EV Charging Demonstrations in MURBs, and Guidelines for MURB Owners and Developers

Electric Vehicle Infrastructure Development Project **EVID-2005**

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Contents

Project Introduction and Overview

This Project de-risked and validated novel solutions for electric vehicle (EV) charging, and demonstrated how the solutions can be applied to address key barriers to EV adoption. The Project specifically focused on Electric Vehicle Energy Management Systems (EVEMS), and open protocols for:

- Control of charging stations.
- Demand response.
- Roaming (i.e. interoperability between different EV charging networks for drivers).
- Payment.

This report is focuses on solutions developed for Multi-Unit Residential Buildings (MURBs).

Background

EV Energy Management Systems

Past versions of the Canadian Electric Code (CE Code) required that each Electric Vehicle Supply Equipment (EVSE) be connected to dedicated branch circuit (i.e. a branch circuit serving no other loads than one EVSE). Often, "Level 2" charging is capable of delivering 40 amps at 208 or 240 volts. Installing dedicated circuits for an entire parking garage can quickly exhaust any spare capacity that may exist in the building, and entails significant cost associated with the amount of copper wiring. Thus, being restricted to the use of unmanaged dedicated circuits increases the costs and electrical system impacts (e.g. peak loads) of providing EV charging.

The 2018 and 2021 versions of the CE Code enable use of EVEMS. EVEMS monitor and control loads, so that the total demand for electricity does not exceed the capacity of a circuit. EVEMS are a critical technology that can enable large proportions (e.g. 100%) of parking in new and existing buildings to be EV Ready, and ultimately feature EV charging. Compared to providing a similar number of EV Ready parking spaces on unmanaged dedicated electrical circuits, designing for use of EVEMS considerably reduces the cost of providing EV Ready infrastructure. Design that leverages EVEMS reduces developments':

- Utility service capacities, and associated utility service connection fees;
- Capacity of buildings' electrical infrastructure (e.g. transformers, switchgear, feeders, branch panels, etc.); and/or
- Number of branch circuits in a parkade.

Later sections of this report provide further detail about EVEMS.

The Challenge of Implementing EV Charging in MURBs

MURBs include owned or rented condominiums, apartments, and housing co-operatives. The vast majority of existing MURB building stock was never designed for EV charging. Retrofitting these buildings with EV charging entails multiple challenges.

There are different legal frameworks in stratas, rental units, and co-op buildings. A strata is a group of individual owners that are part of a whole, who together make up a separate legal entity. Owners have title to their individual strata units while together owning the common property and common assets as a strata corporation. Strata buildings are managed by strata councils. This form of ownership is common in North America.

Approval of strata councils, management companies, or co-op boards is required to install electric vehicle supply equipment (EVSE). In many stratas, legal title to a housing unit is often associated with a particular parking stall, so installing just a few EVSEs where it is electrically convenient may not align with where owners have parking stalls. Because of the challenges of legally trading parking spaces, it often provides the greatest benefit to future-proof the entire parkade in a MURB with an electrical outlet (i.e. a junction box or receptacle) at which EVSE can be installed in the future as drivers adopt EVs. This future-proofing is called “EV Ready”. These 100% EV Ready designs typically use extensive load-sharing to keep EV electrical loads within buildings’ available electrical capacity, and to reduce infrastructure costs.

Because it is often easier to reassign parking in rental buildings and some co-ops, it is sometimes possible to implement phased electrical upgrades in these buildings. However, it is still important to consider at the outset of phased retrofits how a growing amount of parking, ultimately culminating in most or all parking in future decades, can most cost-effectively feature EV charging. Sometimes in rental buildings, it can make sense to make all parking EV Ready, as the cost savings of phased retrofits would be negligible.

Charging Station Network Management Systems

Charging station network management systems (CSNMS) are used to control groups of EVSEs. CSNMS serving multifamily buildings facilitate various services, including EVEMS; billing and payment; reporting; customer assistance; warranty; operations and maintenance; etc.

CSNMS often use proprietary data communication protocols, locking MURBs into a relationship with a particular CSNMS that may be costly, and likely will not interoperate with other vendors’ EVSEs.

All of the above issues represent significant barriers to adoption of EVs. This report discusses how the BCIT Smart Microgrid Applied Research Team addressed some of these barriers.

Objectives

This Project’s overarching objective was to reduce barriers to the adoption of EVs in Canada by demonstrating EV infrastructure solutions that are interoperable, minimize grid impacts, and improve the customer’s charging experience.

The solutions demonstrated include:

- Integrating the latest interoperability software (OCPP v2.0) in Canadian EV Network operators’ charging networks.
- Load-management of EV infrastructure using EVEMS, and utility-control of EV infrastructure to manage peak energy and grid load using OpenADR.
- Enabling the seamless use of EV charging infrastructure when travelling beyond usual charging networks and across Canada and the United States.

- Integrating a PCI-compliant payment system to accept payments through a 3rd-party PCI-compliant hosting provider, avoiding the need to store credit card or customer data.

Of these objectives, the solutions most relevant to MURBs are OCPP and EVEMS. Each of these technologies is described in more detail below.

OCPP

The Open Charge Point Protocol (OCPP) is an open application protocol which allows EV charging stations and central management systems from different vendors to communicate with each other. The protocol is designed and maintained by the Open Charge Alliance, and is free to implement and royalty free to use. The protocol runs on a charging station network management system, operating similar to computer protocols and computer networks, or cell phones and cell phone networks.

Communication and control protocols used by the EVSE vendor solutions are often proprietary. No single EVSE Vendor has a solution that fits for all purposes. Add to that, both the vendor selection criteria and the solutions change over time. Furthermore, vendors can go out of business, their work may become less reliable or may no longer match their clients evolving needs.

Open, non-proprietary protocols provide the required functionality for the solutions developed by original equipment manufacturers (OEMs) and provide vendor agnostic communication solutions. This enables flexibility to move to a new network provider, integrate with Building Management Systems (BMS), implement electric utility demand response (DR), and establishes a common platform enabling larger integration in the future.

As part of a previous NRCan-funded project, BCIT developed charging station network management system (CSNMS) software that uses OCPP to command and control various DC fast chargers (DCFC) and Level 2 units. The current project provided funding to enhance and expand this OCPP-based software. This software component of the Project has helped to de-risk EVSE ownership. Using this OCPP-based software, owners are less vulnerable to individual system suppliers. For example, if a particular vendor product is discontinued, the owners could simply switch to another OCPP-based network provider. Giving charging station customers choice and flexibility to use any network on any charge station helps encourage cost competitiveness and interoperability. These benefits transfer to EV drivers as the charging infrastructure network expands.

Project partners FLO | AddÉnergie, and Sun Country Highway are keenly interested in integrating OCPP into their product lines to address this barrier to adoption of EVs, as are other CSNMS operators. Part of this project involved testing FLO | AddÉnergie's chargers with BCIT's OCPP-compliant CSNMS software.

BCIT's CSNMS software is compatible with OCPP versions 1.5, and 1.6J. The latter is the current *de facto* industry standard for OCPP. OCPP 2.0 was released in March 2018. However, no commercial products have been shipped to date, because this standard is still evolving with version 2.01, and regular updates and changes on an almost weekly basis. It is anticipated that when this process settles, there will be a stable version 2.2, but there will be a time lag before OCPP version 2.2 products hit the marketplace. BCIT has developed and incorporated some OCPP version 2.0 components into its CSNMS software, but these components remain untested until commercial OCPP version 2.x products are on the market.

The BCIT OCPP-compliant CSNMS software developed during this project is available for free download and use. The software includes:

- Backend Server
- Client code to help vendors implement OCPP on their charging stations
- Customer Portal
- Administration Panel
- Plugshare integration for Sending Live Station Status
- PCI Compliant Payment Processing
- Check-In Terminal

BCIT's CSNMS software can be downloaded here: http://files.mgrid-bcit.ca/download/

EVEMS

Electric Vehicle Energy Management Systems (EVEMS) is a means used to control EVSE loads through the process of connecting, disconnecting, increasing, or reducing power to the loads and consisting of any of the following: monitor(s), communications equipment, controller(s), timer(s), and any other applicable device. EVEMS are sometimes known as demand charge controllers for EV, or load managed EV chargers. Since EVEMS has played such an integral role in this project, a more fulsome explanation of EVEMS technology is in order.

An EVEMS allows Level 2 EV chargers to share power, rather than each charger being provisioned on a dedicated circuit. An EVEMS makes more efficient use of installed electrical infrastructure for EV charging. There are various energy management schemes for EVEMS, which include:

- Load switching
- Load sharing
- Load management without monitoring
- Load management with EVSE monitoring.

Each of these is described in more detail below.

Time Allocation

Time allocation uses a rotational algorithm to assign power to EV chargers based on time. It can be used to schedule charging to avoid demand peaks. Time allocation is a simple and inexpensive solution. However, it increases the use of power switching components such as contactors, thereby reducing operational life. Also, some EVs do not resume charging once a charging session is interrupted. Therefore, time allocation is not recommended as an EVEMS strategy for most MURBs.

Power Allocation

Power allocation uses various methods to limit or stop power flow to EV chargers, such as load switching, load sharing, and load management with or without monitoring.

Load Switching

Load switching uses current transformers (CTs) to monitor real-time electrical consumption at an electrical panel. If the panel reaches a certain pre-set maximum threshold, the system de-energizes the EVSE, then re-energizes the EVSE when the electrical consumption at the panel falls below the maximum threshold after a set period of time. While load switching is a simple and relatively inexpensive solution, it is not scalable, and as with time sharing, it increases the use of power switching components, thereby reducing operational life. Also, some EVs do not resume charging once a charging session is interrupted. Therefore, load switching is not recommended as an EVEMS strategy for most MURBs.

Load Sharing

Load sharing allocates equal power across all EV chargers that are connected to a circuit. For example, in an installation with two load shared EVSEs, they may share a 40 A circuit, with each EVSE capable of drawing 32 A. If only one EV is connected, the EVSE it is plugged into is capable of delivering the full 32 A. If two EVs are connected, power is shared between the two EVSEs, and each would deliver 16 A. When one EV finishes charging, the other EV would receive the full 32 A.

Load sharing is a simple installation for small-scale deployments of EVSEs. It may not fully utilize available electrical capacity, but it does not increase the use of power switching components, so is a recommended EVEMS strategy.

Load Management without Monitoring

The load management without monitoring approach delivers power proportional to the actual requirements of an EV. EVs with lower charging requirements, such as a plug-in hybrid for example, receive a smaller percentage of overall charging capacity. This is a relatively inexpensive solution for charging a large fleet of EVs in a building with limited electrical capacity. However, it requires information on each EV, and some inefficiencies are introduced when a battery becomes fully charged and when an EV reduces its charge rate. Tracking information on each EV can be problematic as it requires drivers to register vehicle data with a back-end system, and keep the information updates as they acquire new vehicles.

Load Management with Monitoring

Load management with monitoring controls charging based on the available electrical capacity and the demand request of each EVSE. The system monitors the real-time power consumption of each EVSE and dynamically allocates power to them. Monitoring is done by CTs that are installed in the electrical infrastructure and connected either directly to the EVEMS, or electrical meters which are then read by the EVEMS. This approach is best able to maximize the efficiency of the building's electrical system capacity, and can accommodate larger numbers of EVSEs. The cost of load management with monitoring is higher, and may involve monthly or annual services fees. It also involves a more complex setup and configuration, which should only be done by qualified personnel. Load management with monitoring is the recommended approach for EVEMS installations.

BCIT authored a research paper for CSA Group on EVEMS, which is the first step in creating a standard, and continues to serve on the working group developing a standard for EVEMS. The paper is available on CSA Group's site here:

https://www.csagroup.org/wp-content/uploads/CSA-RR_ElectricVehicle_WebRes.pdf

Test Installations

In order to create EV charging solutions for MURBs, BCIT created testbeds to prove the technology at the following BCIT locations:

- Energy OASIS
- Vancouver Downtown Campus
- Centre for Applied Research & Innovation (CARI)
- Aerospace Technology Campus
- AFRESH Home.

Each of these is described in more detail below.

Energy OASIS

OASIS is an acronym for Open Access to Sustainable Intermittent Sources. The Energy OASIS microgrid facility is an NRCan-funded project that was completed in 2014 on BCIT's main Burnaby campus. Energy OASIS includes 250 kW of solar panels on two large parking canopies, a 500 kWh lithium-ion battery energy storage system (BESS), an advanced energy management system, and the main loads are two DCFC stations, and ten Level 2 EVSEs.

As part of the current project, and a previous NRCan-funded EVID project, BCIT created a Charging Station Network Management System (CSNMS) that uses the Open Charge Point Protocol (OCPP) to command and control EV chargers. BCIT was able to successfully demonstrate the ability to control the two DCFC units, and the collection of ten Level 2 EVSEs using this CSNMS. BCIT's CSNMS software also has EVEMS capability, and we were able to successfully demonstrate the ability to manage the load of up to ten concurrently charging EVs. This was critical as the electrical feed for the Level 2 chargers was only sufficient for 6 dedicated circuit EVSEs, so an EVEMS was necessary to manage these loads.

The Energy OASIS installation used two different vendors' DCFC units – one from Efacec, and one from BTC Power, thus demonstrating interoperability of OCPP. All ten Level 2 units are from project partner Sun Country Highway. A Schneider EM4805 meter measures the load on all ten EVSE electrical feeds, and ensures that individual EVSEs are obeying OCPP commands from the CSNMS. BCIT's EVEMS monitors the aggregate load to ensure it does not exceed system capacity. The entire system is "fail-safe", in that if communications are interrupted at any time, the EVSEs stop charging, then resume charging once communications are restored.

This installation provided the BCIT SMART team with invaluable learnings and experience, paving the way for real-world MURB installations.

BCIT Downtown Campus

The BCIT Downtown Campus is located at 555 Seymour Street in downtown Vancouver. The building has an underground parking garage, and as part of this project, BCIT installed five EVSEs from project partner FLO | AddÉnergie. These units are energy-managed, and use FLO's commercial EVEMS. The circuit capacity at this installation could support two dedicated circuit EVSEs, but with the EVEMS approach, all five are supported.

CARI

The BCIT Centre for Applied Research & Innovation is located at 4355 Mathissi Place in Burnaby, close to the main Burnaby campus. As part of this project, BCIT installed four energy-managed EVSEs from project partner IBX variablegrid. BCIT also installed two non-energy managed EVSEs from project partner FLO | AddÉnergie. The four IBX variablegrid EVSEs share a 50 A electrical feed. The two FLO | AddÉnergie EVSEs are used to test OCPP interoperability and integration. These two units were connected to BCIT's CSNMS system, thus demonstrating that FLO | AddÉnergie's OCPP implementation is interoperable and compatible with BCIT's OCPP implementation.

The CARI installation also includes a dual-port EVSE from Efacec that was installed as part of a previous NRCan-funded project. These two ports are also controlled by BCIT's OCPP-based CSNMS software.

Aerospace Technology Campus

As part of a previously funded NRCan project, BCIT installed six energy-managed FLO | AddÉnergie EVSEs. These chargers used the electrical feed from existing parking lot lighting circuits. The streetlights are included in the energy management strategy.

AFRESH Home

AFRESH is an acronym for Affordable and Accessible, Flexible, Resilient, Energy-Efficient, Sustainable, and Healthy. The AFRESH home is a demonstration net-zero home located on the main Burnaby campus at BCIT. As part of a previously funded NRCan project, BCIT installed three energy-managed Level 2 EVSEs from project partner IBX variablegrid. This installation used a load management with monitoring strategy, with monitoring at the electrical panel.

MURB Installations

While the BCIT test installations allowed us to implement and test solutions that we felt would work in a MURB scenario, we needed to test in real MURBs. BCIT launched a web and email marketing campaign to raise awareness of our project, and to collect Expressions of Interest (EoIs) from various condos, apartments, and housing co-ops. Over 100 applications were received and reviewed. One of the main selection criteria was whether a strata had already had an annual general meeting where installation of EV charging had already been approved. Once prospective sites were selected, agreements were signed, with caveats that BCIT could exit if sites were found to be unsuitable or overly expensive during engineering feasibility study.

Following this process, three sites were selected for installation:

- Riverbend Housing Co-operative
- Anchor Pointe Condominium
- Siena of Portico Condominium.

Each of these installations is described in more detail below.

Riverbend Co-op

Riverbend Housing Co-operative is located at 1050 Quayside Drive in New Westminster, BC. It consists of 72 housing units, and a parking garage with 96 stalls including visitor parking. BCIT contracted AES Engineering to develop an electrical engineering plan to electrify 100% of the parking stalls in the parking garage. The project funded upgrades to the electrical infrastructure to allow for future growth. BCIT contracted PowerPros Electrical to undertake these upgrades under guidance of AES Engineering.

Electrical upgrades included a new 600 A distribution board off the main board, which feeds a new 225 A panel board. This panel board feeds six dedicated 40 A circuits to EVSEs. The six Level 2 EVSEs are from project partner Sun Country Highway. The project also installed a new City of New Westminster electrical meter, as well as a Dent meter to measure main panel load, and each individual EVSE circuit load. BCIT's CSNMS software monitors these loads to ensure panel capacity is not exceeded. Communications are hard wired CAT6 ethernet cable from BCIT's CSNMS to each EV charger. The project used Riverbend Co-op's existing internet connection to avoid any additional monthly fees from cellular SIM cards, etc.

The Sun Country Highway EVSEs are monitored and controlled by BCIT's CSNMS software, which uses a load management with monitoring strategy, with monitoring at the electrical panel. So while the individual EVSE circuits are dedicated, the system as a whole is still energy managed. The system is OCPP compliant, and additional chargers can easily be added to the system.

Riverbend Co-op has the authority to allocate parking stalls to owners. Many strata-owned condos do not have this flexibility, so BCIT had the flexibility to install the chargers where it was electrically convenient. However, the electrical engineering plan, and electrical infrastructure upgrades, allow for future expansion of up to 100% of the parking stalls at minimal cost.

Testing the EVEMS functionality of BCIT's CSNMS software took place on September 28, 2021. Test EVs included two Tesla Model 3s, one Tesla Model X, one Tesla Model Y, one Chevrolet Bolt, and one BMW i3. Testers connected one charger at a time, then gradually added concurrent charging session until all chargers were in use simultaneously. A full 32 A demand was confirmed on each charger. The EVEMS charging limit was then set to 60 A at the three phase panel, and testers confirmed each charger dropped to 16 A demand, as expected. The EVEMS charging limit was then reduced to 20 A at the three phase panel, and testers observed three chargers reduced their demand to 8 A, and three chargers were set to a 'waiting' state, as expected.

Communications failure was simulated by unplugging the network cable when all six EVSEs were charging at a full 32 A each. Testers observed all six EVSEs dropped to 0 A draw, demonstrating the system was 'fail-safe'. When the network cable was reconnected, all but one EVSE resumed charging at 32 A demand. Testers observed there appears to be a 'bug' with some EVs in that they sometimes do not resume charging after a charging session has been interrupted.

Anchor Pointe

Anchor Pointe is a hi-rise condominium located at 1135 Quayside Drive in New Westminster, BC. It consists of 110 suites, and a parking garage with 155 residential stalls and seven visitor stalls. BCIT contracted AES Engineering to develop an electrical engineering plan to electrify 100% of the parking stalls. The project funded upgrades to the electric infrastructure to allow for future growth. BCIT contracted Mott Electric to undertake these upgrades under guidance of AES Engineering.

Electrical upgrades included a new 1200 A distribution board off the main board, with a new 1000 A breaker, which feeds a new 225 A panel board. This panel board feeds three 40 A circuits to the EVSEs. In total, eight EVSEs were installed on the three circuits. One circuit feeds four EVSEs, one circuit powers three EVSEs, and one circuit powers one EVSE. Three additional 225 A circuit breakers were installed to accommodate future growth. In future, the plan is to connect six chargers on each circuit.

The eight Level 2 EVSE installed at Anchor Pointe are from Lite-On, which have been rebranded to SWTCH. SWTCH's CSNMS software was used at Anchor Pointe. The EVEMS is a load managed solution, although there is no meter monitoring of the circuits. SWTCH uses a local EVEMS that is built in to one of the Lite-On EVSEs. This EVEMS acts as a gateway for up to 12 additional EVSEs. The EVEMS keeps track of the power on each EVSE. If more than 13 EVSEs are required, an additional EVSE with embedded local EVEMS is required. SWTCH's system is an OCPP 1.6J solution.

Communications at Anchor Pointe involves a mix of cellular, wifi, and ethernet. The link to SWTCH's backend in Ontario is via cellular. A gateway device pulls the cellular signal from outside the parking garage, converts the signal to ethernet, then to wifi antennas that communicate with the SWTCH EVSEs.

Similar to Riverbend Coop, Anchor Pointe is somewhat unique among strata-owned condominiums in that the strata council has the authority to allocate parking stalls. This allowed BCIT the flexibility to install the eight chargers where it was electrically convenient. However, as is the case with Riverbend Co-op, the electrical engineering plan, and electrical infrastructure upgrades, allow for future expansion of up to 100% of the parking stalls at minimal cost.

Testing the EVEMS functionality of the SWTCH system took place on September 7, 2021. Test EVs included three Tesla Model 3s, one Tesla Model X, one Tesla Model Y, one Chevrolet Bolt, and one BMW i3. At the time of the test, a total of six EVSEs were installed, with three chargers on two separate circuits. BCIT added two more EVSEs at a later date.

Testers connected one charger at a time, and a full 32 A demand was confirmed on each charger. Then two EVSEs were tested on each circuit simultaneously. Testers observed the charging rate reduced to ~16 A per charger, demonstrating the load limiting feature of the EVEMS. With all six EVSEs charging simultaneously, testers observed the charging rate reduced to ~10 A per charger.

SWTCH's team then reduced circuit #2's maximum power draw to 20 A, and testers started the three EVSEs on that circuit charging EVs. Testers observed two EVSEs charging at ~7 A, and the third EVSE was waiting in queue, as expected.

Communications failure was simulated by placing a large metal board in front of the communications gear, thereby blocking the wifi radio signal. Before the communications interruption, the EVs were observed charging at 32 A. During the communications failure, the EV charging rate was observed to drop to 10 A, which SWTCH considers a 'fail-safe' charging rate for the system. After communications were restored, the 32 A charge rate resumed.

Siena of Portico

Siena of Portico is a hi-rise condominium located in Vancouver, BC. It consists of 78 suites, and 14 townhouses, and a parking garage with 129 stalls. BCIT contracted AES Engineering to develop an electrical engineering plan to electrify 100% of the parking stalls. The project funded upgrades to the electric infrastructure in order to allow for future growth. BCIT contracted Clear Energy Solutions to undertake these upgrades under guidance of AES Engineering.

The Siena of Portico installation, unlike Riverbend Co-op and Anchor Pointe, is a more typical scenario in that title to a particular parking stall is part of the legal title to a suite. Therefore, the strata council does not have the ability to allocate parking stalls. In order to at least partially accommodate this challenge, BCIT installed a special busway that allows charging stations to be easily moved from one stall to another. The long, continuous overhead busway has 'tap-offs' that are inserted to provide power to a charger. The busway contains the three electrical phases, and each tap-off taps into two of these phases. Six tap-offs were installed, with two tap-offs on each of the three phases for load balancing across the phases.

While the electrical plan developed by AES Engineering addresses 100% of the parking stalls, it divided the parking garage into four areas of roughly the same size, each to be serviced by four separate electrical circuits. The project had funding to electrify one of these circuits, providing the ability to charge to approximately 25% of the parking stalls. That is, the busway is installed in approximately 25% of the stalls, with six tap-offs installed in the busway to provision the six installed EVSEs. More tap-offs can be installed as more EVSEs are ordered by residents at Siena of Portico. BCIT and AES Engineering, in consultation with Siena of Portico, selected the circuit that would provision the most residents who had EVs at the time of project initiation. Residents with EVs whose parking stalls were not in the 'quadrant' selected for electrification were able to arrange agreements with residents in the selected quadrant who didn't drive EVs, to temporarily swap parking stalls.

The six EVSEs installed at Siena of Portico are from two vendors – Phihong and Lite-On. These are controlled by a CSNMS from ChargeLab. ChargeLab's system is an EVEMS that uses a load management strategy, but does not monitor the circuits with a meter. ChargeLab's CSNMS is an OCPP 1.6J solution. Initially, the project was going to use EVSEs from five different vendors, namely Phihong, Lite-On, Siemens, Blink, and EVbox. However, during testing, problems were encountered with the Siemens, Blink, and EVbox units, so ChargeLab supplied replacement units from Phihong and Lite-On. The Siemens, Blink, and EVbox units worked in ChargeLab's laboratory environment, but did not work in the real MURB environment of Siena of Portico. At the time of this writing this report, the Lite-On units work satisfactorily, but the Phihong units required a firmware upgrade to address an issue where the EVSEs would sometimes stop responding to power level commands. BCIT tested the new firmware remotely, and at the time of report writing, ChargeLab is in the process of testing the new firmware in their lab before pushing it out to the chargers at Siena of Portico.

A limitation of the ChargeLab system is that it is currently designed only for single phase electrical circuits. The Siena of Portico electrical infrastructure is three phase, as are the other MURB installations discussed in this report. BCIT discussed this with ChargeLab, and sent ChargeLab's technical team source code for the three phase logic, so hopefully this issue will be addressed soon.

Recommendations for MURBs

Options for Providing EV Charging in MURBs

Broadly, multifamily buildings that are not future-proofed at time of construction with EV charging infrastructure can pursue one of two strategies to implement EV charging:

1. Incremental Installations

   Incremental installations bring EV charging to a few parking spaces at a time. Often the EVSE are placed in shared spaces, like visitor parking, to be shared between a few residents that have adopted EVs. Sometimes, charging may be provided to individual households' assigned parking space.

2. 100% EV Ready

   A parking space is "EV Ready" when it has an adjacent electrical outlet capable of supporting L2 charging; EVSE are installed over time, as households adopt EVs. A comprehensive "100% EV Ready" approach involves one major electrical retrofit, making each parking space (or one parking space per dwelling unit) EV Ready. Typically, projects are designed to use EVEMS to enable load-sharing between EVSE. Load-sharing in this manner can substantially reduce the electrical capacity and expense needed to provide all residents with access to EV charging. The amount of load sharing using EVEMS that is viable for a particular building is a product of how far residents will drive on a daily basis, vehicles' average efficiency, and other factors.[1]

Comprehensive EV Ready retrofits typically cost more upfront than the first tranche of adding a few charging stations to a MURB. However, in light of the rapid transition to EVs that is under way, this approach will typically realize the greatest value for multifamily condominiums and many rental building owners over the medium to long term.

Table 1 compares these two models for providing EV charging in existing multifamily buildings. Table 1 makes clear that there are significant challenges to retrofitting multifamily buildings to provide EV charging. Comprehensive 100% EV Ready retrofits often provide the greatest value over the life cycle of the building but are complicated and entail greater costs than future-proofing new construction. To avoid perpetuating the challenge of providing EV charging infrastructure in multifamily buildings, Canadian local governments are increasingly adopting 100% EV Ready residential parking requirements for new construction.

[1] For more on determining appropriate charging performance requirements and the extent of sharing that is viable in multifamily buildings see AES Engineering. 2021. *EV Charging Performance Requirements*. Prepared for the Clean Air Partnership. https://cleanairpartnership.org/cac/wp-content/uploads/2021/11/2-21-050-EV-Charging-Performance-Requirements-in-GTHA.pdf

Table 1: Comprehensive EV Ready retrofits vs. incremental EVSE additions

	Comprehensive 100% EV Ready retrofits	Incremental additions of EVSE
Life-Cycle Cost Per Parking Space	Less expensive, when designed with appropriate levels of load sharing and EVEMS.	More expensive over time, assuming that most vehicles in multifamily buildings will ultimately be EVs.
Process	One-time significant electrical renovation.	Repeated electrical renovations.
Location of charging stations	In drivers' assigned parking space.	Often initially in commonly accessible parking (e.g. visitor parking). Sometimes in assigned parking.
Process for drivers to install chargers	Simple (after initial comprehensive electrical renovation). An EVSE compatible with the buildings' EVEMS will be installed.	Typically lengthy and complicated.
Convenience	Highly convenient for drivers, EV charging in regular assigned parking spot.	When chargers are located in commonly accessible parking (e.g. visitor parking), scheduling can be less convenient
Futureproofing	With EVEMS, frequently can ensure sufficient electrical capacity for all parking spaces to have EV charging.	Initial installations are sometimes not compatible with later expansion (e.g. may not leave electrical capacity or physical space). Potential for stranded assets. Potential to exhaust limited electrical capacity if design for EVEMS not considered.
Market adoption	Currently very uncommon. Where incentives are available (e.g. BC's EV Ready Rebate program) 100% EV Ready retrofits are growing more common, but still nascent. .	Typical approach to adding EV charging in existing multifamily buildings.
Electrical Permit	Typically, only a single electrical permit is required.	New electrical permits will be required for each electrical renovation.

Recommendations for Implementing EV Charging in MURBs

It is recommended that condominium associations, rental building owners, cooperatives, and other MURB owners:

Engage owners and residents to gauge level of interest and identify any questions – Surveys, interviews, meeting(s), and other strategies can be used to determine the extent of interest amongst residents in access to "at home" EV charging. Important questions to ask include: Whether residents are considering an EV as their next vehicle? Whether condominium owners believe access to EV charging will add value to their property? What are important principles/values that owners hold regarding how EV charging is implemented (e.g. users pay for cost of electricity they consume; value for money; a good quality of EV charging experience, e.g. a full battery in the morning; etc.)?

Gather information about applicable incentive and financing programs – Explore what incentive programs are offered by different levels of government (Federal, Provincial, local), utilities, and other stakeholders, to subsidize the cost of EV charging infrastructure in MURBs. At the time of this writing, a number of provinces offer incentives for implementing a few EV chargers at a time (i.e. incremental EVSE installations). The Province of BC offers the EV Ready Rebate Program to plan and implement comprehensive 100% EV Ready retrofits to make all residents' parking EV Ready; at the time of this writing, other jurisdictions were exploring similar programs.

Consider the buildings' parking tenure and how this impacts the ability to implement EV Ready retrofits in phases – Parking tenure (i.e. who has a right to use what parking space) is an important consideration when considering how to implement EV charging. MURBs should consider the following:

- Are residents allowed to park in visitor parking, as is necessary if EV charging infrastructure is located at visitor parking? In some cases, there may municipal restrictions on residents regularly using visitor parking. Different buildings vary in the level of demand for their visitor parking, and whether it will be acceptable for residents to regularly use this parking to charge their vehicles.
- Can residents reassign and "swap" parking spaces? The ability to swap parking spaces can allow for 100% EV Ready parking to be built out in phases in some developments, deferring some costs without stranding assets (however, it should be noted that in many cases, particularly in smaller or medium sized MURBs, the value of phasing upgrades may be limited). In many rental buildings, parking can be relatively easily reassigned by the building owner. In many forms of condominium parking tenure (e.g. long-term leases; limited common property; stratified parking spaces; etc.), there are significant barriers to legally reassigning parking spaces. Condominium owners will often pay for the cost of installing EVSE. They thus expect a long-term right to the parking space. This usually makes any phased approach to installing EV charging infrastructure in residents' assigned parking not viable – EV drivers are very unlikely to all happen to be clustered in one part of the parking space.

Conduct a engineering feasibility assessment (i.e. an "EV Ready Plan") to explore comprehensive 100% EV Ready retrofits and other EV charging infrastructure scenarios – Condominiums and building owners should engage a qualified entity (e.g. an electrical engineering firm with experience designing similar projects) to conduct a feasibility assessment of how to cost effectively provide for all residents to ultimately have access to EV charging. At minimum, this assessment should include:

- An electrical load capacity analysis, to determine how much electrical capacity is available in the building.
- Determination of charging performance requirements for the building – i.e. how much load sharing using EVEMS is viable for the building, while providing a good quality of drivers experience. As the extent of load sharing significantly impacts project costs (more sharing will reduce infrastructure costs), building owners should push their consultants to justify how they determined how much load sharing is viable. AES Engineering have developed statistical methods to evaluate how much load sharing in viable in different locations, depending on how far vehicles tend to drive, vehicle types, and other factors.[2]
- Conceptual electrical designs of options to provide EV charging. These conceptual designs should include an electrical single line diagram, plans, and communications infrastructure.
- Identification of what EV charging station network management systems (CSNMS) are compatible with the electrical design, and guidance for the building owner on selecting a CSNMS(s) for the building.
- Cost estimate(s) for the electrical design(s) to enable the building to budget for the work.

Carefully consider the value of comprehensive EV Ready retrofits compared to incremental additions of EV charging infrastructure. Consider life cycle costs. Consider that properly executed comprehensive retrofits can solve the problem of EV charging for the life time of the building, while incremental retrofits will require regular expansion of infrastructure and potential for stranded assets.

Consider selecting CSNMS service providers that use open communication protocols (e.g. OCPP) and have a proven track record of delivering quality services in MURBs. Open communication protocols can ensure that if a building has a challenge with a CSNMS (e.g. poor service; cost increases; CSNMS goes out of business), they are able to switch to another CSNMS with rendering already installed EVSE inoperable and needing to be replaced. The *de facto* industry standard open communications protocol is Open Charge Point Protocol (OCPP). Building owners should likewise consider CSNMS's pricing and services such as warranties, maintenance, helplines, customer billing and utility bill reconciliation, etc.

Project Monitoring

The project will be staffed and monitored to complete the follow-on reporting period. Monitoring will include gathering and analysis of electric vehicle charging data. Data will be available to share with stakeholders and replication projects. The monitoring activities will feed into the annual post-project completion reporting.

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[2] See e.g. AES Engineering. 2021. *EV Charging Performance Requirements.* Prepared for the Clean Air Partnership and Ontario municipalities. https://cleanairpartnership.org/cac/wp-content/uploads/2021/11/2-21-050-EV-Charging-Performance-Requirements-in-GTHA.pdf