to an immediate need for their service and load shifting may be less practicable. The limited flexibility of responding to demand charges by public-access infrastructure, particularly DC Fast stations, should be taken into account in the hypothetical development of rates to support plug-in vehicles. In many instances, public access charging is a suitable market for load shifting via smart charging. It is critical to remain cognizant of the opportunities, current or future, for innovative technologies to help address these questions (e.g. under the broad umbrella of smart charging). *Strategies pursued to address the connection of plug-in vehicles and the grid should preserve a marketplace that incentivizes startups and other innovators to discover new ways to address issues.* We believe this is important to maximize environmental and economic benefits from vehicle electrification, as well as enable further legitimization of plug-in vehicles and integration into regional economies.

Two possibilities are summarized below:

Table 7. Illustrative examples of EVSE financing based on innovation in rate structures

Model	Concept	Example structure	Financing
Ramp demand charge	Create a demand charge scale for the 0-35 kW bracket, the revenues from which can be used in part to finance charging infrastructure	\$0.14 per kW for first 35 kW	Green conservation bank, with appropriation for EVSE deployment and resulting demand charges After appropriation for EVSE bank, revenues recycled back to customers (for example, based on income, savings between successive bills, etc.)
Demand charge exchange	Trade demand charges in a billing period from charging infrastructure to other customer brackets.	\$X from charging infrastructure demand are absorbed according to formula by customers in the first demand charge bracket	Eliminates demand charge costs from charging infrastructure

The examples in the table are included for the purpose of discussion and to expand upon by including other possible configurations. We emphasize that the proposed model builds upon a balance between conservation and economic benefits from increased use of existing generation capacity. The model thus works only if the resources allocated to charging infrastructure ultimately result in increased kilowatt-hour consumption. Increased consumption can result first from growth in the regional plug-in vehicle market and also from more e-miles driven plug-in vehicle households. Thus, it is not clear that resources from utility financing ought to be dedicated to charging infrastructure exclusively. Ideally, the best allocation of resources would result from an understanding of the relative strength of various instruments in spurring more plug-in vehicle electricity use. Such instruments could include financing of charging infrastructure as well as financing of plug-in vehicles.

We are not aware of existing electric utilities programs that offer financial

incentives for the adoption of plug-in vehicles. *We suggest, contingent on conservation rules that integrate electricity with other transportation fuels, that such incentives could be thought of as an extension of the appliance replacement programs that are common in many electric utilities.*

It is important to emphasize that the value of charging infrastructure in supporting plug-in vehicle adoption and use is dependent on effective deployment planning, particularly location and reliability.

Notice that in the preceding discussions, institutional framework does not include direct financing of charging equipment or equipment installation. Innovation is generally not supported by excessive market power, and this may occasionally be the result of well-intended policy decisions.

The integration of the electric vehicle with the grid

The concept of the smart grid suggests developing IT based communication and control solutions on the grid, allowing grid operators to balance electricity supply and demand in a reliable and efficient manner. The growing load of PEVs has the potential for both creating challenges, and if managed properly, acting as a helpful resource for the grid operations. Previous scientific literature on PEV-grid integration evaluated the technical and environmental aspects of the PEV charging, as well as the viability of using PEVs as a resource for the energy and ancillary services on the grid. This is research area that has already been extensively analyzed, in particular by the Pacific Northwest National Lab (Gerkenmeyer et al, 2010, Kintner-Meyer et al, 2007) as well as researchers at the Electric Power Research Institute and University of California, Berkeley. As such, this report does not include a discussion of the grid capacity, load impacts, and upgrading necessary, but focuses conceptually on the potential new developments that could come from vehicle grid integration.

Given the potential for the number of PEVs to grow rapidly in the near term, PEV loads have become one of the major focuses for the smart grid developers. For

instance, Moghe et al (2011) illustrated that adapting controlled PEV charging may increase the life expectancy of an average 50 kVA neighborhood transformer by up to six times depending on the rate of PEV adoption in that area. On the other hand, PEV load is also seen as a useful resource for the grid operations in applications such as frequency regulation, power generation, and renewable electricity integration. Thus, utilizing Demand-Side Management (DSM) to manage the growing load of PEVs may create an economic benefit for consumers and utilities while reducing the negative impacts on grid capacity. *Early development of active “PEV-grid integration” should specifically focus on the PEV demand side management strategies and potential ancillary service opportunities such as frequency regulation.* Some major issues such as consumer PEV charging behavior, the competitiveness of the DSM relative to wholesale electricity, and developments in communication technologies will vary based on the most recent PEV and electricity market data. These factors vary widely by region, and need to be thoroughly evaluated, though learnings from early pilot programs and coordination between utilities, car companies, and standardizing organizations will be critical to the future success of PEV-grid integration.

One early project that will provide some insights is the BMW-PG&E collaboration called the iChargeForward Program launched in August 2015 in the San Francisco Bay Area. This small 18-month pilot program incentivizes BMW i3 drivers who participate in a managed charging program which aims to meet consumer needs while also allowing for grid-load reductions. BMW will manage the at-home charging of enrolled consumers, including up to a one-hour charging delay at their home charger. Consumers set a preference for battery state of charge and departure time, but are given the option of opting-out of each managed-charging event. Their incentive will vary based on their participation. This project allows for a test-run of early networking and remote charging control software, and at the end, BMW and PG&E will have a better understanding of consumer compliance and grid-load modification (BMW USA, 2015). This project is on-going through December 2016. Project results which would be relevant to utilities and EVSE network operators will

follow.

Conclusion

Infrastructure investments in the current market should be made with an eye toward future PEV market developments. Considerations include expanding vehicle range, increasing adoption, faster charging, and increasing grid-connection and charging control. Expanding vehicle ranges will lead to a need for a geographically expanding charging network. Increasing PEV adoption will lead to more charger demand over time, and in less prime locations - requiring home or workplace charging to meet the needs of owners who live in multi-unit dwellings and older homes without the option for dedicated home-based charging. In the short term, planning should be for limited EVSE installations, but siting and conduit which will allow for easier expansion of the number of chargers at existing locations will allow for economic expansion when charger congestion becomes an issue.

The vehicles on the market have already moved from 3.3kW charging in the early models to 6.6 to 10kW for current model PEVs. The Tesla SuperCharger can charge up to 120 kW currently, but there have already been announcements from automakers that the Audi E-Tron Quattro and the Porsche Mission-E will be able to charge at speeds of up to 300kW, and forward-thinking charging companies are already preparing for this (InsideEVs, 2015). Finally, while some limited ability to schedule charging – for example a timer on the charger, or a delayed charging start time in the vehicle control are currently available, the next wave of development will be for more specific demand management of the charging load, either at an aggregated network operator level, or a utility-controlled demand management system. This will allow for more efficient use and integration of renewables with the electrical grid. Beyond demand management, it could lead to the use of PEVs as

distributed storage for a highly variable, renewable-dependent electrical grid.

The early EVSE supplier and network operator market was flooded with options, though that has now calmed. If government funds for incentivizing infrastructure are used, funding distribution should consider the past performance of EVSE suppliers and/or network operators in terms of their reliability, maintenance and downtimes, plans for future expansion and operations, and their ability to adapt and operate demand management strategies and eventually vehicle-to-grid (V2G) capabilities with two-way electricity flow.

In order to increase PEV sales, there needs to be an ecosystem of supporting infrastructure and policies to support the developing market. In successful PEV markets worldwide, this includes financial subsidies for private purchase of PEVs, free and priority parking locations in busy cities, bus or carpool-lane access, government investment in charging infrastructure, vehicle emissions regulations and government sales goals, utility support often in the case of special time-of-use rates for EV drivers, education and outreach programs. The suite of supporting policies varies, but what is common is that successful markets do not rely on just one or two incentives for PEV buyers, but combine many incentives to help grow the PEV market. British Columbia is already well-suited compared to many other provinces in Canada in creating a suite of supportive policies and incentives.

One way to make the funding stretch further would be by motivating car manufacturers to engage in partnerships with state and local governments for the planning and deployment of charging infrastructure, by tying government incentives to this engagement.

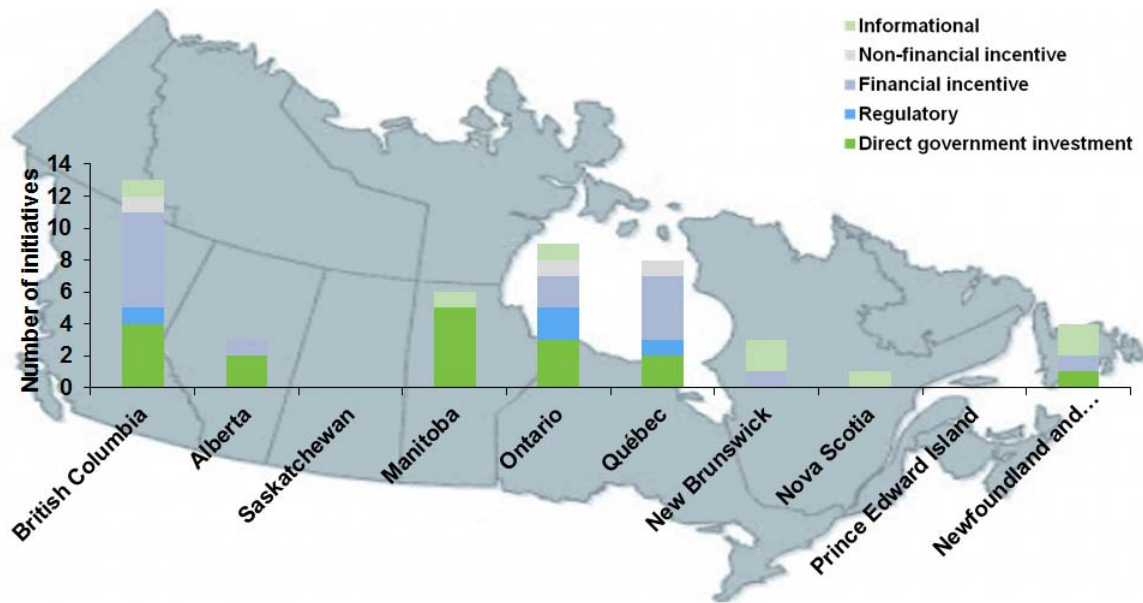


Figure 17: Canadian PEV Policy Assessment (Melton and Goldberg, in progress)

As a city, Vancouver can take several actions that can help create the ecosystem to encourage both PEV adoption and EVSE installations. Adopting clear building codes, and implementing a streamlined EVSE installation and inspection process, for both public and home charger installations is something that can have an impact and be managed at the city level. Installing EVSEs at desirable city locations, with either free or discounted parking and charging, is another city initiative that can have an impact on PEV adoption and use. The city of Vancouver can provide strategic investments contingent on private match funding for charging infrastructure installation, which should focus on overnight and workplace charging which can satisfy the bulk of PEV charging needs, similar to the Massachusetts workplace charging program.

Finally, educating all the participants in the decision chain – from city inspectors and electricians, to dealers and end consumers may be the largest hurdle to overcome. Some of the most effective methods are by requiring, versus just offering, dealer training about new technologies and vehicle models, providing clear and consistent regulations and local permitting processes, and having easy to understand information regarding charging costs and rate options provided by the

local utility. Using some of the available resources on an educational campaign can help increase PEV adoption.

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Appendix 1: Electric Vehicle Charging Station Financing Program

<http://www.treasurer.ca.gov/cpcfaca/calcap/evcs/index.asp>



Electric Vehicle Charging Station Financing Program

The goal of the CalCAP Electric Vehicle Charging Station (EVCS) Financing Program is to expand the number of electric vehicle charging stations installed by small businesses in California. The program, funded by the California Energy Commission, provides small business borrowers and lenders incentives to finance electric vehicle charging station equipment acquisition and installation.

Who Benefits

- ❖ **Borrowers** may be eligible for a rebate equal to 10% or 15% of loan amount.
- ❖ **EV Practitioners** can access capital to accelerate EV infrastructure installation, increase PEV adoption and attract new customers.
- ❖ **Lenders** may be reimbursed for up to 100% of loan defaults if funds are available in the lender's loss reserve account.
- ❖ **Public Agencies** can promote the program as a financial solution to accelerate implementation of EV readiness plans, help small businesses acquire capital for EV infrastructure, and assist their communities or constituents in complying with local air quality and transportation policy goals.

What's Eligible?

- ❖ Costs of installation and acquisition of electric vehicle infrastructure, design and development costs, operation and maintenance costs, as well as hardware and software costs necessary to operate the charger.
- ❖ Almost any corporation, partnership, cooperative or other entity with 1,000 or less employees.
- ❖ Enrolled loans are insured for up to 48 months and are limited to \$500,000 per borrower.

How it Works

- ❖ Small businesses reach out to participating lenders for charging station financing. *(The list of EVCS Financing Program Participating Lenders is located at the program's website or <http://treasurer.ca.gov/cpcfaca/calcap/evcs/lenders.pdf>)*
- ❖ CPCFA contributes a portion of the loan amount (20-30%) into the lender's loss reserve account to cover the lender in the event of a default.
- ❖ After loan repayment or following 48 months after the loan is funded, the small business may be eligible for a rebate equal to 10-15% of the enrolled amount.
 - The base rebate is 10% of the enrolled loan amount.
 - The rebate will be 15% if the EVCS installation is located at a Multi-Unit Dwelling or in a Disadvantaged Community.

Contact Program Staff at (916) 654-5610 or at CalCAP@treasurer.ca.gov
<http://treasurer.ca.gov/cpcfaca/calcap/evcs/index.asp>