Installation of Charging Infrastructure for Electric Vehicles in Multi-Unit Residential Buildings in British Columbia

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Abstract:
Electric Vehicles (EVs) contribute to the mitigation of climate change through reduced greenhouse gas emissions, when powering with sustainable sources of electricity. The province of British Columbia (BC) is an attractive location for EV deployment since most of its electricity is sourced from clean renewable energy sources. Due to their driving range and potential to reduce local emissions, EVs work well in urban contexts, where most residential buildings are located. As a result, residents from Multi-Unit Residential Buildings (MURBs) are among those interested in becoming EV owners, thus requiring access to charging infrastructure, especially overnight home charging, which is the preferred charging alternative. However, most residential buildings are not equipped with charging infrastructure and its installation can have numerous challenges that can turn into barriers. This study aims to explore the implications and challenges involved in the process of EV charging infrastructure installation in MURBs. By identifying present and future barriers to infrastructure provision, potential policy actions to address them can be recommended.

Keywords:
Electric vehicles, EV charging infrastructure, residential buildings.

1. Introduction

Electric vehicles (EVs), as an alternative to traditional fossil fuel vehicles, have become a reality for many countries including Canada. EVs contribute to the reduction of fossil fuel dependency of the transportation sector, as well as the improvement of air quality and mitigation of climate change through reduced greenhouse gas emissions [1], [2]. Since the first EV sold in Canada in 2011, the market has been growing and sales have been increasing significantly as manufacturers release new models, and consumer understanding and trust of the technology continues to increase [3].

Powering EVs with sustainable sources of electricity has added benefits in terms of sustainability metrics [4]. The Canadian province of British Columbia (BC) is considered as one of the most attractive locations in the world for EVs since 85% of its electricity is sourced from large hydropower, a clean renewable energy source [5]. In addition, current residential electricity rates in this province means the cost of charging a vehicle at home is less expensive than fueling a conventional vehicle with gasoline [6]. BC is also the province with the third highest EV sales in 2017, as well as the second highest increase in the adoption rate, a 48.6% increase over 2016 [7].

EVs, understood in this study as light-duty vehicles partially or fully fueled by grid electricity, have the commonality of having to be plugged in to charge the vehicle's battery pack. Charging can be made possible in workplaces and public spaces, but research suggests that 80-90% of charging happens at home where it is most convenient for drivers [3]. Due to their driving range and capacity to reduce emissions significantly, EVs fit well in city contexts. Thus, there is growing interest from vehicle drivers in cities, including residential building inhabitants, to have access to EV charging infrastructure, which is considered a prerequisite to EV ownership [3].

For these reasons, the deployment of charging infrastructure in residential buildings in BC (also known as Multi-Unit Residential Buildings or MURBs), has been receiving attention recently from the provincial and municipal governments and from residential building associations. These groups have recognized the importance of home charging in promoting EV adoption, but also the fact that achieving charging infrastructure access in MURBs has an additional layer of complexity compared to detached homes. Installing new infrastructure in existing buildings has numerous implications and barriers, which can hinder the installation of charging infrastructure in MURBs.

This study aims to explore the implications and challenges involved in the process of EV charging infrastructure installation in MURBs. By identifying present and future barriers to infrastructure provision, potential policy actions to address them can be recommended.

2. Problem dimensions

The problem of EV charging infrastructure installation in MURBs in BC was analyzed from three different perspectives or dimensions: EVs and charging

infrastructure, existing MURBs, and regulations and policy. These dimensions were mapped on a Venn diagram (Figure 1) to analyze the intersections among them.

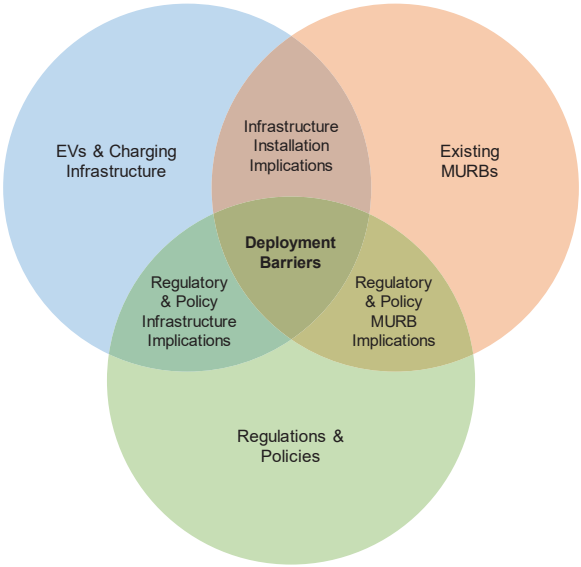

Figure 1 Venn diagram framework

First, the EV types included are only the Plug-In Electric Vehicles which can be partially or fully fueled by grid electricity [3]. This includes both plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs) but excludes hybrid electric vehicles (HEVs) because they do not have the capacity to be plugged in and charged with electricity from the grid, and therefore do not need nor benefit from the electric charging stations. The EV offer in Canada is quite comprehensive. There are currently 15 different models of BEVs and 26 models of PHEVs [7]. BEV sales in BC exceed the PHEV sales by more than double, mainly led by the Tesla models (only available as BEVs) which account for more than 40% of the total BEV sales in the province [7].

Regarding charging levels, there are three levels of EV charging: Level 1 (Opportunity), Level 2 (Primary) and Level 3 (Fast) [8]. There are also two types of charging infrastructure, public and private. Public charging infrastructure includes the charging stations that are available for use to the general public and are publicly accessible. Public infrastructure is useful for EV owners that need additional charging during the day or that don't have access to overnight charging at home. As EV sales increase, so does the network of charging stations. There are currently around 1,000 public charging stations in BC, most them being Level 2. Private charging infrastructure refers to the charging stations located on private property and not available for use of the general public. Private charging stations are usually located on home or office premises and can only be used by the station owners (in the case of households) or other authorized personnel (such as office employees). Private charging infrastructure is usually Level 1 or Level 2, since Level 3 works on DC and is not currently considered viable and safe for installation within residential buildings. The decision between Level 1 and Level 2 installation depends on several factors, among them the user's charging needs and daily driving range, the EV model they own, the cost they are willing to invest for charging infrastructure, as well as the desired location and existing electrical system where the charging station will be installed.

Second, the term "existing MURBs" refers to buildings in the operation phase for which EV charging infrastructure was not installed during the construction phase. In B.C. there are mainly two types of MURB ownership: purpose-built rental buildings and strata or self-owned buildings. Depending on the type of building, the decision of installing charging stations is handled differently. In purpose-built rental buildings, tenants can request the installation of a charging station in their parking stall to the landlord or property manager and the decision relies on them. Strata buildings, on the other hand, have strata councils that can vote on the decision and the majority is achieved usually with 75% of the votes. In both cases, if the request is approved, agreements, bylaws, and rules may need to be put in place.

MURBs can also be classified as either traditional buildings or green buildings. Although green buildings are more likely to have had charging infrastructure installed during construction, this is not necessarily a rule. For instance, the LEED V4 for New Constructions (NC) standard, in its Green Vehicles credit, requires the designation of 5% of all parking spaces as preferred parking to EVs and install EVSE in an additional 2% of all parking spaces [9]. However, not all building developers will pursue this credit as it is optional and not a prerequisite, and even if they did, prioritizing only 7% of parking spaces for EVs might not be sufficient in the future. Because there is no requirement to prepare the building for future infrastructure needs, LEED-certified green buildings might face similar challenges as traditional existing buildings.

The electricity produced by the electric utility—in this case, BC Hydro—is fed through a meter, into the building, and is distributed to units and other areas by the building's power distribution system. The particular characteristics of each system vary among buildings, but the current BC Building Code and other applicable City Bylaws govern the overall design.

Third, it was observed that regulations and policies play an important role in the deployment of charging infrastructure in MURBs. Conventional fossil fuel vehicles have been on the market for over 100 years and have established a clear market lead relative to

other Alternative Fuel Vehicles (AFVs), which could be defined as a case of technological lock-in [10]. EVs as an emerging technology can benefit widely from external private and public support. Governments, through policy instruments such as regulation, taxation, subsidies, and incentives have helped shape the current EV market globally. Other initiatives such as setting long-term goals and providing R&D funding further support EV and infrastructure technical development [10]. The role of policy around EVs has been studied in more detail recently to enable the understanding of its potential influence and overall relevance in encouraging EV market development and diffusion. The methodology of these studies usually consists of creating or using models that forecast EV uptake based on several factors, and then perform policy analysis to measure the effects certain policies could have compared to a base case "no policy" scenario.

An example is a study conducted by Wolinetz and Axsen [11]. According to them, a large-scale transition to EVs is likely to require strong government support.

3. Problem dimensions intersections

From the Venn diagram, there are four intersections between the three main dimensions. First, the interaction of EVs and MURBs is modeled through the installation of charging infrastructure into the building electrical system. This new concept emerged from the commercialization of EVs, and the fact that these vehicles can be charged at home using grid electricity as other appliances do. New buildings are increasingly including the installation of charging infrastructure during construction to be "EV-ready" and provide charging infrastructure to its residents. However, existing buildings don't have the same opportunity and, in turn, should make adaptations to the existing building system.

Regarding the characteristics of the charging infrastructure that can be installed, the levels of charging available for residential building are Levels 1 and 2. Level 1 charging can be considered sufficient for PHEVs, which have a shorter electric range and therefore a smaller onboard battery pack. However, this is not the case for BEVs that rely only on their onboard battery pack to operate, which would take between 11 and 36 hours to fully charge on this charging level. In addition to this limitation, BEV adoption in BC is approximately the same as PHEV adoption (excluding Tesla BEVs that use fast-charging methods). Therefore, it is preferable to install Level 2 charging infrastructure in MURBs to accommodate the needs of both BEV and PHEV users. As reviewed previously, there is also a general preference from all EV users to achieve a full charge faster than what Level 1 can offer. As technology evolves and battery capacity improves, faster charging will be prioritized.

The second and third intersections are the implications of policy and regulations on EV charging stations and on the existing MURBs respectively. In terms of the EV charging infrastructure, there are standards and codes that regulate charging stations and their installation. The document that regulates EV charging stations in Canada is the Canadian Electrical Code, specifically the recently added Section 86 – Electric Vehicle Charging Systems. There is also another relevant rule within this code for new equipment installation in apartment buildings: Rule 8 - 202(3)(a)(d) of this code, in its Circuit Loading and Demand Factor section. New equipment installed into an existing building creates additional electrical loads to the system. According to this rule, the load of equipment installed in a common area of an apartment building (among them, the parking lot) should be continuous, as if the equipment was operating constantly. This is a conservative approach to ensure that overloading of electrical systems does not occur and the public is protected, but unrealistic since not all vehicles will begin and end charging at the exact same time, neither will all charge stations be continuously charging a vehicle [12]. Therefore, the calculated load of the new charging stations on the electrical system will be greater than the actual load. This can lead to unnecessary and costly upgrades in the building's power distribution system, given that the parts of this system might need to be changed to allocate for the extra loads as calculated by this rule.

Regarding the existing MURBs, residential buildings in BC and their electrical systems are regulated by the 2012 BC Building Code based on the 2010 National Building Code of Canada. Each municipality within BC can also develop their own bylaws that address issues outside of the scope of the BC Building Code. For example, the City of Vancouver has its own building code known as the Vancouver Building Bylaw, which is more stringent than the provincial code. As reviewed, the City of Vancouver has included a provision in their Building Bylaw to provide charging stations for 20% of the parking stalls within MURBs and to make technical considerations to reach 100% in the future. Although this ensures that new buildings in this City will be suitable for charging EVs now and in the future, it does not address existing MURBs. In terms of green buildings, different standards, codes, and certifications and rating systems focus on mitigating the environmental impact of new and existing buildings. The most popular green building certification in Canada is LEED. Although LEED v4 for New Constructions (NC) does allocate credits to EV charging infrastructure as reviewed previously, there is no such consideration in LEED v4 for Existing Buildings Operations and Maintenance (EBOM). Therefore, there is no incentive for installing charging stations in existing buildings when pursuing a green building certification.

The center intersection, where all the dimensions interact, refers to the potential deployment and policy

barriers that can hindering the installation of charging infrastructure in MURBs. These barriers were analyzed and categorized using a framework based on Browne, O'Mahony, and Caulfield [13]. The comprehensive set of categories assist in the identification and organization of the potential barriers. The categories, as well as the potential barriers in each category are:

- **Financial:** cost of charging infrastructure and installation, and the cost of the building system upgrades
- **Technical:** building system limitations
- **Institutional and administrative:** governance issues
- **Public acceptability:** liability issues associated with EV installation, lack of support from non-users, and limited understanding of new technology
- **Legal and regulatory:** lack of regulation of rights and obligations of stakeholders, limited technical guidance, conservative regulatory requirements, and planning permission for charging points
- **Physical:** spatial building constraints and lack of parking within MURBs

The characteristics of these potential barriers, as well as the types of policies that could be used to solve them, were also analyzed. According to the timeline and significance criteria, all the barriers that were identified as short-term barriers were also judged to be of low significance. These are: 1) the governance issues that arise from charging infrastructure procurement and installation; 2) potential liability issues associated with EV installation; 3) limited technical guidance throughout the process, and 4) planning permission for charging infrastructure installation.

The medium-term barriers with the most significance (medium) include: 1) the cost of charging infrastructure and installation as an additional investment for users; 2) the lack of support from non-users, especially relevant within strata corporations; 3) the lack of regulation of rights and obligations of users, strata corporations and landlords; and 4) the conservative regulatory requirements, especially referring to the contingency in the Canadian Electrical Code. Other medium-term barriers with less significance are the limited understanding of the new EV charging technology and the lack of parking available for all the residents within their MURB (off-street parking).

The long-term barriers identified are considered of high and medium significance, and although they belong to different categories, they all refer to the implications of accommodating the additional loads and the EVSE in the existing building power distribution system. These barriers are 1) the actual building power distribution system limitations; 2) the cost of the building power distribution system upgrades needed due to the limitations, and 3) the spatial building constraints.

The analysis also reflected that the most significant barriers are related to the financial and technical categories. Most of the other categories have a combination of medium and low significance barriers.

The level of implementation is predominantly local, which means that municipal governments can take relevant actions through policy and successfully address most of the barriers. The cost of building power distribution system upgrades is of high importance and it is likely that policies will come from the provincial government level (due to the economic scale of a potential financial incentive). While the government is the most likely to take action, associations can also play an important role in addressing these barriers, especially with regulatory, education and awareness policies that do not require a large financial investment.

The financial barriers naturally require financial and fiscal policies, but most barriers can be addressed through regulatory policies, which, as mentioned, do not necessarily require large investments, unlike the financial or tax incentives.

4. Conclusions

As EVs become a viable and clean alternative to light-duty conventional vehicles and the EV market in BC grows, new opportunities and challenges emerge due to the different fueling mode of EVs. Because they are charged with grid electricity, which can be sourced from households, the majority of EV owners want to charge their vehicles overnight at home for convenience. Making charging infrastructure available in MURBs is a new and complex process that has numerous technical, financial, social and regulatory implications. Therefore, the goal of this study was to analyze the implications of installing charging infrastructure for EVs in Multi-Unit Residential Buildings in BC to uncover present and future issues that can emerge throughout the process and to identify the actions that should be taken to address them.

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