Keeping it Current

Primer on EV Charging Infrastructure

metrovancouver SERVICES AND SOLUTIONS FOR A LIVABLE REGION

TRANSLINK

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ABOUT THIS REPORT

Well-planned EV charging infrastructure is a core component of supporting continued EV adoption. As a federation of 21 municipalities, one electoral area, and one treaty First Nation representing nearly 2.5 million people, Metro Vancouver is well placed to develop a long-term regional strategy for EV charging infrastructure investment, in line with its commitments in its *Climate 2050 Transportation Roadmap* and *Clean Air Plan*.

Metro Vancouver and its partners, TransLink and BC Hydro, have retained Dunsky Energy + Climate Advisors to develop guidance for the development of EV infrastructure that will support local governments, utilities, and companies in the region by suggesting where charging infrastructure of different types should be located, outlining the estimated costs and business case for building and operating this charging infrastructure, and identifying policies that governments can implement to enable construction.

This Charging Technology Brief, which represents Task 1 of this project, summarizes information regarding EV charging technologies relevant for this project, including:

- **Charging users and locations** (Section 1), including the categorization of charging that will be used in our modelling and analysis;
- **Charging technologies** (Section 2), including networked chargers and load management practices;
- **Charging installation approaches** (Section 3), including EV-ready parking and buildings and considerations for planning and installing public charging infrastructure;
- **Charging networks and operations** (Section 4), including how to work with EV charging service providers and options for ownership models and payment structures; and
- **Indicative EV infrastructure costs** (Section 5).

While the EV charging guidance will be focused on infrastructure for light-duty vehicles, this document includes information on charging for medium- and heavy-duty vehicles as well.

The concepts and prevailing understandings outlined here will underpin the assumptions and principles used to develop the subsequent EV charging guidance. This report can also be used as a tool for internal and stakeholder education on key EV and charging concepts.

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List of Abbreviations and Terms

DCFC: Direct current fast charging
EV: Electric vehicle
EVSE: Electric Vehicle Service Equipment (e.g., "EV chargers")
EVEMS: EV energy management systems
OCPP: Open Charge Point Protocol
LDV: Light-duty vehicles
MHDV: Medium- and heavy-duty vehicles
Multifamily building: sometimes referred to as multi-unit residential building (MURBs) (e.g., apartment or strata buildings)

1. Charging Users & Locations

1.1 Overview

Electric vehicle (EV) charging users include the **public** (residents, workers, and tourists) and **fleet operators**. Each of these user groups has different needs related to how, when, and how much they charge; as a result, they each use different combinations of charging locations, as shown in Figure 1.[1]

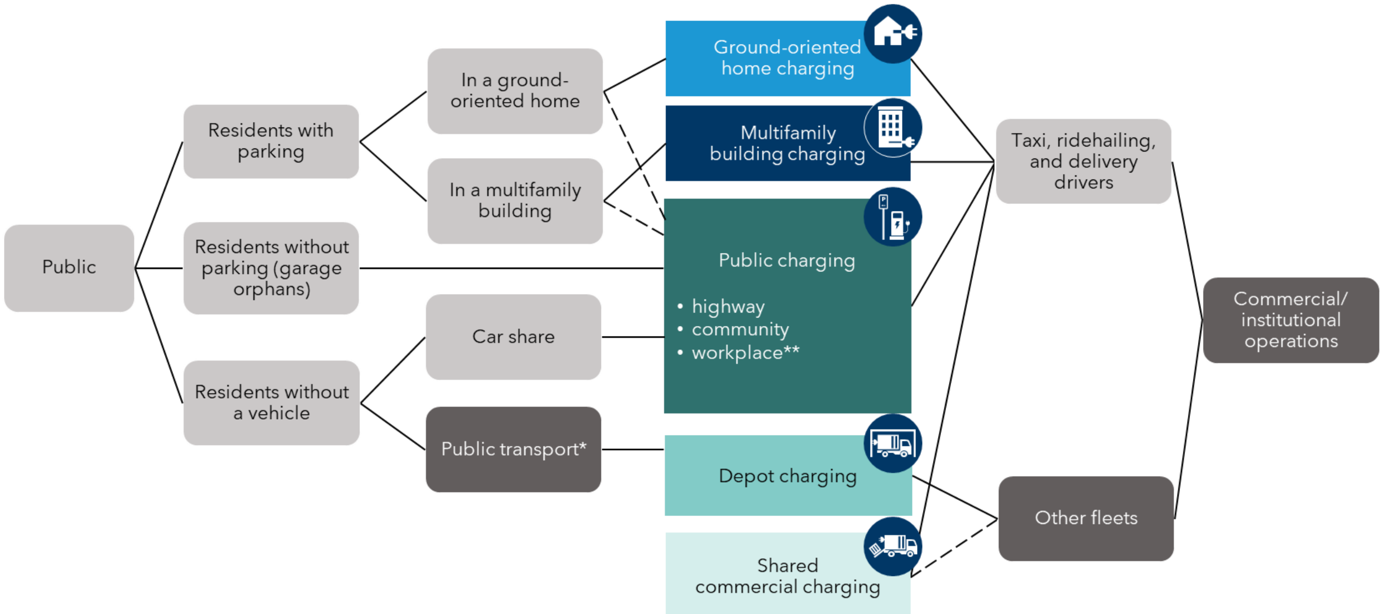

Figure 1. Charging Users and the Charging Categories that Meet their Needs

* Public transport fleets occasionally use on-the-go/overhead charging, but this practice is not yet widespread.

** We consider workplace charging to be a form of public charging because it serves the public, even if sometimes workplace charging is only open to employees.

1.2 People without Home Charging

The group of people without home charging is made up of the following two groups:

1. **Garage orphans:** people without any access to private home parking. For example, many pre-war neighbourhoods in urban centres, many multifamily buildings, as well as secondary suites or apartments within ground-oriented homes, do not have onsite parking. Likewise, some households that have garages use all potential parking spaces for other purposes (storage, etc.). Garage orphans who use EVs must rely fully on public charging.
2. People living in multifamily buildings who have access to parking, but where that parking space has not had the electrical upgrades required to support the installation of EV charging; or, where

[1] The EV Charging Needs Assessment that will be produced as a later step of this work will cover only charging for light-duty vehicles (LDVs); however, this document covers charging for medium- and heavy-duty vehicles (MHDVs) as well.

the resident is otherwise prevented from installing EV charging. This second group can use public charging, or their parking space can be retrofitted to become EV ready (see Section 3.1). As more multifamily buildings are retrofitted, this group will rely less on public charging.

While detailed data about parking access by housing type is unavailable in Canada, a survey of current EV owners showed that only 12% of current EV owners in Canada live in multifamily buildings,[2] whereas 33% of Canadians live in multifamily buildings overall. In Metro Vancouver, this share is even greater. As of 2021, 43% of residents lived in apartments, and this share is growing: since two-thirds of new dwellings that were put on the market between 2016 and 2021 were apartments.[3] This suggests that barriers to EV access are higher for multifamily building residents in general, though variations in urban form exist from one community to the next.

1.3 Characteristics of Different Charging Locations

Charging at home (whether in ground-oriented homes or in multifamily buildings) plays the largest role in the charging ecosystem in terms of the number of ports and the overall amount of energy dispensed at those locations (Figure 2), and this will continue in the future. According to a survey of BC EV drivers conducted by BC Hydro in late 2022 of their public EV charging network members, 86% of EV drivers respondents use home charging. Meanwhile, most of these drivers also use public charging at least some of the time; 88% and 77% of EV drivers respondents use BC Hydro and other public charging stations, respectively.[4]

However, the important role of public charging cannot be overlooked. It is the only choice for residents who do not have access to home charging, as described above. Further, the presence and visibility of public charging is crucial to helping consumers overcome range anxiety and feel confident purchasing an EV.

A similar dynamic plays out for commercial vehicles. Most commercial vehicle charging takes place at the depot (the facility where commercial vehicles park), but shared commercial charging outside of the depot (see definition below) enables electrification of certain fleets who, for a range of reasons, cannot rely on depot charging.

The role of governments and utilities is particularly important in the development of robust public and shared commercial charging infrastructure, since public charging is more costly to develop and requires access to land in key locations.

[2] Pollution Probe (2022). Assessment of the Consumer EV Charging Experience in Canada. Commissionned by Innovation, Science and Economic Development Canada.
[3] Metro Vancouver (2022). Metro Vancouver Housing Book.
[4] BC Hydro, 2023. Public EV Charging Service Rates Application submitted to BCUC. Exhibit B-1.

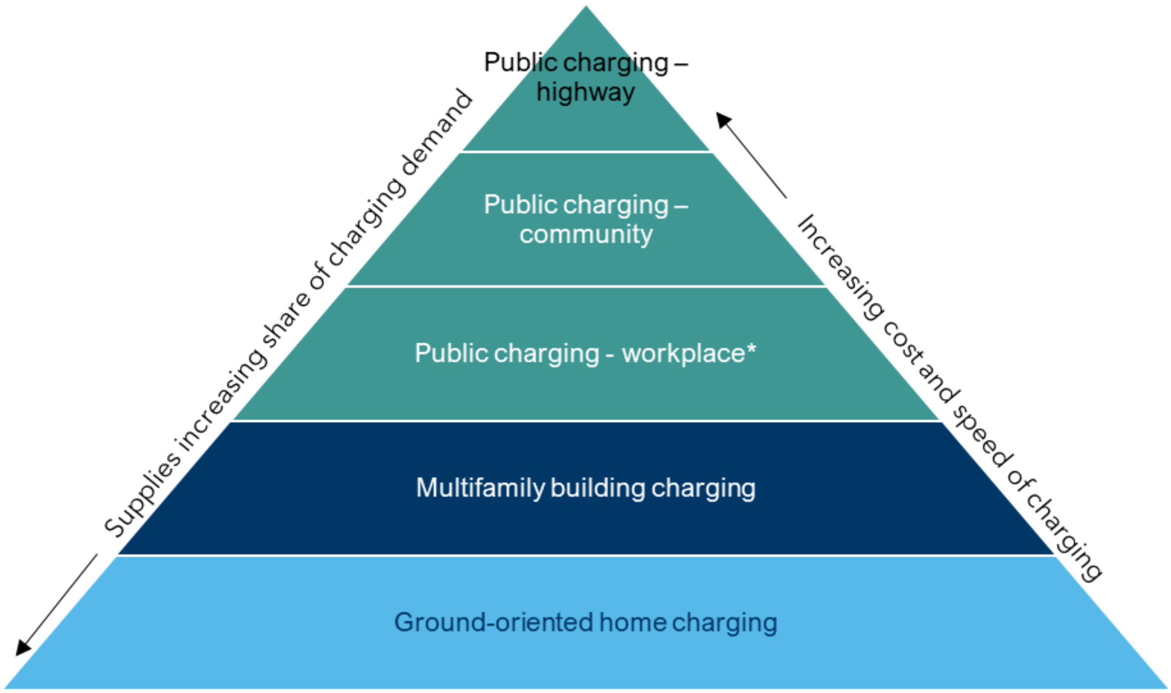

Figure 2. Relative Importance of Different Charging Categories, by Total Energy Dispensed[5]

* We consider workplace charging to be a form of public charging because it serves residents, even if sometimes workplace charging is only open to employees.

For the purposes of this brief and the analysis that will follow, charging locations are divided into the following categories:

- Ground-oriented home charging
- Multifamily building charging
- Public charging, which includes workplace, community and highway charging
- Shared commercial charging
- Depot charging

The following sections describe each of these charging categories in further detail.

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[5] Figure adapted from: U.S Department of Energy, *A Guide to the Lessons Learned from the Clean Cities Community Electric Vehicle Readiness Projects*, 2014.

Ground-oriented Home Charging

People living in ground-oriented housing (single family homes, duplexes, triplexes and row houses) are more likely to have access to, and ownership of, a parking space attached to their living space (e.g. a private garage or parking pad). Installation of EV charging in these settings can be relatively simple, although panel and/or service upgrades or other electrical works are sometimes required; indeed, load management in townhomes, duplexes or any building with multiple meters can sometimes be complicated. Generally, these building types are amenable to incremental additions of EV charging infrastructure as households adopt EVs. Many municipalities in BC have adopted requirements to ensure that new residential construction be built with EV-ready parking, meaning that panel and service upgrades will not be required for residents of new homes.

Multifamily Building Charging

Multifamily building apartments feature shared parking areas. It is more challenging for multifamily building residents to install EV charging, even when they do have access to a parking spot, due to legal, financial, technical and logistical barriers inherent in both condominiums and rental apartments. Nonetheless, home charging remains the most attractive, affordable and convenient option for the one-third of Canadians that live in multifamily buildings.[6] Emerging best practice, stemming in particular from leadership in BC, is to provide charging infrastructure in multifamily buildings where parking is available.

Public Charging

Reliable and widespread public charging infrastructure is crucial to:

- Reassure prospective EV adopters that they will be able to charge on long-distance trips,
- Provide charging for people without EV charging at home,
- Provide charging for people with EV charging at home but whose daily trip surpasses their battery's capacity,
- Provide charging for carshare fleets, and
- Provide charging for tourists.

There are three sub-categories of public charging:

- **Community charging,** which can be on-street (curbside) or off-street (for example, in publicly accessible parking lots or garages).

[6] Statistics Canada. (2017). Census in Brief: Dwellings in Canada.

  - Many cities are prioritizing off-street public charging where feasible, to preserve space in the public right-of-way for other uses (cycling, walking, public realm, green infrastructure), avoid accessibility concerns, and save costs (curbside charging is generally more expensive).[7]
  - However, in some neighbourhoods, curbside charging can be accommodated and is the best option to serve residents and workers. The City of New York, which has piloted curbside charging deployment in neighbourhoods surrounding a major employer (hospital), commissioned the report *Curb Enthusiasm*[8] to highlight best practices for on-street EV charging deployment.
- **Workplace charging,** which is designed for employees, can also be provided on- or off-street.
  - Workplace charging can be an excellent option for people without home charging, as it is provided at a place where they are already going.
  - More studies are needed to examine the viability of workplace charging for office workers as many employees are adopting hybrid work policies. If employees are commuting less often, they will be less able to rely on workplace chargers.
- **Highway charging,** which is provided on major corridors, mostly serving people making long trips, such as for vacations or trips.

Depot Charging

For fleet operators with "back-to-base" operations (where vehicles return to the same parking space after each shift), depot charging is expected to meet most charging needs. Examples of fleets with back-to-base operations include delivery vehicles, government fleets and public transit.

Like home charging, depot charging typically takes place in the evening/night.

Shared Commercial Charging

Shared commercial charging is different from public charging in that it is exclusively dedicated to fleets. It is shared among users and placed in strategic locations for fleets. For example, shared commercial charging can be established at taxi stands, downtown delivery zones (where trucks already park), and on trucking routes.

Fleet operators use shared commercial charging in the following circumstances:

- When fleet vehicles do not return to the depot, for example, long distance trucks and intercity buses. These heavy-duty vehicles will need ultra-fast charging (see section 2.2).
- When the vehicles' daily duty cycle exceeds the capacity of the battery.
- When the vehicles do not belong to a depot. This group includes taxi and ridehailing fleets (such as Uber and Lyft) and sometimes telecom fleets. Notably, drivers of these vehicles will also use home charging where the driver has access, as well as general public charging. This

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[7] Source: Interviews conducted by Dunsky with the cities of Montreal, San Fransisco, New York. October 2021.
[8] City of New York, 2019. *Curb Enthusiasm*.

group also includes owner-operator drivers, which represent approximately 26% of truck drivers employed in Canada and 35% in BC.[9]

- When the depot does not yet have sufficient EV charging installed.

Modelling suggests that shared commercial charging, specifically charging provided for taxi and ridehailing vehicles, offers a potential profitability that is higher than most fast charging infrastructure due to these vehicles' higher drive cycles (and therefore higher energy demand) and their business need for fast charging. As a result, strategically designed shared commercial charging networks could help finance broader investment in public fast charging.

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[9] Source: Statistics Canada, *Statistiques sur l'emploi dans l'industrie du camionnage selon les provinces et territoires,* 2015.

2. Charging Technologies

2.1 Charging for Light-Duty Vehicles

For light-duty vehicles (LDVs) (cars, vans, SUVs and light trucks) there are three main charging levels: Level 1, Level 2, and direct current fast charging (DCFC), sometimes referred to as Level 3 or, simply, fast charging. The main characteristics of these charging types for LDVs are provided in Table 1.

Table 1. Main Characteristics of Different Charging Types for LDVs

Charging Type	Charging Power	Approx. charging time for 300 km of range[10]		Charging Location					Type of light-duty EV that can use
		Typical car	Typical SUV/ light truck	Ground-oriented	Multifamily building	Public	Depot	Shared commercial	
Level 1	1.3-2.4 kW	46-25 h	69-37.5 h						BEV and PHEV
Level 2	3 kW	20 h	30 h						BEV and PHEV?
	7 kW	8.5 h	13 h						
	9.6 kW	6 h	9.5 h						
	19.2 kW	3.25 h	4.75 h						
DCFC	25 kW	2.5 h	3.5 h						BEV
	50 kW[11]	1.25 h	1.75 h						
	100 kW	36 min	54 min						
	150 kW	24 min	36 min						
	350 kW	10 min	15 min						

Although most electrical systems use alternating current, EV batteries use direct current. A converter, which is installed in an EV, converts alternating to direct current. Charging supplied by Level 1 and 2 charging ports passes through the converter, while fast charging supplies the battery directly, bypassing the converter (Figure 3).

[10] Many vehicles do not require a full 300 km charge on a typical day.

[11] While many public DCFC today are 50 kW, it is recommended to install minimum 100 kW DCFC for public charging in most instances, except where users are consistently staying for over two hours.

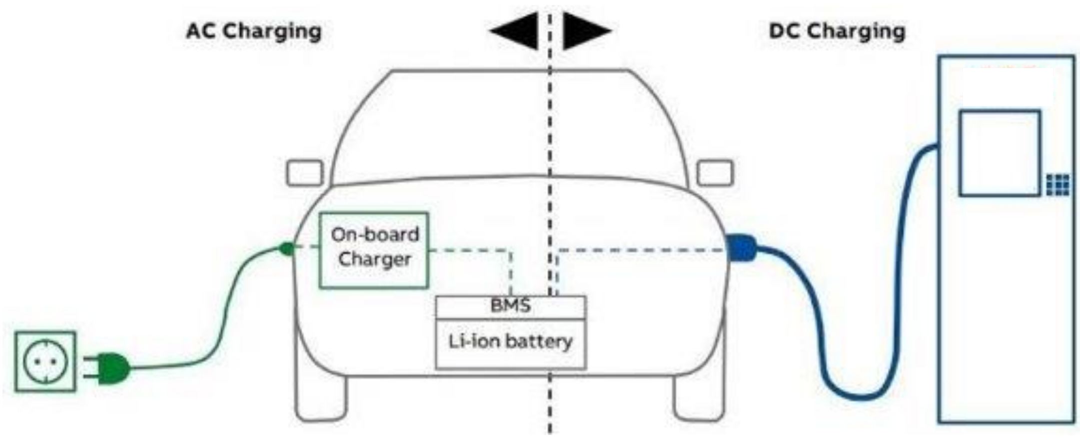

Figure 3. Configuration of direct current and alternating current charging, showing the function of the converter (on-board charger). Source: ABB.com

DCFC

As shown in Table 1, DCFC provide a charge faster than Level 2 and 1 EV charging, but they are much more expensive to install and operate. For LDVs, DCFC is mostly used for public charging. Frequently a new electrical service is required to enable the installation of DCFC at a given site.

DCFC encompass a wide range of charging power from 25 to 350 kW. Not all vehicle models are capable of charging at higher levels; however, market trends show that new models are increasingly designed for higher charging powers, as shown in Figure 4. Indeed, the following models can charge at rates between 250 and 350 kW: Porsche Taycan, Audi e-tron GT, Hyundai IONIQ 5, KIA EV6 and Lucid Air.

As the charging capacity of EVs on the road increases, the need to supply higher power fast charging increases as well. Based on a non-quantitative scan,[12] most non-Tesla public fast charging stations in Metro Vancouver offer 50 kW ports. However, an increasing number of faster ports (100-150 kW) are planned or under construction. Tesla charging ports typically offer a higher power; in Metro Vancouver the Tesla supercharger stations range from 72 to 250 kW.

Notably, most plug-in hybrid EVs (PHEVs) cannot use DCFC charging. For this reason, the share of PHEVs versus BEVs in the total EV population influences the relative share of Level 2 versus DCFC public charging that is needed, alongside other factors. There is significant uncertainty about the role of PHEVs in the vehicle landscape going forward; studies show that they will need to be phased out in the 2030s if Canada is to meet its net-zero targets.[13]

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[12] Using PlugShare.com
[13] International Council on Clean Transportation (ICCT), 2022. Canada's Path to 100% Zero-Emission Light-Duty Vehicle Sales: Regulatory Options and Greenhouse Gas Impacts.

Level 2

Level 2 charging is appropriate for instances where the vehicle will be parked for a longer period of time, for example overnight or during a work shift.

Level 2 charging requires a 208V or 240V outlet. Since the charge required can often be achieved in three to five hours (shorter than the full overnight period), Level 2 charging presents opportunities to sync charging time and power draw with the overall needs of the grid or building, by avoiding charging during building or grid peak hours. See Section 2.5 for further discussion of energy management opportunities.

Level 1

Level 1 charging is the simplest form of charging, since it uses a typical household 120V outlet and a single electrical cable. Given the particularly long charging times, Level 1 charging is only used in a residential setting and is not suitable for vehicles with long daily drive cycles. In a survey of current EV owners in Canada, 81% of respondents with home charging use a level 2 charging station, while 13% use a level 1 standard wall electrical outlet.[14]

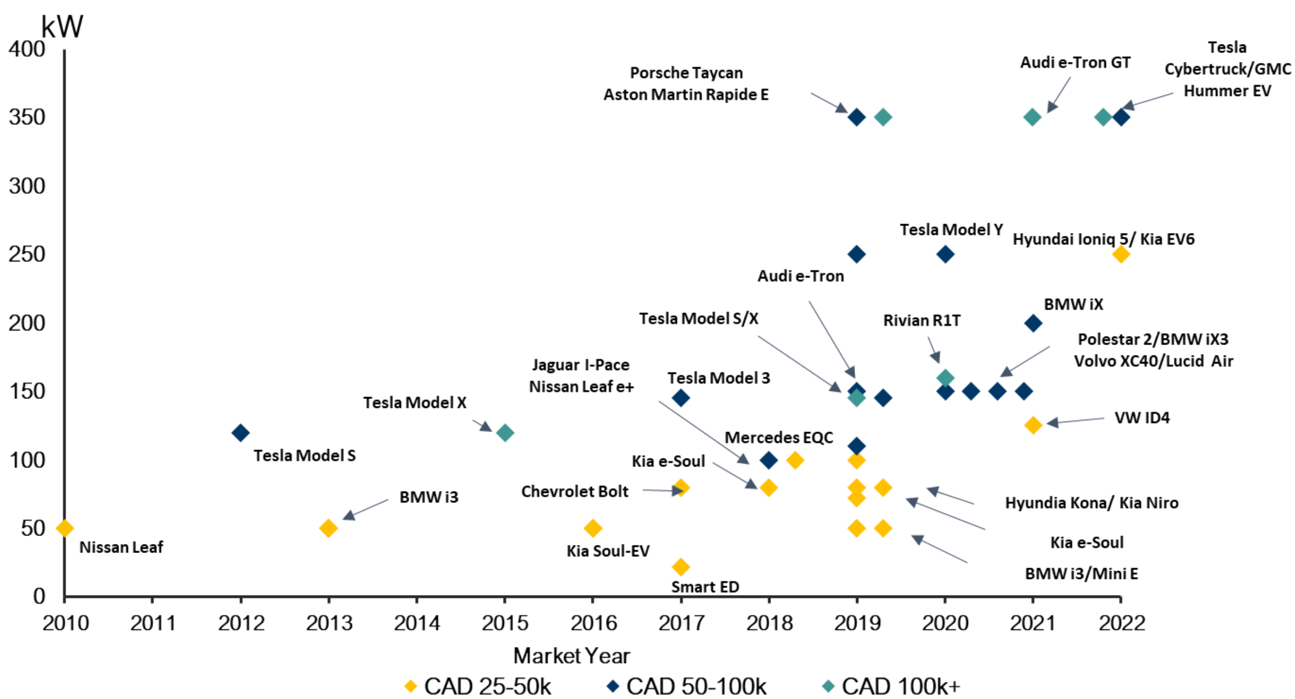


Figure 4. Maximum Fast Charging Power Capabilities for Different EV Models, 2010-2022

[14] Pollution Probe (2022).

2.2 Charging for Medium- and Heavy-duty Vehicles

The main characteristics of the different charging types for medium- and heavy-duty vehicles (MHDVs) are provided in Table 2. As shown in the table, heavy-duty vehicles like garbage trucks and transit buses typically need a DCFC of 50 kW or more for overnight charging in a depot. For long-distance heavy-duty trucks, or other trucks operating with multiple drivers without a long pause overnight, ultra-fast DCFC of 1 MW or more will generally be needed.

Table 2. Main Characteristics of Different Charging Types for MHDVs

Characteristics		Level 2	DCFC	Ultra-fast DCFC / MCS
Typical charging power		3 kW-19 kW	25 kW-350 kW	1 MW plus
Charging time for 300 km of range	Medium truck	~ 9.5-26 h	~ 30 min. – 7h	~ 11 min.
	Heavy truck	~ 19-51 h	~ 1 h – 14h	~ 22 min.
Charging location				
• Depot charging				
• Shared commercial charging				
Type of EV that can use		Medium-duty BEV (too slow for heavy-duty)	Medium- or heavy-duty BEV	Medium- or heavy-duty BEV

Megawatt Charging Standard

The Megawatt Charging Standard (MCS), which allows the supply of charging at 1 MW or more, is currently under development by Daimler Trucks, Tesla, and other manufacturers. Some pilot projects are underway, and commercialization is expected in 2025.

2.3 EV Charging Connectors

Table 3 shows the range of connector types that are available globally, by region and by type of current.

All EVs sold in North America are compatible with J 1772 connectors, which are used for Level 1 and 2 charging (in the case of Tesla vehicles, an adapter is required to use a J 1772 connector).

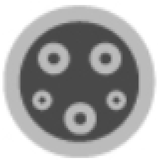
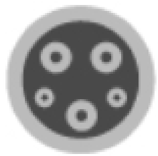
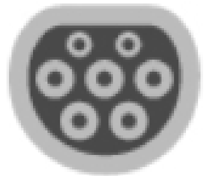
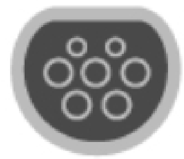
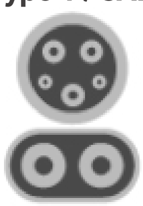
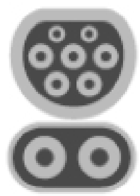
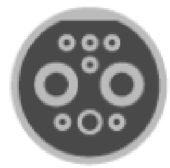
For fast charging, most vehicles in North America use a CCS Combo connector, although some use CHAdeMO connectors (these are vehicles manufactured in Japan, namely the Nissan LEAF and the Mitsubishi Outlander PHEV).

Currently, most fast charging stations in Metro Vancouver (other than Tesla stations) offer both CCS Combo and CHAdeMO connectors, based on a non-quantitative scan.[15] However, manufacturers

[15] Using PlugShare.com

using CHAdeMO connectors have announced that they will move toward CCS Combo connectors only. Moreover, Tesla has recently deployed a CCS Combo adapter in Europe and South Korea.

Table 3. Connector Types by Region and Charging Power

	North America	Japan	Europe	China	Others
Alternating current (Level 2, 3 to 19.2 kW)	**J 1772 Type 1** 	**J 1772 Type 1** 	**Mennekes (Level 2)** 	**GB/T** 	**Tesla*** 
Direct current (Fast charging, 25 to 350kW)	**CCS Combo Type 1 / SAE** 	**CHAdeMO** 	**CCS Combo Type 2** 	**GB/T** 	*Tesla offers adapters allowing users to charge with a J1772 charger

2.4 Networked Chargers

For the purposes of this report, the term **networked chargers** refers to EV chargers that can communicate over an electronic communications network such as a cellular, wireless, or ethernet network. Such network communications capabilities allow for chargers to accommodate a variety of functions, including:

- EV energy management (see Section 2.5),
- Utility demand response (whereby EV loads are adjusted based on grid operator signals to optimize charging to reduce grid-system costs),
- Remote monitoring and diagnostics,
- Reservation systems for shared chargers, and
- Tracking use and applying time-based or volumetric user fees (e.g. per kilowatt hour).

The term "smart chargers" is often used to refer to what we define as networked chargers above.

Open Protocols

Networked chargers can communicate via either proprietary or open protocols. The benefit of using open communications protocols is that different chargers and charging management systems can communicate with one another, reducing the risks of stranded assets. The Open Charge Point Protocol (OCPP) administered by the Open Charge Alliance is the predominant open protocol. It can facilitate communications between EV chargers, EV energy management systems (see Section 2.5) and charging service providers' management systems (see Section 4).

2.5 Load Management and EV Energy Management Systems

Unlike some electric equipment, EV charging is a flexible load that offers significant opportunities for managing loads to minimize impacts on peak demand at the building or grid level.

EXAMPLE OF LOAD MANAGEMENT OPPORTUNITIES FOR RESIDENTIAL CHARGING

- 89% of Canadian EV drivers travel less than 60 km per day.[16]
- Most home charging takes place using a Level 2 port.[17]
- For a typical vehicle energy consumption of 20 kWh/100 km, the charging time required to top up the battery is approximately **one hour and 45 minutes.**
- Meanwhile, the vehicle is likely parked for **eight** or more hours overnight, illustrating the opportunity to displace or spread out the energy demand to the most beneficial time for the electrical grid, with no negative impact on the consumer.

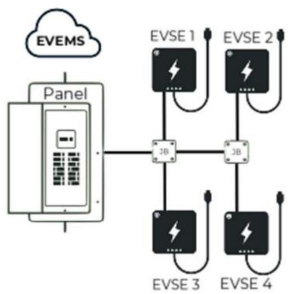
The textbox above illustrates the opportunity for load management for residential charging. Networked charging enables utility grid operators to provide signals specifying when it is most valuable for an EV to charge (for example, when wholesale power prices are low and the distribution grid is not congested).

Similarly, EV energy management systems (EVEMS) monitor and control loads so as not to exceed the capacity of an electrical circuit. They can be used can be accommodate more EV charging at a facility than could otherwise occur without EVEMS. EVEMS make it possible to provide large amounts of parking (e.g., 100% of parking in an apartment building) with EV charging. By controlling the rate and timing of charging, EVEMS charge multiple vehicles while reducing the required circuit capacity.

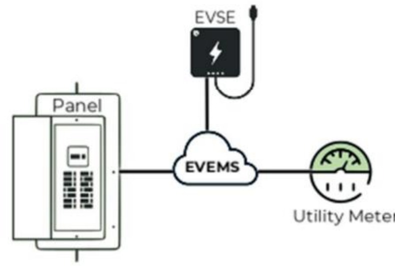
While the speed of charging slows when multiple EVs are charging simultaneously on a shared circuit, using reasonable amounts of load sharing is perfectly appropriate in situations where vehicles are parked for longer periods of time (e.g., overnight in residential parking, or the course of a day at a workplace). Notably, load sharing approaches are appropriate not only in residential and workplace settings, but also in depots for commercial fleet charging.

Most networked chargers are compatible with EVEMS. As shown in Figure 5, there are multiple possible EVEMS configurations.

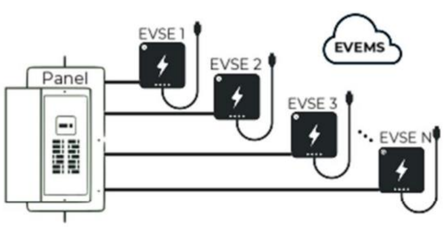
[16] Roulez Électrique (2014). Les distances moyennes de déplacement au Canada : étonnamment courtes!
[17] Pollution Probe (2022).



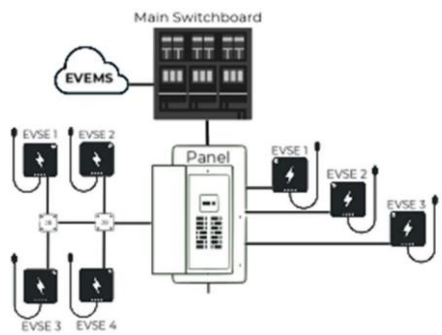
Circuit sharing: Multiple EV chargers on a circuit, with control to ensure capacity is not exceeded.



Feeder sharing (demand control charger): On-off control of EV charging based on available capacity on the supply to an electrical panel.



Panel sharing: EV charging loads in excess of panel, with control to ensure capacity is not exceeded.



Service monitoring: Monitoring of spare capacity on building's main electrical board and control of EV loads accordingly.

Figure 5. Possible EVEMS Configurations. Source: Brendan McEwen and AES Engineering.

2.6 Wireless and Overhead Charging

Wireless Charging

Wireless charging is an emerging technology that is not yet widely commercialized. It can be broken down into two categories: static wireless charging when the vehicle is parked, and dynamic wireless charging while the vehicle is in motion.

Static wireless charging is a direct substitute for traditional conductive charging with a cable. Wireless charging uses electromagnetic induction, similar to what is used for wireless charging of smartphones and other electronic devices. This approach is primarily seen as a convenience feature for personal vehicles but may also be a key enabler for applications that benefit from frequent top-ups, such as taxis in a queue or emergency vehicles that spend considerable amounts of time idling but that may need to leave quickly. Wireless charging may be a necessity to enable fully autonomous vehicles.

There has been limited commercial availability of static wireless charging solutions so far, with aftermarket retrofit options available for certain EV models, but no automaker has yet included static wireless charging as a factory option. SAE International has released the J2954 standard that establishes industry-wide specifications for static wireless charging to ensure safety, performance and interoperability across manufacturers.

If static wireless charging becomes more common in the future, it will be able to use much of the electrical infrastructure implemented for physically connected EV chargers used today. Therefore, static wireless systems do not present a substantial risk of stranded assets.

Dynamic wireless charging relies on inductive charging infrastructure that is integrated into the road surface. This approach is at a much lower level of technology readiness, with a limited number of proof-of-concept trials currently under development. It has yet to be seen whether this technology can be deployed cost effectively. If technical and economic barriers can be addressed, it would likely be at least a decade before this technology can be commercialized and incorporated into production vehicles. Most analysts foresee that dynamic wireless charging, if it ever gains appreciable scale, would be used more for goods movement vehicles and not light-duty passenger vehicles. That said, if dynamic wireless charging becomes viable, it could have a significant impact on the demand for other types of charging – vehicles that can charge while on the highway (or portions thereof) would have no need for fast charging infrastructure to enable longer trips.

Overhead charging

Overhead charging may be used for heavy truck and bus charging at depots or on-route charging facilities. The SAE J3105 standard was established to ensure safety and interoperability of such systems. Results of overhead charging pilots by transit agencies have presented mixed results so far.

Overhead wires could allow pantographs to connect vehicles to a source of power as they move, similar in concept to how trolley buses are used today (catenary charging). Such systems are being piloted on major corridors to support electrification of heavy trucks for goods movement in Norway.

3. Charging Installation Approaches

3.1 EV-Ready Parking and Buildings

As described in Section 1.3, emerging best practice is to provide charging infrastructure in multifamily buildings where parking is available. Multifamily building charging represents a more affordable, convenient, and attractive alternative to public charging for apartment and strata dwellers.

DEFINITIONS

EV ready parking is a parking space that features an adjacent electrical outlet (a junction box or a receptacle) capable of providing at least Level 2 EV charging (as defined by the SAE standard J1772). See Figure 6. This definition is reflected in the requirements for access to the BC Hydro EV charging rebates for apartment and condo buildings.[18]

We define **EV ready buildings** as those buildings where EV ready parking is provided at scale:

- For residential: where **100%** of parking stalls (or at least one stall per dwelling) are EV ready.
- For commercial: where **20%-40%** of parking stalls are EV ready, depending on context.

Fully EV ready residential buildings are the most cost-effective, practical, and fair way to ensure charging access in existing multifamily buildings. This comprehensive approach is reflected in the municipal bylaws for new construction adopted in many BC municipalities, as referenced in Table 4.

[18] BC Hydro. EV charging rebates for apartment and condo buildings.

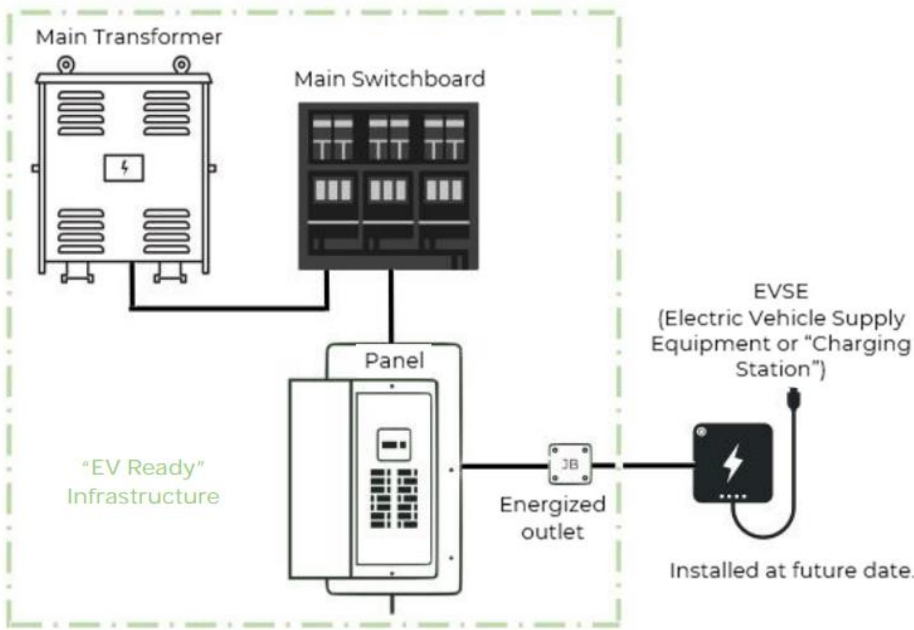


Figure 6. EV Ready Installation Showing All Infrastructure Required up to the Energized Outlet

New Construction

Thirteen of 23 Metro Vancouver members, covering a majority of the Metro Vancouver population, have adopted parking design requirements in parking or zoning bylaws requiring EV Ready parking for 100% or near-100% of residential parking in new developments. Eight members also require significant proportion of new commercial parking to be EV Ready, ranging from five to 45%. The Province of BC has clarified that the BC Building Act does not prohibit local governments from making such requirements.

Table 4. Metro Vancouver Members Having Adopted EV Ready Requirements

Metro Vancouver Member	EV Ready Requirement	
	Residential	Commercial
City of Vancouver	100%	45%
City of North Vancouver	100%	45%
City of Port Moody	100%	20%
City of Surrey	100%	20%
District of North Vancouver	100%	20%
City of Richmond	100%	In development
City of Burnaby	100%	--
City of New Westminster	100%	--
District of West Vancouver	100%	--
City of Coquitlam	1 EV ready/dwelling	--
Township of Langley	1 EV ready/dwelling	--

Metro Vancouver Member	EV Ready Requirement	
	Residential	Commercial
City of Port Coquitlam	1 rough-in/dwelling[19]	--
Village of Anmore	--	--
Village of Belcarra	--	--
Bowen Island Municipality	--	--
City of Delta	--	--
Electoral Area A	--	--
City of Langley	--	--
Village of Lions Bay	--	--
City of Maple Ridge	--	--
City of Pitt Meadows	--	--
Tsawwassen First Nation	--	--
City of White Rock	100%	--

Existing Buildings

For existing buildings, there are unfortunately complex barriers to pursuing EV-ready retrofits, spanning high upfront costs and limited access to capital, the need to foster the appropriate services and approach amongst engineering consultants and contractors, a lack of awareness among rental building owners and strata boards, and complicated strata decision-making processes. EV-ready retrofits involve ensuring there is sufficient electrical capacity to supply EV charging (often via an electrical upgrade) and installing all necessary electrical infrastructure to supply the parking stalls with a wired outlet (which often involves civil works and renovations).

There are different approaches to retrofitting multifamily buildings. A **comprehensive EV ready retrofit** is an approach that can help overcome these barriers, and is particularly valuable for multifamily condominiums, rental housing, workplaces, retail, and many depots. In this approach, a building undertakes an electrical renovation to make a significant proportion of parking EV ready. For example:

- A strata makes all parking EV ready, to accommodate all drivers adopting an EV in the coming decades.
- A workplace implements a 10% EV ready retrofit to accommodate parking for the foreseeable future). As drivers adopt EVs, EV chargers are installed at their assigned parking space.

Comprehensive EV ready retrofits are an alternative to incremental additions of EV chargers, wherein a building implements a few chargers at a time, typically in common parking areas (such as visitor parking) to be shared by multiple residents or building occupants. Over time, as more EVs are

[19] City of Port Coquitlam is unique in Metro Vancouver for requiring "roughed in" electrical circuit breaker on a branch panel and raceway to the parking space. Dunsky recommends EV Ready (i.e. wired outlets) future-proofing. However, such rough-in requirements are better than nothing.

adopted, new electrical renovations are undertaken to implement more charging. Comprehensive EV ready retrofits offer multiple benefits over an incremental approach, as shown in Table 5.

BC Hydro's globally-leading EV charging rebates for apartment and condo buildings programs provides funding for building owners to conduct an EV ready study before proceeding to retrofits, in order to encourage a comprehensive approach.

Table 5. Benefits and Challenges of Comprehensive EV Ready Retrofits versus an Incremental Approach

Benefits		**Comprehensive EV ready retrofits**	**Incremental additions of EV chargers**
To building owner or investor	Upfront cost	Higher one-time upfront cost	Lower individual project costs (but significantly more expensive in aggregate)
	Project manage-ment	One project	Series of smaller projects
	Total cost	Lower total cost	Higher total cost
	Future proofing	Avoids stranded assets	Initial installations may not be designed for later expansion; some potential for stranded assets
To resident or user	Certainty of access to charging	Typically, can ensure that all drivers get access to charging	Potential to exhaust limited electrical capacity if design for EVEMS not considered, meaning some drivers may not get access
	Charger installation experience	Simple process to install chargers (after initial comprehensive electrical renovation)	Process to implement new chargers is frequently lengthy, and usually complicated
	User experience	Charging can be conveniently located in drivers' assigned parking space	Often, initially in visitor parking; though sometimes in assigned parking

Launched in 2021, the CleanBC GoElectric program provides rebates for the following aspects of EV-ready retrofits:

- EV Ready plan rebate: up to $3,000 for creation of EV Ready plan – strategy for a building to make at least one parking space per residential unit EV Ready.
- EV Ready infrastructure rebate: up to 50% of costs to install electrical infrastructure required to implement EV Ready plan, to a maximum of $600 per parking space, and a project maximum of $120,000.
- EV charger rebate: up to $1,400 per to purchase and install L2 networked EV chargers to implement a building's EV Ready plan, to a maximum of $14,000.

BC communities are at an advantage compared to other jurisdictions in that this program offers building owners the option to implement comprehensive EV ready retrofits, an approach that will, in many circumstances, provide the greatest value over the lifetime of the building and most cost-effectively enable wide-spread EV adoption, optimizing use of public and/or utility ratepayer funds.

3.2 Public EV Charging Siting, Design and Operational Considerations

There are many important considerations relating to the siting, design, and operations of EV charging systems. Key goals for policy makers and charging network operators should include:

- **Cost efficacy.** Minimizing the capital and operating costs of EV charging is important to enabling successful deployment at scale. The electrical upgrade costs associated with implementing DCFC, as well as many Level 2 public charging installations are significant, which means that siting the infrastructure with a view to grid capacity is key.
  - Privately-operated public charging service providers will expect to make a return on charging infrastructure, while public sector or utility operators may consider operating these networks at a loss, since the availability of public charging fosters EV adoption and the associated societal benefits (reduction in greenhouse gas and air contaminant emissions).
  - Likewise, it is important that user fees are set at rates that users can afford and that these fees are competitive compared to gasoline and other fuels.
- **Siting infrastructure proximate to demand.** This project forecasts the demand for EV charging across different geographies in Metro Vancouver.
- **Physical safety**. The station should be Is the station well-lit, and have additional safety features such as security cameras, help buttons, and visibility to passers-by. Further, the equipment should meet applicable technical safety standards.
- **Accessibility.** EV charging infrastructure should be provided in wheelchair accessible spaces and all infrastructure should be designed so that people with a range of disabilities can use the chargers and associated interfaces and mobile applications.
- **Durability**. The equipment should withstand frequent use and seasonality.
- **Comfort and amenities**. Charging stations should be sited in proximity to amenities such as food, drink, washrooms, parks or public attractions within easy walking distance. Stations should be weather-protected and comfortable for users.
- **Site safety**. There should be bollards or other designs to protect the charging equipment.
- **Visibility, signage and branding**. Road users should be able to navigate easily to the charging station.

- **Uptime, reliability and availability.** A very high degree of charger uptime (i.e. time when the charger is not in need of repair) is paramount to ensure drivers have reliable access to EV charging. To ensure that users are confident they can access public charging conveniently when they need it, it is important that enough public charging is available in a given area and that it is priced appropriately to avoid overstays.
- **Effective customer service**. It is important that drivers have a convenient means of troubleshooting issues when they are accessing public charging.
- **Privacy and cybersecurity**. The service provider must take appropriate steps to protect user data. They should consider whether data stored in Canada and secure the process for remote firmware updates.

Detailed design and operational guidelines are beyond the scope of this project. BC Hydro has published *EV Fast Charging Design and Operational Guidelines for Public DCFC Stations in BC* and a *Level 2 Public Sector Charging Stations Best Practices Guideline*. It is recommended that all public charging operators carefully consider these guidelines, and adhere to all relevant guidance.

4. Charging Networks and Operations

4.1 EV Charging Service Providers

There are many actors in the EV charging ecosystem. Some companies focus on selling charging equipment only. In the public charging space, it is more common for the companies that provide the charging equipment to also operate the network as part of a full service offering. These players are referred to as **EV charging service providers.** They manage public charging networks and, in some cases, work with various entities including multifamily buildings (building owners and strata groups), employers, fleet owners, public charging site hosts, to support EV charging. Some examples of EV charging service providers include FLO, Chargepoint, Tesla, GreenLots, SWTCH Energy, Electrify Canada, Petro-Canada, and BC Hydro.

EV charging service providers that operate public networks will often work with **site hosts** that wish to implement public charging at their facilities. Site hosts can include municipalities and businesses.

In addition to supplying charging equipment, EV charging service providers typically also supply management systems with functions that include:

- User apps and administrator dashboards
- Access controls and reservation platforms
- The ability to reconcile electricity costs by applying user fees
- EV energy management services
- Warranties
- Operations and maintenance
- Customers assistance and support
- Management of opportunities to create value for sites through, for example:
    - Utility demand response
    - Valorizing carbon credits through the BC Renewable and Low Carbon Fuel Requirements

EV charging service providers will typically use networked chargers.

4.2 Ownership Models

Public charging infrastructure rarely has an attractive rate of return for private investors. Some exceptions to this rule include charging ports in very high-demand areas, or investors that have a broader financial incentive to offer charging (for example, utilities who will drive more electricity consumption, retail outlets who want to attract customers, or automakers who want to sell more EVs). As a result, there is a crucial role for municipalities and First Nations in deploying infrastructure to meet residents' needs and ensure that a lack of charging does not present a barrier to EV adoption.

In deploying a public charging network, the deploying organization needs to choose from among a range of potential models for owning, operating and maintaining the infrastructure. In a **vertically integrated model**, sometimes referred to as "charging as a service," the EV charging service provider offers a full service, providing the charging equipment and charging management systems while also being responsible for maintenance, reporting, and often price setting.

In a **decoupled** model, the deploying organization takes on and coordinates more of the activities while contracting out one or more aspects of deployment. For example, under a decoupled model, a municipality might issue an RFP for the design and construction of the EV charging station, and a separate contract for operation.

There are benefits and drawbacks to each model; broadly speaking, a vertically integrated solution requires fewer resources from the deploying organization but also affords less control, whereas a decoupled solution offers more flexibility and control, but at the cost of needing more skilled in-house resources. A full comparison of these models is presented in Table 6.

Table 6. Strengths and Weaknesses of Vertically Integrated versus De-coupled Vendor and Network Solutions

		Vertically integrated (proprietary) solutions ("charging as a service")		**Decoupled solutions**
Complexity		One vendor relationship and packaged sourcing Less complex process for site owner Full service offering		Internal staff needed to coordinate between vendors and handle technical issues
Harmonization		Alignment of infrastructure with payment method		Payment solution between hardware and software may not be aligned Hardware and software may not work perfectly together
Flexibility		Less flexible Software customization features may not be possible		Flexibility in selecting vendors
Resilience		Possibility of stranded assets if proprietary service terminated operations		Offers potentially higher resilience if one network's connection is no longer available
Vendor cost		Potentially higher costs		Potentially lower costs
OCPP compliance		Most solutions moving towards OCPP compatibility		All open standard solutions are OCPP framework compliant

4.3 Payment Systems and User Fees

Although early public charging networks have sometimes offered free charging, networks are now moving away from this model. Though some public charging operators offer free charging as an amenity or to attract visitors, increasingly users are expected to pay for the electricity that their vehicles use.

Regulatory amendments in recent years have clarified the ability of various third parties to charge user fees for EV charging:

- In 2018, BC made a legislative update to *Strata Property Regulation 6.9* to clarify the ability of strata corporations, by bylaw or rule, to create a variable user fee for the use of EV chargers.[20]
- In 2019, BC granted an exemption with respect to the BC Utilities Commission (BCUC)'s regulation of EV charging services, clarifying that third parties can charge fees for EV charging use without being subject to regulation by BCUC, based on a recommendation and inquiry by the BCUC. [21]
- In 2023, Measurement Canada granted a temporary dispensation to allow charging site operators to set fees on a volumetric basis for fast chargers (it is so far unclear whether this dispensation applies to Level 2 charging). [22] This means that operators can set fees on a per kilowatt hour basis, rather than a per minute basis.

EV charging user fees can be set in the following ways:

1. By the amount of time the charger is in use, with per minute rates set according to charging power (ports with load sharing can offer reduced rates),
2. By the amount of power used on a volumetric basis (see Measurement Canada update above),
3. Through other network subscription fee models (e.g. flat rate for unlimited charging in a month; etc).

In terms of the mechanism by which the user pays for the electricity, charging equipment can support a variety of payment options, including:

- For EV drivers with existing user accounts (customer registers with the charging network and maintains an account balance to pay for charging):
  - Payment by RFID card (customer receives a physical RFID card that can be swiped to enable charging and the account deducted according to the usage fee structure).
  - Payment by mobile application (customer downloads an app on their mobile phone that enables user login and payment authentication).
- For EV drivers without a user account:
  - Payment by direct credit card transaction (charging equipment includes a credit card reader that enables charging)
  - Payment by credit card via a toll-free phone number provided on site (customer calls a toll-free number and provides credit card information to customer support to remotely authenticate charging).

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[20] Government of British Columbia. "Changes to strata legislation since 2011."
[21] BCUC (2018). BCUC Regulation of Electric Vehicle Charging Service Inquiry (Project No. 1598941).
[22] Government of Canada (2023). "Temporary dispensation for Level 3+ electric vehicle supply equipment. "

5. Infrastructure Costs

The cost to install EV charging infrastructure varies widely across projects, depending especially on:

- The **power output** of the charging ports.
- **Whether a new or upgraded utility service is required** (high connection costs can prevent projects from moving forward). The costs of new or upgraded services is highly variable between different sites, and is very difficult to predict prior to a detailed request for a service extension from electric utilities.
- **The scale of the investment.** Comprehensive EV-ready upgrades in residential buildings and depots can reduce the per-port cost significantly.
- **The extent to which EVEMS is used** to reduce electrical capacity per vehicle and share infrastructure, like branch circuits, between vehicles.
- In the case of public chargers, the **location of the charging station**. Curbside charging is typically more expensive than off-street charging.
- The **quality of the design**. The use of load management techniques can significantly reduce per-port costs.

Table 7 summarizes high level indicative cost estimates for different Level 2 EV charging infrastructure systems based on in-house knowledge of representative projects.

Table 7. Indicative Per-Port Costs of Level 2 Charging Infrastructure

EV Charging System	Approximate Cost Per Port			
	New Utility Connection	Equipment	Installation	Total Installed
Onsite ground-oriented home charging	Typically NA	$300-$3,000	$100-$2,000	**$400-$5,000**
multifamily building – Incremental approach (a few chargers at a time)	Typically NA	$1,000-$4,000	$3,000-$15,000	**$4,000-$20,000**
multifamily building – Comprehensive EV Ready Retrofit	Typically NA	$1000-$3000	Avg $1,300	**$2,000-$5,000**
Public L2 Charging*	$0 - $20k+	$1,000-$6,000	$3000-$10,000+	**$4,000-$16,000 plus connection costs**

* Public L2 charging on an existing service (e.g., a streetlight or building) will have no new utility connection costs. Generally, public L2 charging located at the curbside (rather than off-street) is at the higher end of the cost range.

A number of studies have estimated average per-port costs for fast charging infrastructure, including both the charging equipment itself and additional installation costs. Figure 7 compares estimates made under previous studies by the International Council for Clean Transportation,[23] the National Renewable Energy Lab,[24] and RMI,[25] showing variation between their estimates. As an outlier, Tesla has been reported to achieve significantly lower per-port costs down to between $60,000 and $80,000 CAD.[26] This suggests that as deployment volumes increase and deploying organizations build internal knowledge and a network of suppliers, per-port costs will come down.

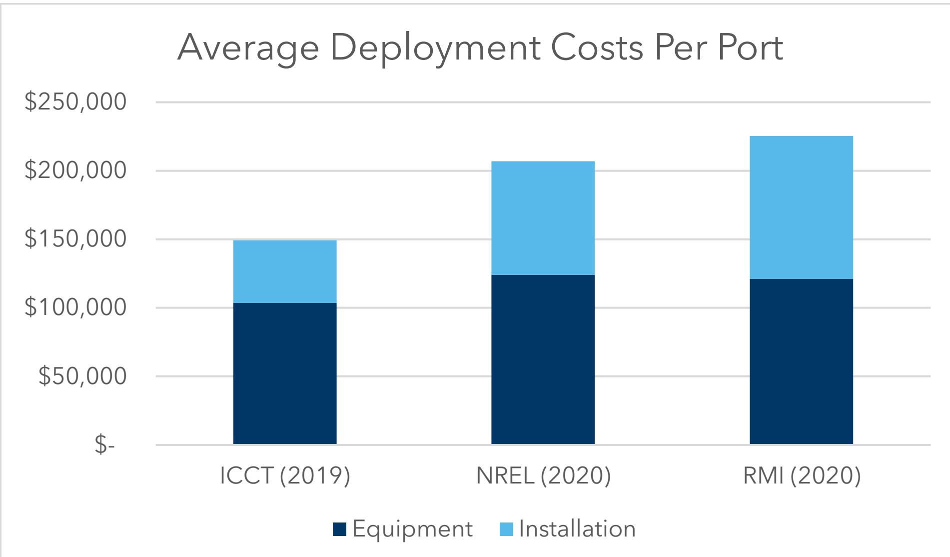

Figure 7. Comparison of per-port DCFC cost estimates across different studies. These values represent an average per-port cost across sites of various sizes using 150kW DCFC.

Moreover, these studies have also demonstrated the economies of scale that can be achieved when multiple ports are installed at the same site (electrical upgrades are used more efficiently in this case). ICCT's study estimated the per-port cost savings associated with larger deployments, shown in Figure 8.

[23] International Council on Clean Transportation (ICCT) (2019). Estimating electric vehicle charging infrastructure costs across major U.S. metropolitan areas.
[24] Borlaug, B., Salisbury, S., Gerdes, M. and Muratori, M. (2020). Levelized Cost of Charging Electric Vehicles in the United States. *Joule,* Volume 4, Issue 7, 15 July 2020, Pages 1470-1485.
[25] Chris Nelder and Emily Rogers, Reducing EV Charging Infrastructure Costs, Rocky Mountain Institute, 2019.
[26] Templeton, B. "Tesla's Texas Charger Grant Applications Fail; It's Bad For Texas But Reveals Tesla's Super-Low Costs." *Forbes,* April 22, 2022.

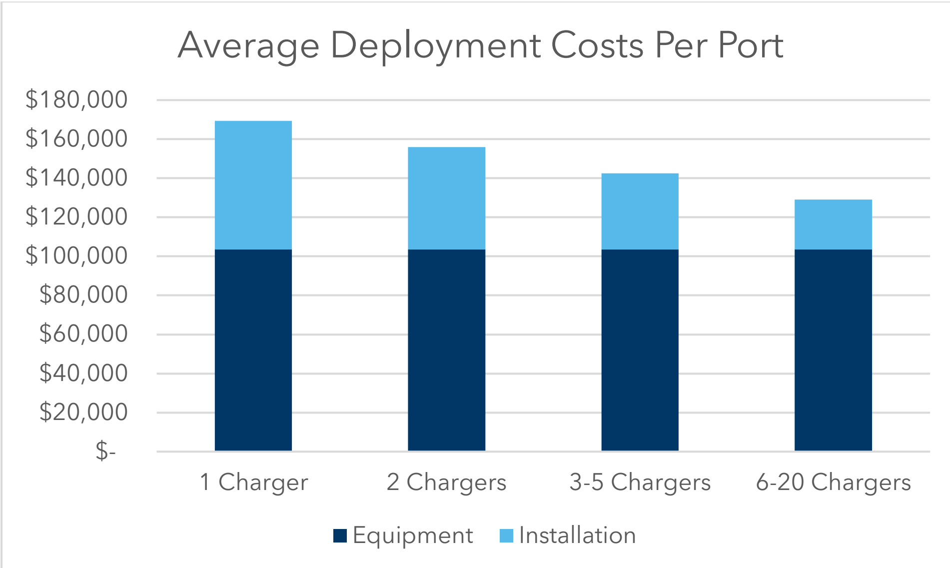

Figure 8. Comparison of per-port DCFC costs as a function of the number of ports per site, using 150kW DCFC. (Source: ICCT, 2019)

Table 8. Indicative Costs of DCFC Charging Infrastructure

Charging Power		1-2 port site			
	New Utility Connection ($)	Equipment ($/port)	Installation ($/port)	**Total ($/port)**	
Public DCFC - 50kW	0 - 100k+	45,000	40,000	**85,000**	
Public DCFC - 150kW	0 - 100k+	80,000	70,000	**150,000**	
Public DCFC - 350kW	0 - 100k+	140,000	84,000	**224,000**	
		4 port site			
	New Utility Connection ($)	Equipment ($/port)	Installation ($/port)	**Total ($/port)**	**Total ($/site)**
Public DCFC - 50kW	0 - 100k+	45,000	24,000	**69,000**	**276,000**
Public DCFC - 150kW	0 - 100k+	80,000	42,000	**122,000**	**488,000**
Public DCFC - 350kW	0 - 100k+	140,000	50,400	**190,400**	**761,600**

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