UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

Options for EV Charging Infrastructure Requirements for New Multi Unit Residential Building (MURB) Construction on the UBC Campus

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Options for EV Charging Infrastructure Requirements for New MURB Construction on the UBC Campus

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EXECUTIVE SUMMARY

Vancouver as the leading adopter of green technology has its ambition in climate change leadership by cementing its role in the provision and market incubation of electric vehicle("EV") charging infrastructure until 2021. EV charging infrastructures are important ancillary facilities to catalyze the transition from fossil-fueled vehicles to EVs over the coming years. The emerging EV sales in Canada is pushing EV charging infrastructure development into next phase. Besides of the support of new charging technologies, policy tools have great power to influence the EV developments as well.

On the UBC campus, the new EV charging capacity is needed to meet increasing demands from the emerging electric vehicles, but also for the greener and more sustainable development plan of the campus in the long term. Therefore, the EV charging stations will be the important ancillary facilities for the new multi-unit residential buildings("MURBs") on the campus.

To evaluate and recommend the options for EV charging standards for the new construction of MURB buildings on the UBC campus, a review of current and proposed EV charging bylaws among the Metro Vancouver cities and the associated technical has been conducted. Meanwhile, collaboration with a local developer, PLG Homes, provided valuable information for policy aspect feedback and analysis. The policy recommendations for new MURBs EV charging infrastructure on the UBC campus have been addressed based on the review results of both policy and technical supports. Moreover, the discussions and review of the future challenges for policy deployment indicated by "Vancouver's EV Ecosystem Strategy" assist the policy makers and public to know what is in front, thereby engaging efficient future-proofing designs and policy deployment methods for new MURB EV charging infrastructure constructions.

1.0 INTRODUCTION

In the first part, the project background of the University of British Columbia (UBC), UBC's greenhouse gas ("GHG") emission goal, and emerging EV market in Canada will be introduced. Based on the project background introduction, the scope of the project is defined for study. Meanwhile, the rationales of the project scope are discussed.

1.1 Project Background

1.1.1 The University of British Columbia

The University of British Columbia is a place of mind. UBC's Vancouver campus located at the west corner of Metro Vancouver area, it acts as a municipal jurisdiction regulated by UBC's

THE UNIVERSITY OF BRITISH COLUMBIA

Board of Governors. The British Columbia University Act confers on the UBC Board of Governors responsibility for the management, administration, and control of the property, revenue, business and affairs of the University. [1] To achieve the long-term sustainable campus development, UBC always follows more strict regulations and bylaws than other cities in Metro Vancouver. For building development aspect, UBC has the Residential Environmental Assessment Program (REAP). Building a sustainable community includes setting high standards for UBC's residential developments. REAP is a comprehensive, UBC-specific green building rating system for mandatory application to all residential construction on campus. All new residential buildings at UBC must achieve a minimum of REAP Gold certification. UBC designed REAP to guide the development of all residential buildings planned for the UBC Vancouver campus. REAP is unique amongst green building rating systems since it can be applied to both low and high-rise buildings. Compared to standard residential buildings, REAP ensures lower consumption of water, energy, and resources, and higher-quality indoor environments and construction practices. REAP building standards also reduce the environmental impact on both the building site and the larger community.[2]

Figure-1 UBC REAP v3.0

REAP awards points in seven performance categories:

Sustainable Sites

Water Efficiency

Energy and Atmosphere

Materials and Resources

Construction

Indoor Environmental Quality

Innovation and Design Process

All UBC residential developers must meet a minimum REAP Gold standard to their projects. After meeting all mandatory measures, developers select from a wide range of optional measures, in any performance category, to earn a REAP rating. [2] And UBC has other guidelines and regulations for building development, such as UBC LEED Implementation Guide and Development & Building Regulations. UBC is applying these strict regulations to achieve its ambition in the climate change commitment.

1.1.2 UBC Climate Change Action Plan

As mentioned above, the University of British Columbia (UBC) developed the Climate Action Plan to reduce greenhouse gas emissions on the Vancouver Campus and address the impacts of climate change. UBC's commitment to climate action is about being an exemplary global institution and mitigating the greenhouse gas emissions that contribute to climate change. [3] In line with this commitment, UBC established some of the most aggressive greenhouse gas (GHG) emission targets in North America in 2010. UBC's Board of Governors approved the UBC Climate Action Plan in 2010, including the following GHG reduction targets against a 2007 baseline for the Vancouver campus:

33% reduction by 2015

67% reduction by 2020

100% reduction by 2050

In 2015, UBC has achieved a 33% reduction in its greenhouse gas emissions from a 2007 baseline, despite an increase in both building space and student enrolment. This success was achieved primarily through three major projects:

i. Converting the Academic District Energy System from steam to hot water
ii. Building the Bioenergy Research and Demonstration Facility (BRDF) to provide renewable heat and power
iii. Optimizing academic building performance and reducing energy consumption through the Building Tune-Up Program

Building on this success, the UBC Climate Action Plan (CAP) 2020 was developed, outlining a series of actions UBC could take towards achieving a 67% GHG emissions

reduction below 2007 levels. A number of options were identified by workshops with stakeholders, subject matter experts, and a campus-wide public consultation in the fall and winter of 2015/2016. [3] Therefore, the option for a combination of transportation and building construction is important for UBC to achieve the goal. The emerging EV is one the most efficient option at the current stage. EV is not only the solution for the transition from fossil-fueled vehicles to lower emission and cleaner transportation methods, but also is accelerating the supply side of EV charging infrastructures. The EV charging infrastructure confront the challenge of much slower development and update than batteries, therefore policy action is a driver to provide continued momentum for EV charging infrastructure development.

1.1.3 Emerging EV Market in Canada and Province of British Columbia

Canada has the commitment of Paris Protocol for 2050, and the current carbon emission trajectory is still so far from the target. Based on the GHG emission study from the City of Richmond, to achieve Canada's 2050 target is still a tough journey ahead. It involves that first, the federal government, provinces and industry act. The new bylaws and regulations will be developed for lowering fossil fuel consumption, setting higher vehicle fuel efficiency standards, and better building code for better building space and energy use. Second, deploying the current and planned city actions contributes to compacting and completing the neighborhood design, upgrading the district energy network, prioritizing walking, cycling, and transiting the transportation behaviors. Additionally, the enforcement and incentives are necessary to promote the energy efficient households and

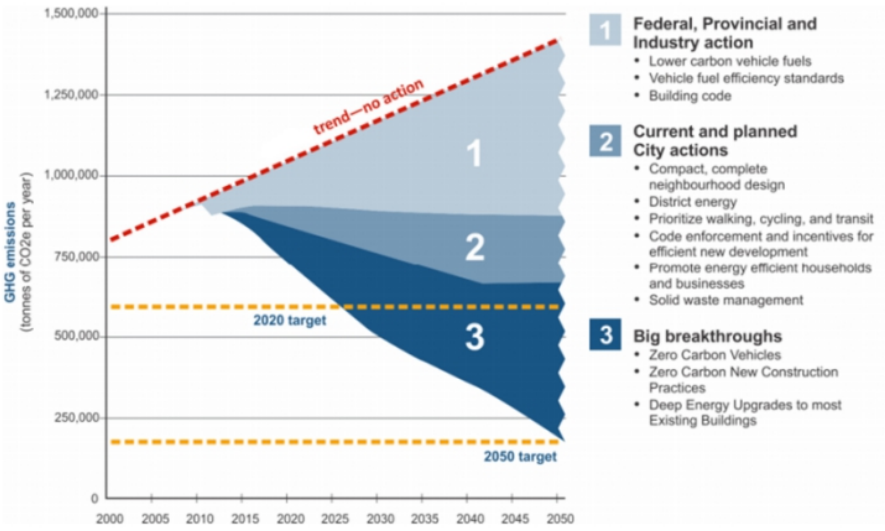


Figure-2. Widespread adoption of Zero Carbon Vehicles Needed to Achieve Targets [4]

businesses. Another big challenge for Canada is how to make the big breakthroughs. Zero carbon vehicles target depends on the technologies of power supply method. Li-ion battery is a good choice right now, but it is not the long-term solution due to

the duration and range capacity associated with the heavy weight of battery units. Meanwhile, lack of mature charging network, the heavy-duty, and long-range travel are hard to achieve now. Therefore, the policy interventions for EV infrastructures may assist the market to grow faster.

The electric vehicles amount has been accumulating with a rapid speed in Canada since 2013. And in Q3 of 2017, EV sales numbers for BEVs and PHEVs have surpassed totals for all of 2016. BEV sales totaled 6,629 at the end of Q3, an increase of 29% over 2016 sales. Meanwhile, PHEV sales have surpassed the previous year totals at 5,841. With three more months in the year, EV sales for the 2017-year-end are expected to reach 16,627 vehicles, a 50.83% increase over 2016. [5] And 2017 BEV sales have reached an estimated 8,800 vehicles sales which present the largest growth rate of a 72% over 2016. [5]

Figure-3. Canada EV Sales Historical Data and Trend [5]

From figure-4 below, when zooming in for province sales data, there are the top three provinces for EV adoption. Province of British Columbia is the third leader in Canada with the second highest increase in the rate of EV adoption, a 48.6% increase over 2016 while Ontario has a 91% growth rate over 2016 totals.

However, for Canada's 2050 target, an annual increase in the adoption rate of 48% is not enough for BC. The fear of running out of battery far from a charging station is so common among electric car drivers, the range anxiety. While electric cars are growing in popularity, charging is a perennial issue. Tesla, whose Model S is the best-selling electric car in America, relies on a network of destination charging stations where drivers can plan to be for several hours or overnight, or supercharger stations, which charge cars in about 30 minutes. Therefore, reliable EV charging network is

the key to EV adoption strategy. In addition, the emerging EV demand also assists the development of EV charging sector.

According to the data from Fleetcarma,it is easily observed that the annual increase rate of EV in Canada is tremendous. One of the main reasons to make BC be the third EV adoption leader with 2.1 times than average increasing rate among all provinces is that the majority of electric car charging happens at home or at work, and in British Columbia 95% of all car trips in BC's urban areas are less than 30km, well within the range of a typical electric car.

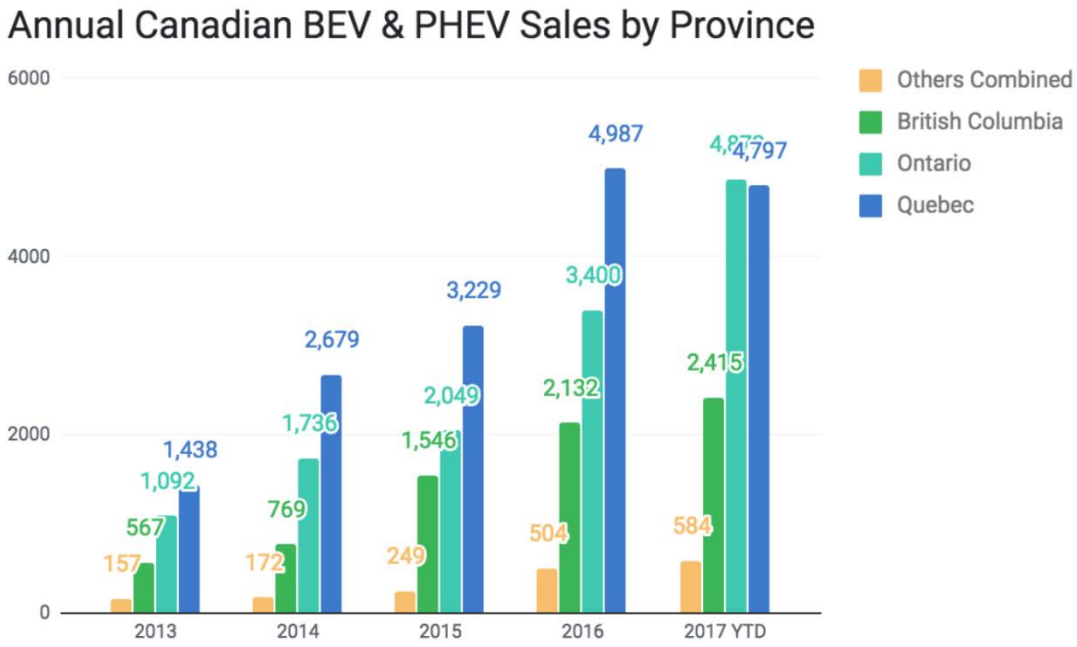
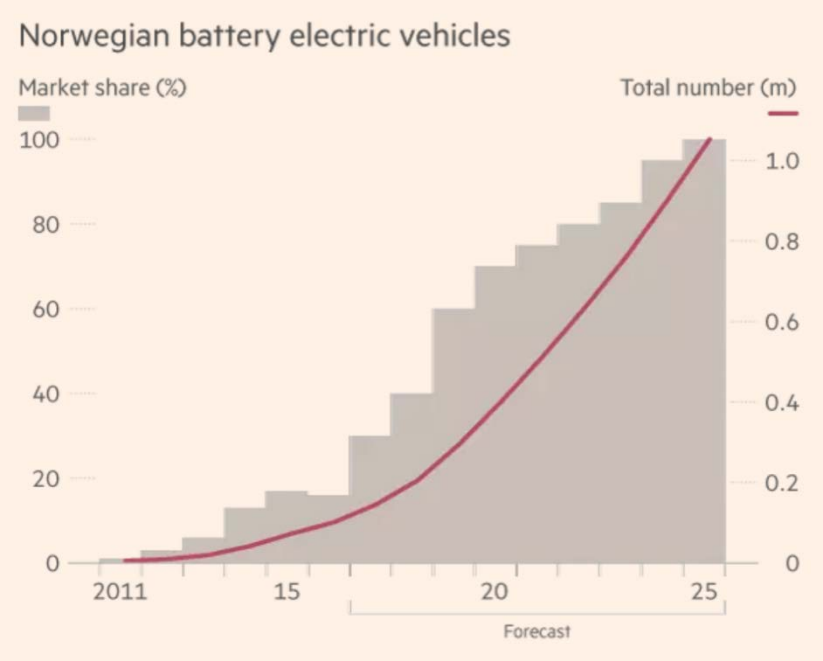


Figure-4. Canada EV Sales Historical Data and Trend by Province [5]

1.2 Scope of project

In the REAP 3.0 certification score system, there are 2 credits SS 2.2 (2 pts, One EV visitor stall w/charger per 100 units) and SS 2.3 (2 pts for 10% L2 EV ready stalls, 4 pts for 20% L2 EV ready stalls) for the EV charging infrastructure sustainable site ("SS") optional design credit. This project is aiming to develop EV charging infrastructure requirements for new MURB constructions on UBC campus. The rationale of the project scope is that alternative fuel vehicles can help UBC reach its GHG reduction goals by reducing greenhouse gas emissions from vehicle operation, and also decrease upstream emissions, by approximately 28% as compared to conventional petroleum-powered vehicles. [6] However, if UBC lacks the ancillary infrastructure, UBC cannot meet the demand of the charging stations, people will not choose the alternative fuel vehicles, like EVs for their transportation, until the facility are available. Meanwhile, without future-proofing design, the MURBs developers and unit owners won't have the willingness to install EV charging stations due to the significant cost of retrofits.

And many other jurisdictions have demonstrated that the policies can speed up the adoption of EV. In Norway, there are over 30% of sold vehicles are EV in 2016 [7] due to a variety of incentives, such as access to HOV lanes, free ferries, and preferred parking. The German parliament has passed a resolution calling for the European Union to pass the directive to allow only Zero Emissions Vehicle by 2030. Additionally, the EU is pushing the draft regulations that require 100% of new homes to have the EV charging electric access.[8] In north America, there are ten American states enacted actions to require 15% of new vehicles be zero emissions by 2025. And the province of Quebec, the leader of EV adopter in Canada, claimed it will follow the same requirement. Therefore, establishing and improving practical EV infrastructure policy for new MURB construction is a key approach to achieve UBC's emission target.



Firgure-5. Norwegian battery electric vehicles forecast [7]

2.0 METHODOLOGY

In this project, all current experience is very valuable. Firstly, the experience of EV charging regulation developing from all cities in Metro Vancouver area has been reviewed. Meanwhile, to choose practical and right technologies to support policy options, the recent EV charging technologies have been reviewed as well. The collaboration with a local developer provided this project valuable frontline information, data, and feedback on current regulations.

Based on the review results, this project addresses the policy recommendations of EV charging infrastructure in new MURB construction on the campus. Additionally, the discussion of the future challenges is to identify the obstacles to future improvements and new requirement deployment. In this project, the influences of

future technologies for EV charging and improvement methods have been reviewed for engaging the future-proofed designs.

3.0 EV CHARGING TECHNICAL OPTIONS REVIEW

3.1 Type of EV charging stations

Level 1-120 Volt AC

Level 1 AC electric vehicle cord sets can plug into a common shared 120V AC branch circuit intended for typical use that is the lowest common voltage level found in both residential and commercial buildings. Typical amp ratings for these receptacles are 15 or 20 amps. A Level 1 AC Cord Set (120 VAC, 15 amp) is provided by many electric vehicles manufactures with the sale or lease of an electric vehicle.

Level 2AC – Greater than 125 Volt AC or greater than 20 amps

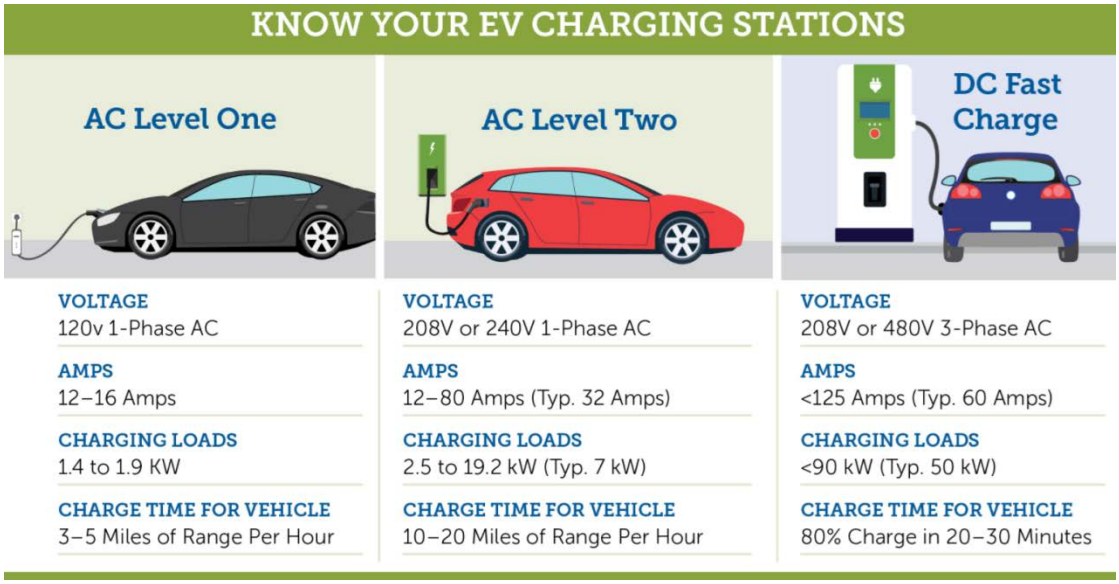
Level 2 AC Charging specifies a 240 VAC, single phase branch circuit. The SAE J1772 approved connector at the vehicle end allows for current as high as 80 amps AC (100 amp rated circuit). However, current levels that high are rare and a more typical rating would be 40 amps AC which allows a maximum current of 32 amps.

This level of charge provides a higher voltage than a Level 1 AC charge which results in a significantly faster battery charge. The Level 2 AC method uses Electric Vehicle Supply Equipment (EVSE), also known as a charging station that plugs into a 240V receptacle, is hard-wired to the premises and may conduct charging wirelessly to the EV.

In addition, when using Level 2 AC charging, the onboard vehicle charger will communicate with the EVSE to identify the circuit rating and adjust the charge to the battery accordingly. For safety purposes, this communication protocol ensures that the appropriate amount of electricity is delivered to the vehicle battery. For example, an EVSE that is capable of delivering only 25 amps will deliver that amount of current even though it is connected to a larger circuit, such as a 40 amp rated circuit.[9] Level 2 charging stations have more charging efficiency than Level 1 and have lowest maintenance fee for all types of chargers right now.

Level 3-DC Fast Charging

DCFCs provide the fastest charging times and typically use an off-board charger to provide the AC to DC conversion. The vehicle's onboard BMS controls the off-board charger to deliver DC directly to the battery. Previously identified as Level 3 charging by the IWC, the SAE has redefined this as DC Level 2 charging. This off-board charger is serviced by a three-phase circuit at 208, 480 or 600VAC. The SAE standards committee is working on a DCFC connector. [9] Comparing to the level 2 charging station, Level 3-DC shorten the charging time from 4 to 6 hours to 30-40 minutes. But the capital cost of DCFC is over 10 times that level 2 charging station in general.



Charging Level	Voltage	Amperage	Apprx km of range per hour of charging	Time to fully Recharge (dependent on battery size)	Applications
"AC Level 1"	120 VAC	12-16 A	~ 7 km/hr	5 to 30 hours	At home, at work.
"AC Level 2"	208 / 240 VAC	<=80A (30 A most common)	15 – 45 km/hr	2 to 8 hours	At home, at work, public charging
"DC Fast Charge"	200 - 400 VAC	80-400 A	200+ km/hr	<10 min to 1 hour	Major public rapid-recharge locations

Figure-6. Types of EV Charging Stations[10]

3.2 Smart Power Charging System-EV Charging Load Share and Management

Nowadays, the most used EV charging station is the dedicated type. The dedicated type EV charging circuit has only one charger installed on the circuit due to the still low EV penetration rate and low charging station demand in the MURB constructions. Meanwhile, as mentioned above, the dedicated type charger was developed well to meet the demand of the single family and townhouse users. In addition, the initiation cost of the charger is not low as well, it is around $4,000 to $6,000 with the installation and labor cost. [10] And the dedicated type charger doesn't have the load sharing and load management capacity to reduce the building peak load issue. Moreover, charging infrastructure development cannot catch up the battery development. Therefore, a method to provide more economic and better building energy performance is sought.

	Level 2 Home	Level 2 Parking Garage	Level 2 Curb-side	DC Fast Charging	Description/Key Assumptions
Charge station hardware	$450–$1,000	$1,500–$2,500	$1,500–$3,000	$12,000–$35,000	
Electrician Materials	$50–$150	$210–$510	$150–$300	$300–$600	• $1.50–2.50/ft for conduit and wire, plus misc other materials • $50–80/hour (per dist?) • $500–1000 if new breaker is required • Assume 2x electrical cost for level 3
Electrician Labor	$100–$350	$1,240–$2,940	$800–$1,500	$1,600–$3,000	
Other Materials		$50–$100	$50–$150	$100–$400	• $25–100/ft for trenching/boring—depends on surface, soil, and underground complexity • Mounting, signage, protection, and restoration also included here, but don't usually contribute more than a few hundred dollars
Other Labor		$250–$750	$2,500–$7,500	$5,000–$15,000	
Transformer	NA	NA	NA	$10,000–$25,000	• 480V transformer installed by utility
Mobilization	$50–$200	$250–$500	$250–$500	$600–$1,200	• Home: 1–3 hours of electrician time for a home installation • Public: $250–500 of time for 1–2 electricians and other labor. We found that the work could usually be completed in a single visit from each contractor.
Permitting	$0–$100	$50–$200	$50–$200	$50–$200	• Varies city to city, often a flat fee for one or several stations

Table-1. Cost of Diverse Types of EV Charging Stations [10]

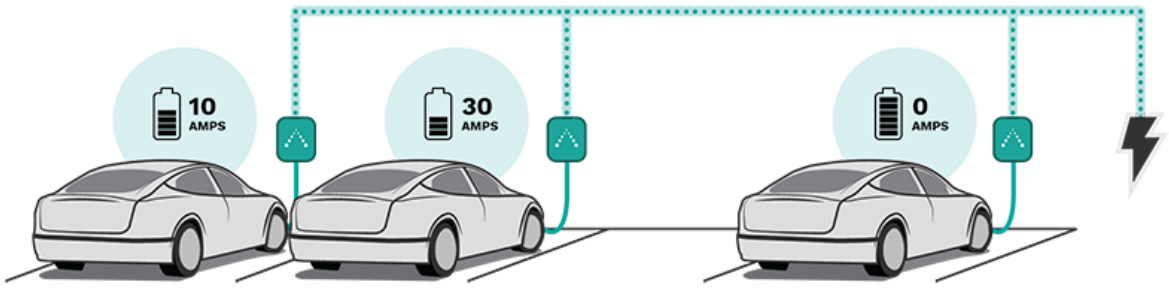


Figure-7. Configuration of Smart Power Charging System [11]

One technology called Smart Power Charging has been developing to deliver a better solution for multi-unit parking. The simple definition of Smart Power Charging is that there are multiple chargers on the Smart Power Charging circuit, all chargers are designed with intelligent functionalities to create and distribute the available power in an efficient and flexible manner to charge the EVs. Meanwhile, the Load Balancing is an indispensable Smart Charging feature for those that operate a charging station with dual sockets or multiple charging stations at a specific location. Operating a charging station requires the power source to carry the cumulative sum of the total capacity of these charging stations. Load Balancing distributes the available capacity proportionally over all active charging stations. In doing so, Load Balancing ensures that optimal charging is provided to all-electric vehicles at your location, within the

limits of charging stations' capacity. [11] The load sharing technologies can make multiple chargers to communicate so as not to exceed the capacity of a circuit, and to time charging to occur when power cost less. The smart charging technology allows the users to receive the sufficient charge with lower electrical costs.

A simple theoretical calculation of a load management module to serve four 240V EVSEs on one 40-amp circuit is demonstrated as below:

Circumstances for charging:

1.Required charging time: Assume vehicles have each traveled 50 kilometers and require 10 kWh of electricity per day supplied over 6-hour period between midnight and 6 am.

2. Charging power: Charging at 6.6 kW will require 1.5 hours per vehicle.

3. Charging order: Unlike the single charger on one circuit, the load management module switches the 40-amp circuit to a different vehicle at a user determined time interval. Using this round-robin switching, all four vehicles will be charged in 6 hours one by one instead of the same time.

4.Smart Power Charging technology: According to the charging requirement from users, the control panel will allocate the load to vehicles. If the charging time interval is from 12am-6am, the first two vehicles can finish charging at 3 am (12am-1: 30 am, 1:30-3am, respectively). The last two will start their charging together when the previous ones are done. But one of the vehicles only have a 3.3 kW charging, it will continue charging for an additional 1.5 hours assuming the other three vehicles are fully charged. However, the power demand on the MURB electrical infrastructure during this additional period will drop from 32 amps to 16 amps. With this technology, it can reduce the load balance issue at the peak hours for MURB operations.

And cost of the load share and management system requires much lower average initial cost. Because there are multiple chargers on the sole circuit which significantly reduces the size of electrical room space for transformers, control panels, and wire installations.

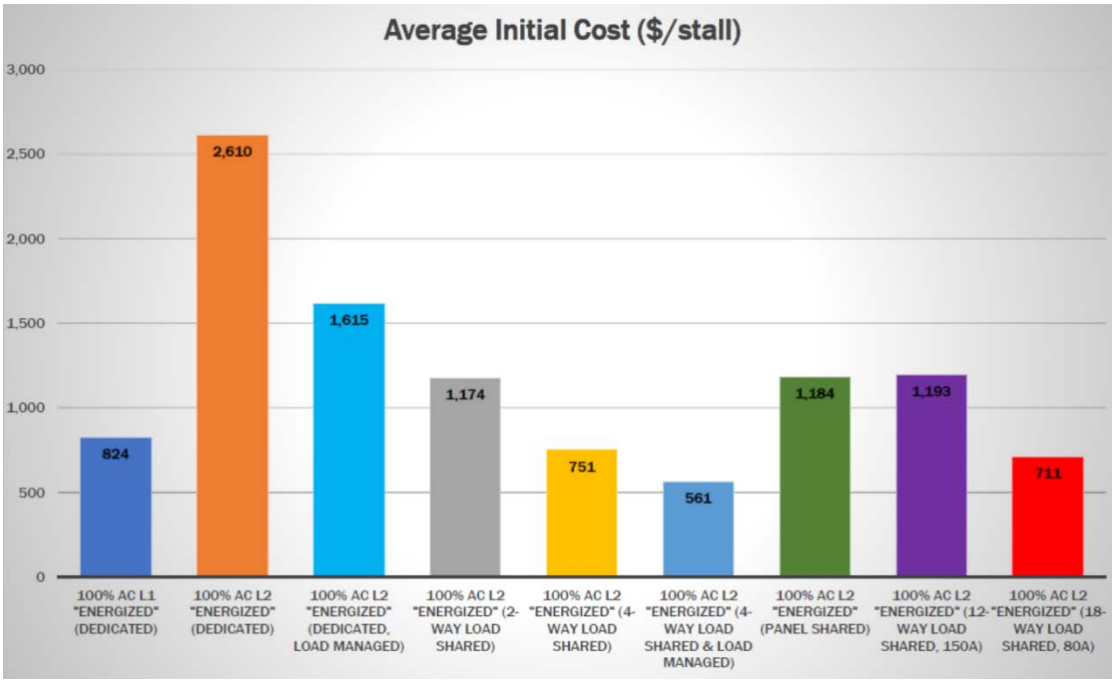


Figure-8. City of Richmond EV Charging Study-Average Initial Cost Analysis [15]

Based on the City of Richmond EV charging study, in the figure-8., it is observed that the highest initial cost of $2,610 is for 100% AC Level 2 dedicated (energized) [15]. Even installing 100% of EV chargers at the beginning, the cost is still very expensive. However, if the EV charging station installation with 100% AC Level 2 4-way load share and management technology, the cost drops by 78.5% to $561 per stall.

4.0 BYLAW REVIEWS

In this part, bylaws, and policies for EV charging infrastructure of different cities provide the valuable guideline for policy recommendations. The City of Richmond, the City of Vancouver, and the District of North Vancouver are the leaders for EV adoption. These cities have either bylaws or policies for EV charging infrastructure which promotes the pilot programs, such as Vancouver's Ecosystem strategy, Vancouver curbside EV parking pilot program, and Richmond City Hall EV charging program, to establish EV charging study database for future policy updates and revises.

In addition, current EV incentives supported by both private and government authorities assist this project to understand the orientation to which policymakers want to guide the public.

4.1 City of Richmond

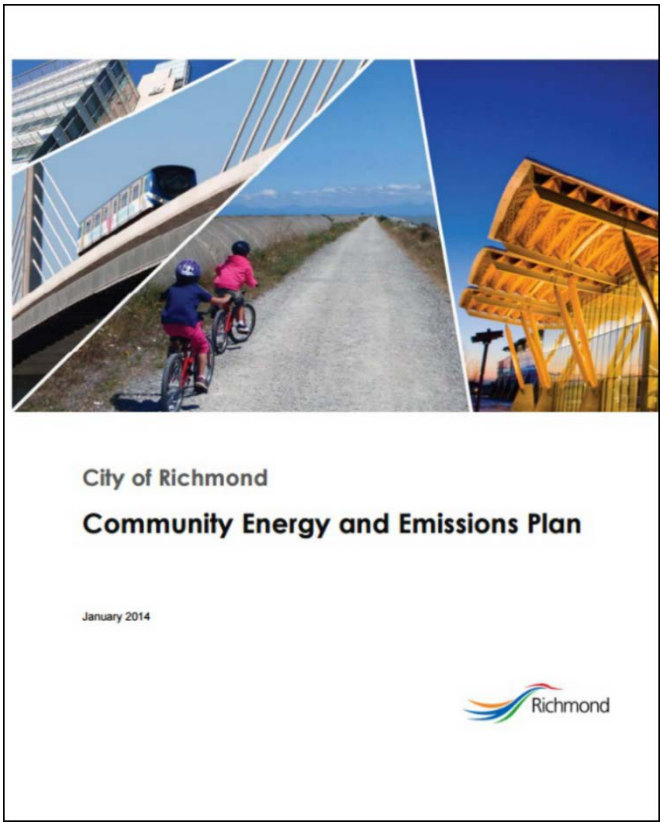


Figure-7. City of Richmond Community Energy and Emissions Plan [12]

4.1.1 Current EV Charging Strategy and Action

In the City of Richmond, it has the Community Energy and Emission Plan(“CEEP”) to guide all the shareholders in Richmond city to engage the EV charging infrastructure improvement [12]. Based on the review of the report of “Electric Vehicle Charging Infrastructure- Requirements for New Developments” by John Irving, in January 2017, Council endorsed a stakeholder consultation program to develop electric vehicle charging infrastructure requirements for new private developments. This consultation also included opportunities for input on the City-owned network of public electric vehicle charging stations, and implementing electric vehicle charging infrastructure in existing buildings. The report supports City of Richmond Council's 2014-2018 Term Goal #4 “Leadership in Sustainability: Continue advancement of the City's sustainability framework and initiatives to improve the short and long-term livability of our City, and that maintain Richmond's position as a leader in sustainable programs, practices, and innovations.” [12] Analysis Background In 2010, Council adopted targets in Richmond's Official Community Plan to reduce community greenhouse gas (GHG) emissions 33% below 2007levels by 2020, and 80% below 2007levels by 2050. [13] Although the City of Richmond has the lower GHG emission goal than that of UBC, it is still a tough task to complete. In the Community Energy and Emissions Plan, there are specific Strategy and Actions to guide and enforce the

public to move forward to the target. The EV charging infrastructure related strategy and actions are reviewed as follows.

"Strategy 7: Promote Low Carbon Personal Vehicles"

According to the City of Richmond GHG emission report, transportation accounts for more than half of the greenhouse gas (GHG) emissions in Richmond's Community Energy and Emissions Inventory, with personal transportation accounting for more than 40% of emissions. Since the personal vehicles don't need the heavy-duty power to drive, switching to electric motor driven by battery unit will not affect the daily travel capacity within low range trip. Therefore, the strategy directs the low carbon development orientation for the City.

"Action 18: Set minimum requirements for electric vehicle infrastructure in new developments."

With the result of modeling undertaken as part of the CEEP indicates Richmond's 2050 emissions reduction targets can only be achieved with the near-universal adoption of zero emissions personal vehicles by the 2040s, in addition to increasing transit ridership, walking, bicycling and rolling. [14] The CEEP states that the City will pursue the widespread adoption of low carbon vehicles, in coordination with senior levels of government and industry. Electric Vehicles (EVs) Plug-in Electric Vehicles (EVs) include vehicles equipped with a plug and battery that can use electricity for propulsion. EV s realize near-zero GHG and air contaminant emissions when using power from BC's electric grid. [14] At the current stage, the John Irving report indicated that most EV ownership is currently concentrated in single family and townhome housing with individual garages, as this household currently have more easy access to EV charging. However, EV ownership in MURBs is less due to the difficulty to have access to EV charging facility in the existing buildings. Therefore, to set policy to accelerate the adoption of EV is necessary.

"Action 19: Continue expanding City-owned network of EV charging stations."

This action is to consider the provisions for detached housing, townhouses, "at work" or "on the go" charging. This action would expand the range of the charging network for the public."

According to the above three aspects, the City has demonstrated leadership by being one of the first municipalities in the region to establish the policy providing for home access to EV charging. Section 8.5.2 d of the 2041 Official Community Plan currently includes this policy for new private multi-family developments to include EV charging infrastructure. This policy specifies that "a minimum of 20% of parking stalls be provided with a 120-volt receptacle [e.g. "Level 1 "] to accommodate EV charging equipment [and] ... an additional 25% of parking stalls be constructed to accommodate the future installation of EV charging equipment (e.g. pre-ducted for

future wiring)". This policy is applied to developments requiring a rezoning and/or development permit application. [14]

4.1.2 Recent City's Policy Proposal

From the EV charging study of "AES Electric Vehicle Charging Infrastructure in New Multifamily Developments – Requirement Options and Costing Analysis" conducted by the City of Richmond and AES [15], the cost of EV charging infrastructure will reduce by a big percentage if the load share and management technology are applied. Meanwhile, the cost of "energized" and "100% conduit design for future" will reduce the retrofitting cost by 100% in the mid-rise projects in the city center.

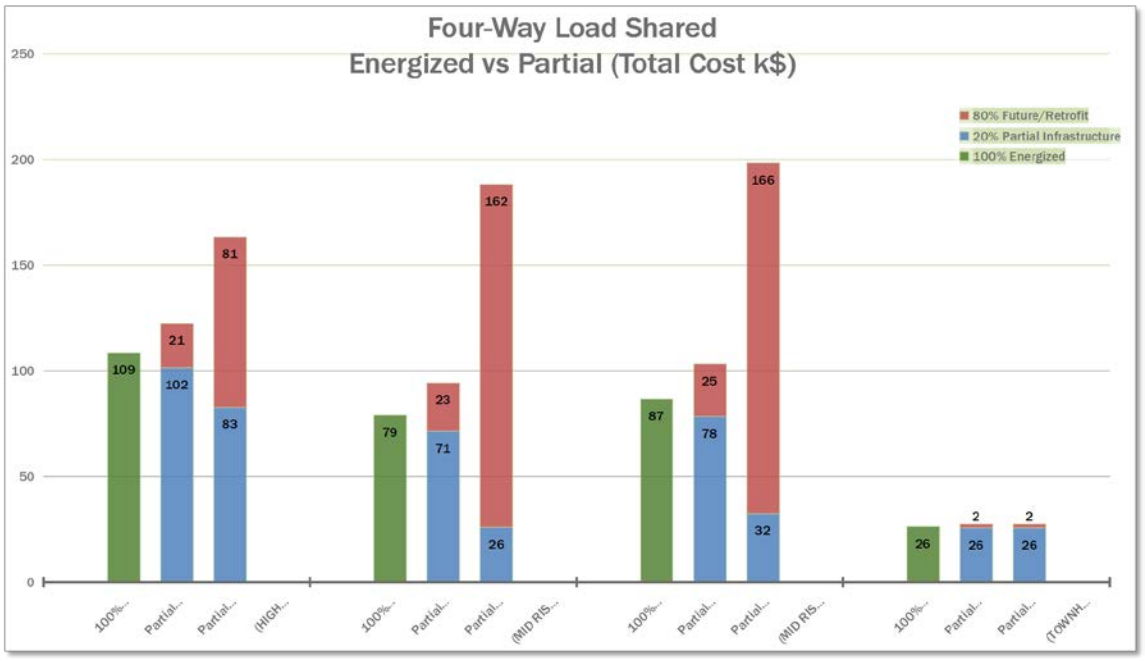


Figure-8. EV Installation Cost of Four-Way Load Shared Energized Vs. Partial [15]

And the City's proposals include the following:

"All residential parking spaces shall be "Energized". "Energized" means – All infrastructure required for charging of an electric vehicle (EV), including all electrical equipment (including metering), cabling and associated raceways, and connections, with exception of the Level 2 EVSE equipment."

"Performance standard – A minimum performance level of 12 kWh per EVSE, over an eight (8) hour overnight period. Load management and/or load sharing may be implemented."

4.2 City of Vancouver

BY-LAW NO. 10908

A By-law to regulate the construction of buildings and related matters and to adopt the British Columbia Building Code

THE COUNCIL OF THE CITY OF VANCOUVER, in public meeting, enacts as follows:

Figure-9. City of Vancouver Building Bylaw 10908 [18]

Besides City of Richmond, City of Vancouver("Vancouver") is also an aggressive player for deploying the EV charging strategy. And Vancouver is the only city in BC province that has the bylaw for EV charging infrastructure. The City of Vancouver Building Bylaw 10908 regulates the construction buildings and related matters and to adopt the British Columbia Building Code. In the bylaw, there is section 10.2.3 to specify the clear construction guideline for EV charging infrastructures, including both EV charging stall and electrical room design.

"10.2.3. Electric Vehicle Charging 10.2.3.1. – Electric Vehicle Charging for Buildings

1) Except as provided by Sentence (2), each storage garage or carport in one-family dwellings, two-family dwellings, one- or two- family dwellings with secondary suites, and laneway houses shall be provided with an electrical outlet box wired with a separate branch circuit capable of supplying 40A at 240 V and labelled to identify its intended use."

In the first part, the bylaw specifies that the multi-family units need to provide the electrical outlet box for "40A at 240V" which refers to LEVEL 2 EV Charging Stations.

Comparing with the action of Richmond's CEEP, "a minimum of 20% of parking stalls be provided with a 120-volt receptacle [e.g. "Level 1 "] to accommodate EV charging equipment [and] ... an additional 25% of parking stalls be constructed to accommodate the future installation of EV charging equipment (e.g. pre-ducted for future wiring)", some industry actors indicated that " Level 1 charging is insufficient for the electric vehicles of the future, which may necessitate Level 2 home charging to provide sufficient overnight charge when battery is low." [12] And in the MURB, the overnight charging is most commonly used by residents, LEVEL 2 charging can provide a better solution for sufficient charging services.

"2) Where the requirements of Sentence (1) would cause demand load to exceed 200 A, the installation of a 40 A branch circuit may be omitted if a raceway no less than 21 mm, leading from the dwelling unit panel board to an electrical outlet box, is installed in the storage garage or carport and is labelled to identify its intended use."

In the second part of the bylaw, this provides a future-proofed requirement for the exceeded load.

"3) A multi-family building or the multi-family component of a mixed-use building with three or more dwelling units, shall be designed with a receptacle for charging electric vehicles in 20 percent of all parking stalls used by owners or occupiers of dwelling units."

In the third part, the bylaw requires at least 20% of the parking slot in MURBs should be designed with a receptacle for charging electric vehicles. This mandatory regulation enforces that the future MURB construction must contain minimum 20% of total parking have a capability to install EV charging station immediately for parking owners. This provides the accessibility for EV charging which may have a major influence on EV purchasing. Meanwhile, more EV charging stations provide more EV public visibility and awareness.

"4) A commercial building, or the commercial component of a mixed-use building shall be designed with a receptacle for charging electric vehicles in 10 percent of all parking stalls."

The city of Vancouver doesn't just focus on the multi-family residents, but also incubate whole EV market from all sectors. This part sets the charging infrastructure requirements for public commercial buildings.

"5) The receptacle required by Sentences (3) and (4) shall be supplied by a separate branch circuit rated no less than 40 A at the nominal alternating current of 208 V or 240 V as applicable."

From the electrical design aspect, the bylaw provides the building design guideline. “no less than 40 A at the nominal alternating current of 208 V or 240 V as applicable.” ensures that the applicable design for current to meet the high load demand at the peak time.

“10.2.3.2. Electrical Rooms 1) In a multi-family building or the multi-family component of a mixed-use building with three or more dwelling units, an electrical room shall be designed with sufficient space for the future installation of electrical equipment to support the installation of receptacles, supplied by the branch circuits for charging electric vehicles, in all residential parking stalls.”

In section 10.2.3.2 specifies the electrical room design requirements. In a MURB component, the electrical room shall be designed with “sufficient space for the future installation of electrical equipment…”. With this bylaw, the future-proofing design must be applied by developers to meet the code for projects. The term in the sentence, “sufficient space” is still a vague definition for developers to specify. However, in the Vancouver’s Ecosystem Strategy [16], it reports that they are in the process of considering updates to their EV charging requirements to strengthen their requirements. And the electrical room of the new MURB construction shall be designed for 100% conduit capacity for future installations. It not only provides the accessibility for EV charging but also provides a solution for reducing the tremendous cost of retrofitting in the future.

4.3 District of North Vancouver

District of North Vancouver

In Metro Vancouver area, the district of North Vancouver is another strenuous supporter of the electric vehicle. The District of North Vancouver states that it is encouraging the use of EVs as part of its overall plan to build a sustainable transportation network in the District. In addition, it has established a policy to encourage EV charging infrastructure in all new District developments. The policy type is an administrative and operational policy for implementation of electric vehicle charging infrastructure with development which was approved on Dec. 15, 2014.

The District’s guideline is that the following electric vehicle charging infrastructure is to be provided with new developments [18]:

“1. For multifamily developments:

- ***20% of parking stalls are EV-ready, wired for level 1 charging***
- ***Conduit is in place so that 100% of parking stalls can later be wired for level 1 charging***

• Allocation of EV parking spaces is the responsibility of developers and/or strata organizations"

In the MURBs, the District requires 20% of parking stall must be EV charging stations, or EV-ready with 100% conduit in place for future installation. What should be emphasized here is that the District of North Vancouver is the only city points out the allocation of EV parking is the responsibility of developers and/or strata. Due to the complexity of strata organizations, like Strata Property Act, this policy provides an approach for later deployment.

"2. For commercial and industrial development, in the range of 10% of parking stalls are EV ready, wired for level 2 charging. The following criteria will be used to determine on a case-by-case basis the appropriate amount of level 1 and level 2 charging to be provided:

- ***Proximity to regional roads and highways;***
- ***Expected length of stay based on long-term land use tenure (e.g. more charging infrastructure will be needed where the stay is longer)."***

"3. All secure bicycle storage is to include level 1 electrical outlets for electric bicycle charging. Requirements are to be revisited based on implementation experience and input heard through developer consultation in Fall 2015."

The second and third ones are policies for commercial building and electric rollers.

4.4 Other Cities and Incentives

4.4.1 Other City EV Charging Infrastructure Policy Progress

For other cities in Metro Vancouver Area, the city of North Vancouver has its Sustainable Development Guideline which states "20% Level 2 outlet with 100% conduit", but it is neither the policy nor the bylaw yet. And District of West Vancouver has its council resolution of "Aim for 100% outlet" without the level of charger specified.

4.4.2 Incentives

Incentives for EVs and EV infrastructure are the boosts for EV adoption. There are three well-known programs funded by the Province of BC to assist the EV developments in British Columbia.

The first one is CEV program, as well as Clean Energy Vehicle program. In this program, BC Ministry of Energy and Mines will work with stakeholders through Plug-In BC, the Canadian Hydrogen and Fuel Cell Association (CHFCA), the New Car Dealers Association of British Columbia (NCDA), automakers, vehicle owner groups, and program participants, to seek advice on the CEV Program. This program has already dispersed fund of $17,720,831 to make BC cleaner and greener.

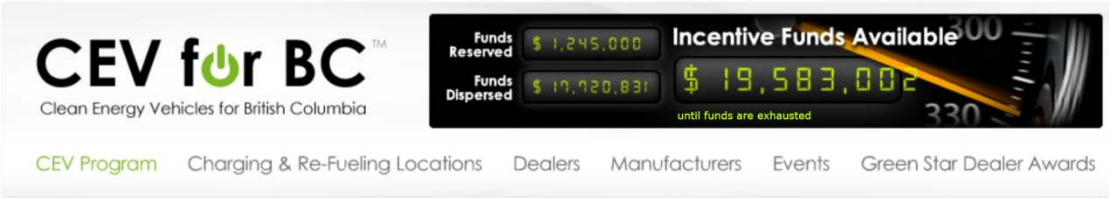


Figure-10. CEV for BC Incentive Funds Available

The second program is BC SCRAP-IT, this program has been operating since 1990s. From SCRAP website, Older vehicle models emit up to 60 times more smog forming emissions than 2008 and later models. For example, replacing a 1990 sedan with a 2009 hybrid can result in a reduction of up to 67% in greenhouse gas emissions. [19] This incentive program is a voluntary early retirement vehicle program that provides incentives to help British Columbians replace higher polluting vehicles with cleaner forms of transportation. The program is designed to reduce greenhouse gas emissions and to lower exhaust pollutants across the province. All scrapped vehicles and their components are permanently and properly recycled. Moreover, the electric vehicle incentive program has been extremely successful.[19] The funds available renew on an annual basis (until the entire fund has been depleted). The 2018 funds are now available.

Figure-11. BC SCRAP-IT Program [19]

The third incentive program is specific for MURBs. It is MURB Charging Program which is funded by the Province of British Columbia, and administered by Fraser Basin Council. And this program supports the cost and installation of electric vehicle supply equipment (EVSE), informally known as charging stations. According to the application form of the incentive, the cost will be cover upon to $4,500, or 75% of the total cost of installation. But this incentive program is only for existing MURBs right now.

4.5 Policy Review Summary

Minimum EV charging requirements in municipalities in Metro Vancouver

	Multi-family	Single family, duplex, coach house	Commercial	Policy Method
City of Richmond (current)	20% Level 1 outlet; electric conduit additional 25%	None	None	Council policy
City of Vancouver	20% Level 2 outlet (dedicated circuits); electric room sized for 100%	100% Level 2 outlet	10% Level 2 outlet	Building Bylaw
District of West Vancouver	Aim for 100% outlet (Level not specified)	None	None	Council resolution
City of North Vancouver	20% Level 2 outlet (dedicated circuits); electric room sized for 100%	None	None	Sustainable development guideline
District of North Van.	20% Level 1 outlet; electric conduit for remainder	None	10% Level 2 outlet	Council policy

Table-2. Minimum EV Charging Requirement in Municipalities in Metro Vancouver [13]

One of the great benefits of EVs is that the distribution system for the energy that powers them is already in place: the electrical grid. And BC Hydro can prove near-zero emission power for EV charging. However, EV charging generally requires expanded or additional electrical infrastructure. The most cost-effective strategy is to install EV infrastructure during the construction of a new building, especially the MURB which has concentrated multiple parking stalls. However, doing so adds costs and because EVs are not yet widespread, building developers are not necessarily going to proactively provide for them during construction. Therefore, regulations that require minimum provisions for EV infrastructure are needed. The appropriate level will vary according to the intended building use, for example, the residential versus commercial or single-family houses. The actual electric vehicle supply equipment (EVSE) need not necessarily be installed right at the beginning, it can be enough that conduits, wiring, and electrical panels be designed and installed with future EVSE installations.

The current policies, bylaw, sustainable development guideline, and incentives in Metro Vancouver are making Vancouver be the most aggressive EV adopter in the world. Based on the bylaw review, the multi-family EV charging policy trends to enforce all new MURB construction to have 20% installed an outlet for charging with 100% conduit design for future installations.

5. RECOMMENDATIONS

Combining the analysis of project background, project scope, EV charging technical option review, and bylaw review of EV charging infrastructure requirement in Metro Vancouver area, there are three recommendations addressed for EV charging infrastructure on UBC campus.

"1. On UBC campus, a multi-family building or the multi-family component of a mixed-use building with three or more dwelling units, shall be designed with Level 2 charging stalls for charging electric vehicles in 20 percent of all parking stalls used by owners or occupiers of dwelling units."

As the bylaw review summary, the 20% partial installation during the construction is an obvious policy requirement trend. The rationale of this percentage is to meet the emerging EV charging demand of the next three to five years.

For example, one under-construction project which has the highest MURB EV-ready percentage of 15% on UBC campus of market developments . In this under-construction project, there are 377 parking stalls as building design (Appendix A). Therefore, there are around 57 EV charging stalls or EV-ready on the move-in day in 2020. According to the project manager, there are 1% of unit owners have required the EV charging stall right now. If assuming of that there will be 3% of unit owner requires the EV charging stalls by end of 2017, there will be 12 EV charging demands. And assuming the EV sales in BC will keep increasing at a conservative constant rate of 48% [5], similar to that of 2017, it takes 4.2 years to fill all 57 installed stalls. But the increasing rate of EV may be much larger than 48% annual increase rate. Therefore, 20 percentage is recommended to be the minimum requirement for future MURB project on UBC campus.

Level 2 charging stations are recommended to be installed since Level 2 charging stations are more reliable than level 1 for charging, it takes less time and has much more functionalities. Meanwhile, for similar sufficient charging level, level 2 charging station has less maintenance cost and capital cost than level 3 DCFC as well. Therefore, level 2 outlet is a suitable choice for EV charging.

"2. On UBC campus, a multi-family building or the multi-family component of a mixed-use building with three or more dwelling units, an electrical room shall be designed with sufficient space for 100% conduit to match future installation capacity of electrical equipment to support the installation of receptacles, supplied by the branch circuits for charging electric vehicles, in all residential parking stalls."

"3. On UBC campus, a multi-family building or the multi-family component of a mixed-use building with three or more dwelling units, shall be designed with Load/Circuit Shared and Load Management System for Level 2 charging stalls."

The second and third recommendations are recommendations to make MURBs to meet the demand of future EV adoptions. 100% conduit design for electrical room equipment, such as transformers and wires, can reduce significant cost of retrofitting as discussed above. And this is also part of the future-proofing design. From Vancouver's EV Ecosystem Strategy, "Approximately 70 percent of light-duty vehicles will plug into an external power source, according to modeling done for the Renewable City Strategy." [17] Therefore, 100% of EV

Renewable City Strategy: Passenger Vehicle Count by Vehicle Type in 2050

Charging capacity will be needed in 30 years.

Associated with level 2 charger, the load share, and management technology should be applied to lower building energy consumption and higher building energy performance by maximizing building capacity to charge significantly more vehicles with less infrastructure. And the third recommendation also provides the approach to reduce the cost of EV charging which can boost the increase in EV charging installations.

6.CHALLENGES

Challenges always exist. Although EV and EV charging are under very fast development, the market, technologies, and associated regulations are not mature. There are challenges including many aspects. In Vancouver's EV Ecosystem Strategy, it lists very detailed challenges for MURBs which can be applied anywhere in Metro Vancouver area.

"1. Retrofit cost: Retrofitting parking areas with EV charging is often prohibitively expensive, owing to necessary upgrades to the building's electrical supply. EV charging circuits are not present in MURBs built before 2011, although some have standard power outlets that may support EV charging. Most standard wall outlets in MURB parking areas are common property and would be off-limits for EV charging."

For the existing building, the retrofitting cost is expensive which proves that it is necessary to have the 100% conduit for future-proofing design.

"2. Lack of Awareness: Owners, stratas, property managers and developers have limited understanding of EV charging technologies and options. To reduce construction and retrofit costs, and opposition to creating EV charging access,

greater awareness of implementing technologies and managing electrical loads throughout the sector is required."

The public awareness and education of EVs and EV charging have great influence to make the deployment of policies. The energy behaviour can save huge amount of energy consumption. Therefore, the visibility of the EV and EV charging should be engaged in public parking as well.

"3. Metering: How charge stations are owned and managed within MURBs presents challenges for deployment. While ownership and liability concerns related to station installation are ostensibly under the mandate of the provincial Strata Property Act, these are not specifically addressed within that act and have not historically been considered in strata by-laws, leaving stratas without clear direction."

Strata are the most popular housing choice in BC, the owners and residents in all strata properties must the follow the Strata Property Act and regulations as well as the strata's bylaws and rules. Therefore, the limitation of the current strata's bylaws and rules cannot match the high-speed development of EV charging. For the council meetings, all other stakeholders should encourage the strata council to revise their regulations to support EV charging.

"4. Regulatory: The provincial Strata Property Act and the Rental Tenancy Act regulate the use of common property areas (e.g., parking in strata corporations and rental buildings). Under these laws there is no legal mechanism for a strata lot owner or renter to compel the installation or activation of EV charging equipment if their strata or landlord objects. The allocation of parking in stratas is determined through strata plans and may be assigned through at least 18 different configurations [16], as outlined in a recent report by the BC Condominium Homeowners Association13. Many configurations do not allow the flexibility to ensure that EV drivers (or prospective EV drivers) are assigned parking stalls that have a charging station or could have one installed."

Infrastructure Challenges

"1. Electric Panel Sizing Exemption (affects renters and owners): The current Vancouver Building By-law provides an exemption to providing EV infrastructure if the additional supply causes the house panel to exceed 200A. For larger (e.g. ~ 15 m wide) lots, this exemption would be triggered in most cases, and would not specifically be a result of the addition of EV charging loads. These homes would be left unequipped with EV charging supply."

"2. Electrical Distribution System Impacts (affects renters and owners): Impacts on neighbourhood-level electrical distribution systems are not well documented at

present, but in some cases, upgrades to the BC Hydro system in the neighbourhood may be necessary, increasing costs."

100% conduit capacity design is the best way to solve these challenges.

"3. Regulatory Barriers for Renters: For renters in either one- or two-family homes, there is no legal mechanism to ensure EV charging is present in parking spaces under the BC Rental Tenancy Act."

"4. Regulatory Barriers for Owners: Two-family homes that are stratified are regulated under the provincial Strata Property Act, and can therefore face similar opposition as MURBs, described in the previous section. For homeowners in single-family homes, upgrades to their electrical systems to accommodate EV charging are not likely to be limited by regulatory barriers."

"5. Garage Orphans: In Vancouver, many homes do not have off-street parking stalls. Approximately 2,000 one- or two-family homes do not have off-street parking. Residents of some multi-unit residential buildings also do not have their own parking stalls. Referred to as "garage orphans", residents of these homes typically rely on on-street parking."

One of the primary advantages cited by EV drivers is the ability to charge overnight at home and start each day with a fully charged battery. Residents who must rely on public Level 2 locations to charge do not realize this advantage, removing a significant incentive of EVs over fossil-fueled vehicles. No legal mechanisms currently exist to allow the provision of privately-owned, on-street charging connected to a home's electrical panel, nor does it allow for the assignment of parking stalls on-street for individual residents.

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Appendix

Appendix A

Recent Projects at PLG Homes

Project A - REAP V2

8 L2 ready stalls
3.2% EV-ready
186 total Stalls
Electrical Service room -156 sq ft

Project B – REAP V2.1

8 Visitor L2-ready Stalls
4 L2 Chargers installed
316 total stalls
3.75% EV or EV ready
795 sq ft Main electrical Room

Project C – REAP V3.0

3 L2 Chargers planned for install in Visitor Stalls (SS 2.2)
5 L2 Chargers planned for install in Residential Stalls(SS 2.3)
32 L2 ready stalls (SS 2.3)
377 total stalls,
10.6% EV or EV-ready
Transformer Room – 768 sq ft

Project D – REAP V3.0

3 L2 ready stalls planned for visitor stalls
27 L2 ready stalls planned for Cityhome stalls.
26 L2 ready stalls planned for townhomes
3 L2 Chargers planned for install in Residential stalls
377 total stalls
15% EV or EV-ready
Transformer room = 765 sq ft