

Impact of public electric vehicle charging infrastructure on EV adoption

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Introduction

The electric vehicle (EV) market has seen significant growth in the last few years. According to the International Energy Agency, the electric car market hit a new record in 2017, surpassing 1 million sales worldwide that year. The total global electric car stock surpassed 3 million vehicles in 2017 after crossing the 1 million thresholds in 2015, and 2 million in 2016¹.

Canada's Battery Electric Vehicle (BEVs) sales increased at nearly double the rate of Plug-in Hybrid Vehicle (PHEV) sales. A total of 9,840 BEVs were sold nationally in 2017, which increased by 92% compared to the previous year. PHEV sales across the Country were 8,730, which increased 48% compared to the previous year.

In line with this trend, there are a growing number of electric vehicle charging stations in homes, at workplaces, and in public places throughout British Columbia, with over 1,000 public charging stations available.

The use of public charging stations is growing in Metro Vancouver, but it is not yet clear the degree to which they are relied upon compared to residential charging. Currently, there are more than 500 public charging stations located through the region.

¹ International Energy Agency. (2018). Global EV Outlook 2018, 9. https://webstore.iea.org/download/direct/1045?filename=global_ev_outlook_2018.pdf, 5.

This project was developed to better understand the impact that public charging infrastructure has on EV adoption, trip behaviour and lifestyles in Metro Vancouver. Table 1 shows the total number of public Level 1 and 2 charging stations and the total number of public Direct Current (DC) fast-charging stations in each municipality, with Vancouver, Surrey, Richmond and Burnaby accounting for over 76% of the total.

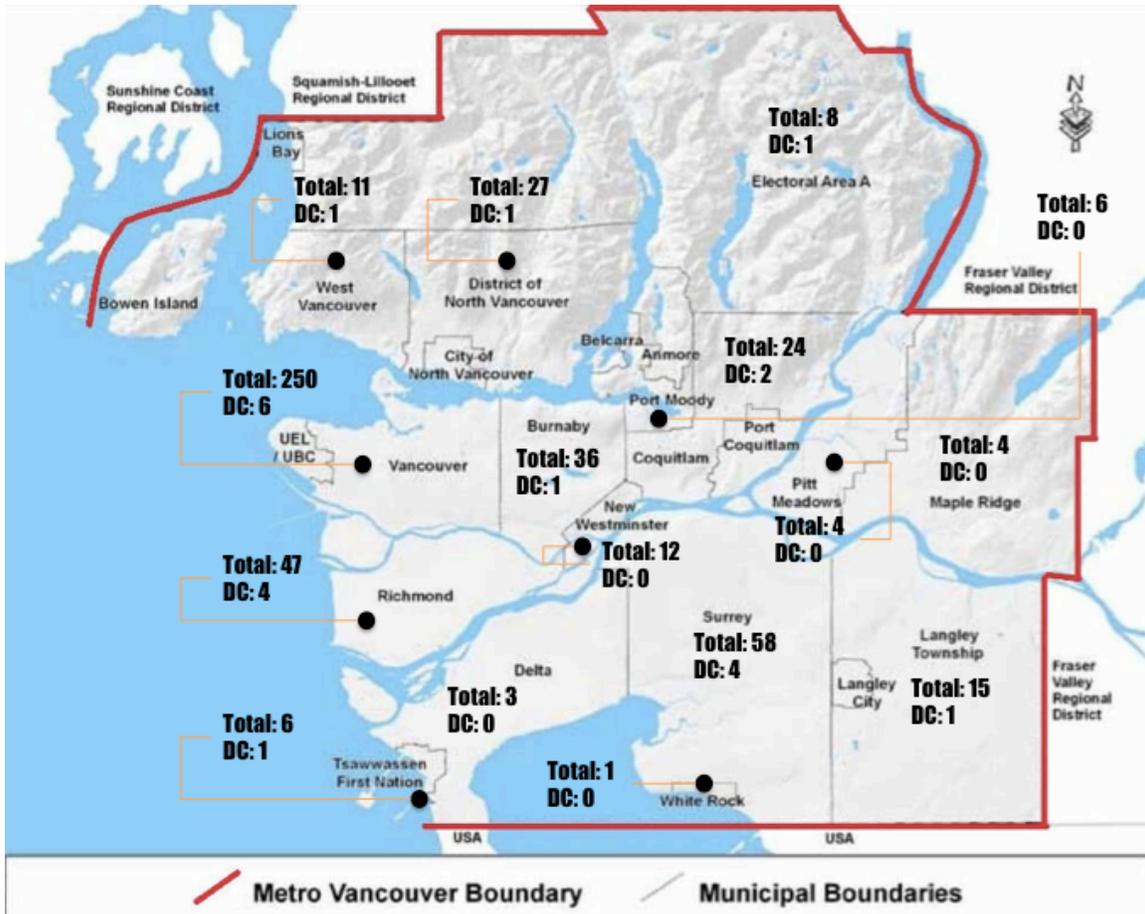


Figure 1 Number of public and DC fast charging stations for each municipality in Metro Vancouver.

Notes: This image uses the most updated information available on www.plugshare.com. It should be noted that based on field survey experience, some of the charging stations shown on www.PlugShare.com belong to the private sector or do not actually exist.

Background on EVs and Infrastructure

Electric vehicles (EVs) use a battery pack to store electrical energy, which powers the motor and propels the vehicle. EVs include fully electric, battery electric vehicles (BEVs)², or plug-in hybrid electric vehicles (PHEVs)³. Plugging the vehicle into an electric power source charges EV batteries. Although electricity production may contribute to air pollution (the amount depending on the region's grid generation), BEVs are considered a zero-emission vehicle because it produces no direct emissions at the tailpipe. In BC, electricity is a low carbon energy source, making EVs a very good low-carbon alternative to conventional fossil fuel vehicles.

Plug-in hybrid electric vehicles (PHEVs) use batteries to power an electric motor and use another fuel, such as gasoline or diesel, to power an internal combustion engine. Using electricity to run the vehicle some or all of the time reduces operating cost and fuel use, relative to conventional vehicles.

For a list of fuel consumption ratings for BEV and PHEVs, see table 12 and 13 in Appendix A.

The network of charging stations in North America is growing every day. There are three levels of charging offering different amounts of power. The more power a charging station provides, the faster the vehicle is charged⁴.

- Level 1 (120volt, One hour of charge ~ 8 km of Range): Regular outlet, also known as “trickle charge”, best used when parked overnight or long-term;
- Level 2 (240volt, One hour of charge ~ 30 km): Typical for at home, at work, or short- to medium-term parking, e.g. while shopping; and

² <https://www.afdc.energy.gov/vehicles/how-do-all-electric-cars-work>

³ <https://www.afdc.energy.gov/vehicles/how-do-plug-in-hybrid-electric-cars-work>

⁴ <http://pluginbc.ca/ev101/>

- DC Fast Charging (One hour of charge ~ 250 km of Range): Best for longer trips, allowing travel between cities. There are three standards: CHAdeMO, CCS, and Tesla Supercharger (Tesla).

Many public charging stations are free to use, but require drivers to join a service network to access the stations. Members are offered diverse ways to authorize the use of a charging station, such as scanning a member card at the desired station. By registering online with the different charging service networks, EV owners can obtain a member card. Some networks' stations (ChargePoint, FLO, and GreenLots) can also be authorized through a smartphone app or a credit card.

Research Approach

The survey intent was to understand the role of public EV charging infrastructure and host organizations, to have a better sense for future investment in public charging assets and to identify how to help increase the number of future EV owners and maintain ownership among current EV owners.

The survey targeted EV owners in the Metro Vancouver region. Three methods were used to distribute the survey: in-person at public charging stations (Burnaby, North Vancouver, Richmond, Surrey, Vancouver and West Vancouver), online (EV owners groups) and by a flyer left on electric vehicles that were charging at public stations (QR Code and URL).

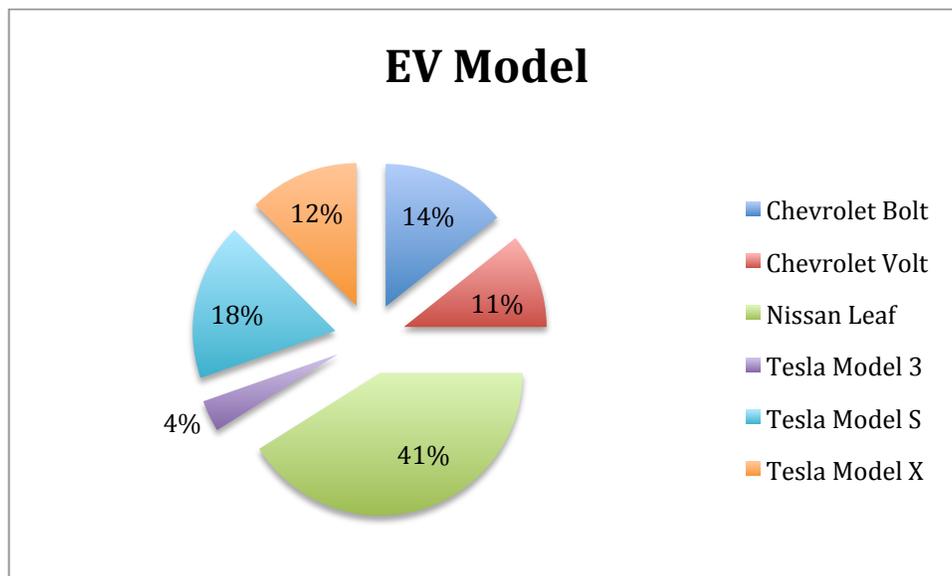
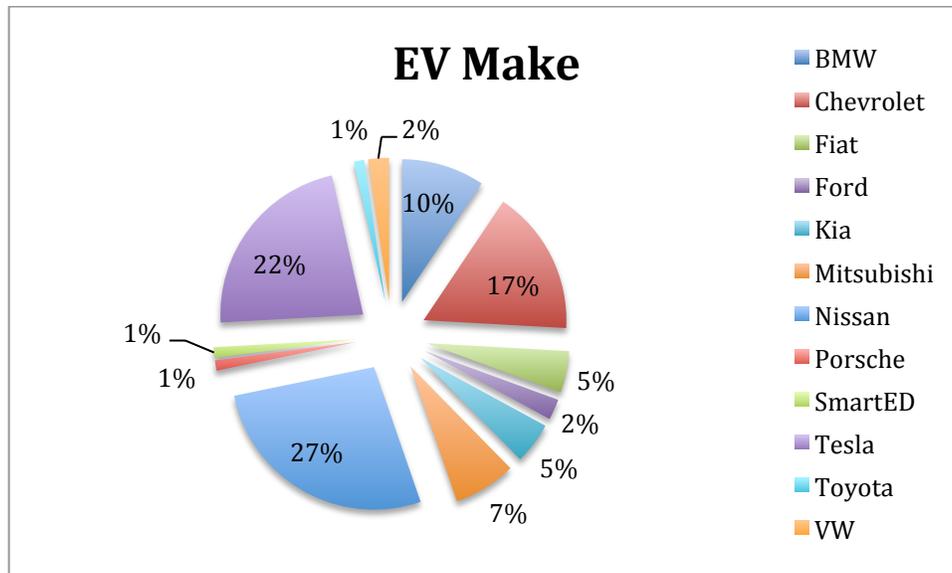
The 85 in-person surveys were conducted at 52 charging stations, selected based on their energy dispensed (higher-level of use stations were targeted), and accessibility for the researchers.

There was a conventional pretesting, which involved a relatively small number of interviews (Fraser Basin Council and Metro Vancouver employees) with a draft

version of the questionnaire, followed by an informal group debriefing session and pilot surveys. This identified some improvements to the survey design.

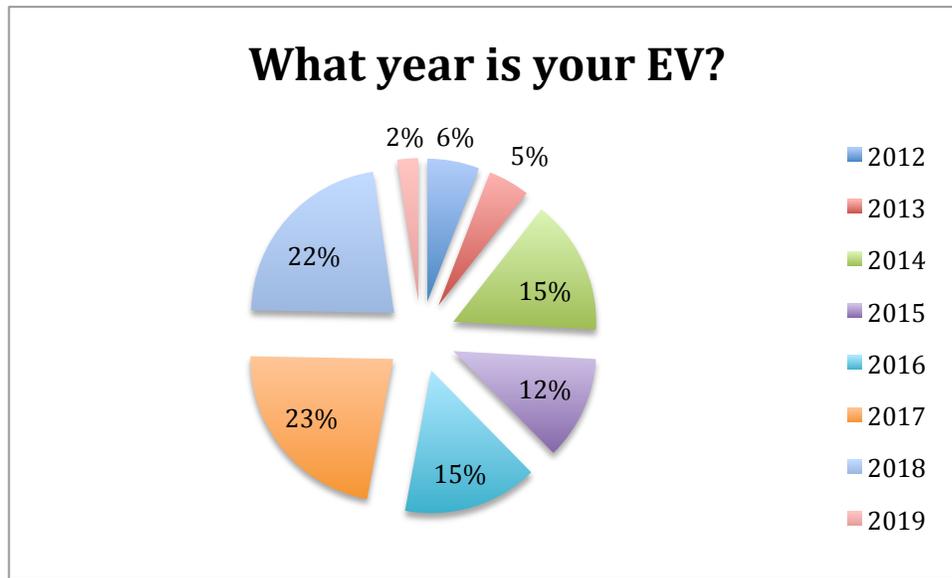
Analysis

The following analysis was done individually for each of the 29 questions in the survey, using Excel and NVivo. Additionally, some groupings were done to test correlations and potential value for future initiatives and projects.

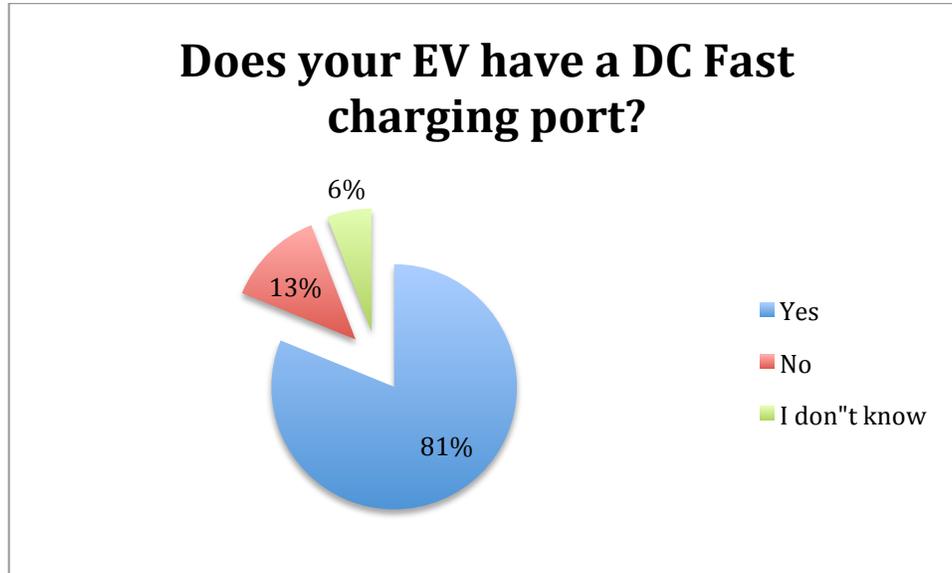


Of the 85 surveys, two-thirds of the respondent's vehicles were one of three makes: Nissan (27%), Tesla (22%), and Chevrolet (17%). While 9 of the 12 other makes of EV comprised the remaining third of the remaining vehicle types.

The Nissan Leaf was the most popular vehicle of those surveyed, followed by the Tesla Model S and Chevrolet Bolt at 12% and 9%, respectively.

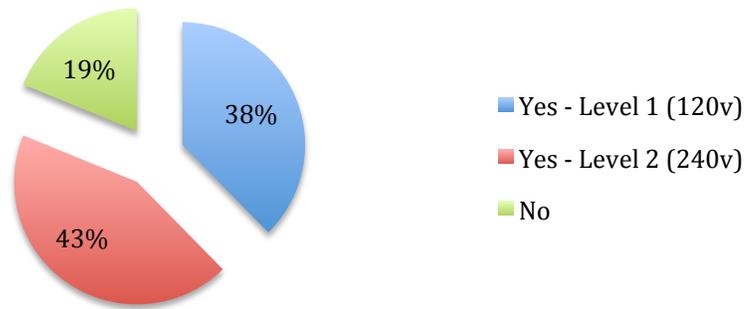


Newer model years (2017 and 2018) were the most represented in the survey, suggesting the survey included relatively new EV drivers (although some vehicles may have been the owner's second EV).

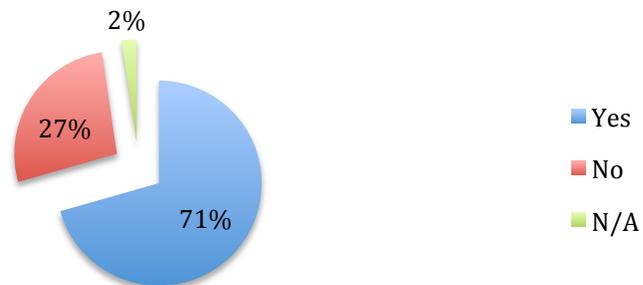


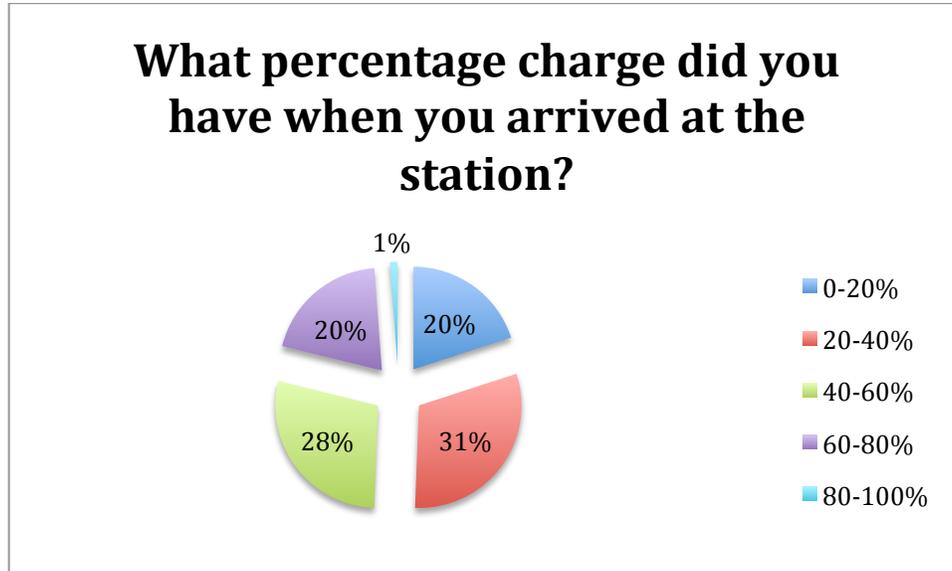
Whether a participant's vehicle has a DC fast charging port is insightful to understand what public stations they are able to access. However, this question also made it apparent that some EV owners lack sufficient knowledge about their EV. Of the 85 surveys, 13% answered that they don't have a DC Fast charging port. Two Chevrolet Volt owners answered, "Yes", however the vehicles do not have fast-charge ports and a Tesla Model X driver owner responded, "I don't know". Therefore, an EV easy owner guide that comes with the vehicle purchase might be very helpful to outline charging options and vehicle capabilities.

Do you have access to charging at home?



Do you have a backup plan for getting a charge if this station is unavailable?



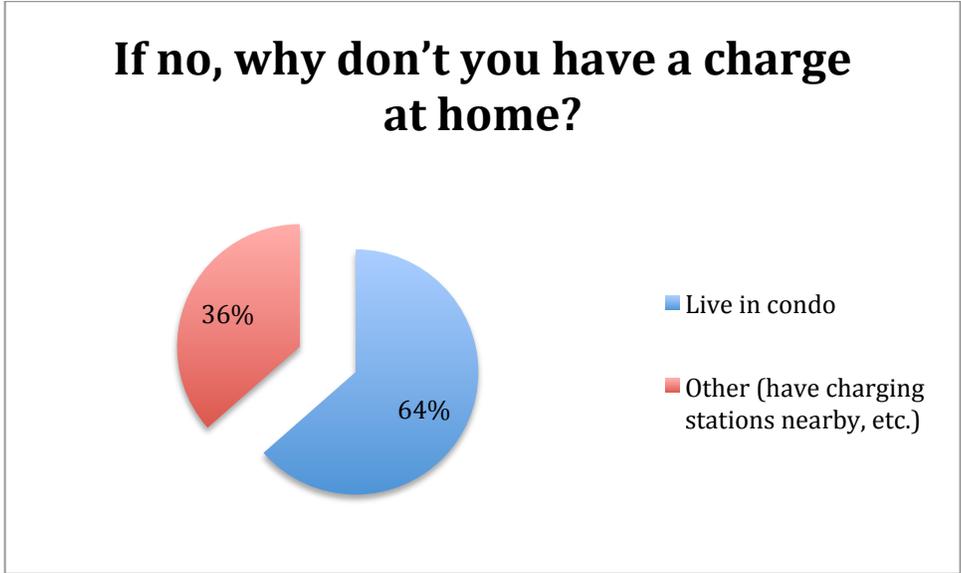


Of the 85 surveys, 19% answered that they don't have access to charging at home. This was higher than expected, an important consideration for charging plans in Metro Vancouver.

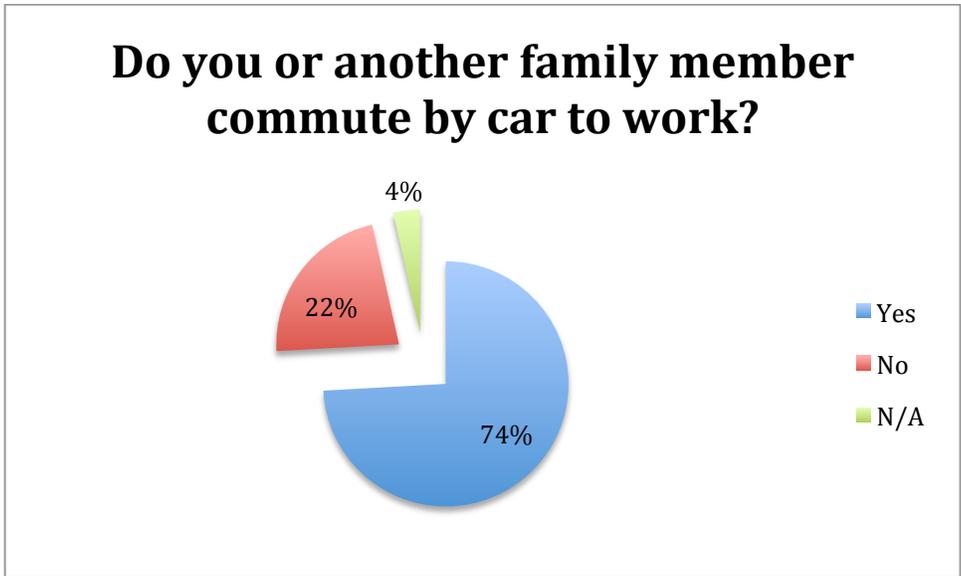
When asked whether drivers had a back-up plan, 15 EV owners answered that their backup plan was their home charger, from which four of these responses had Level 1 (120v), and 11 of them had Level 2 (240v). Additionally, 45 EV owners rely on other nearby public stations as their backup plan.

According to the responses, of the 20% of EV owners that arrived with a percentage charge between 0-20%, 88% didn't have a backup plan.

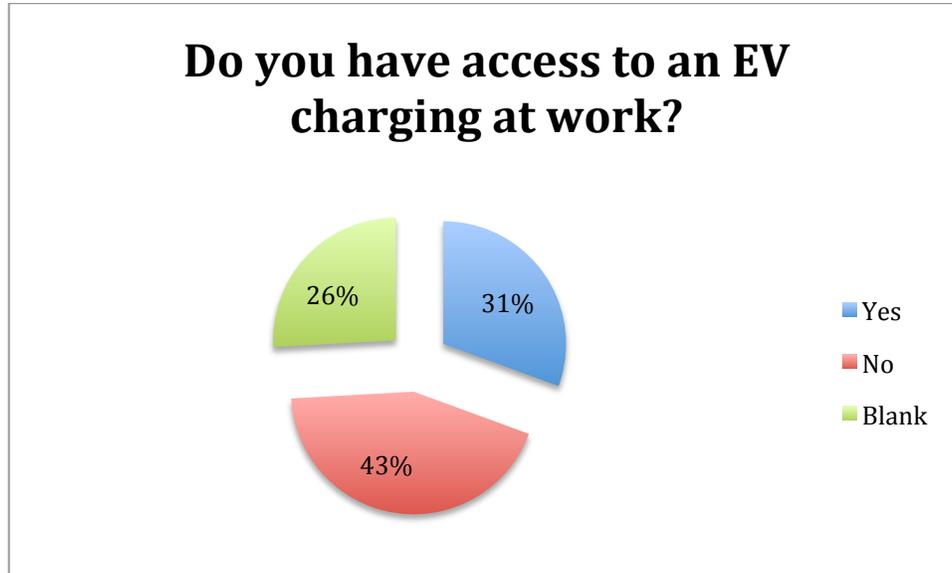
EV owners seem to be using public charging stations mostly because they have an immediate need to charge their EVs, and were relying on the public infrastructure to do so.



Among all the interviewees who don't have a charger at home, 11 of them provided a reason, of which 64% answered that they do not have because they live in a condo. Other responses included that there are public charging stations near their home, or they park their car on the street.

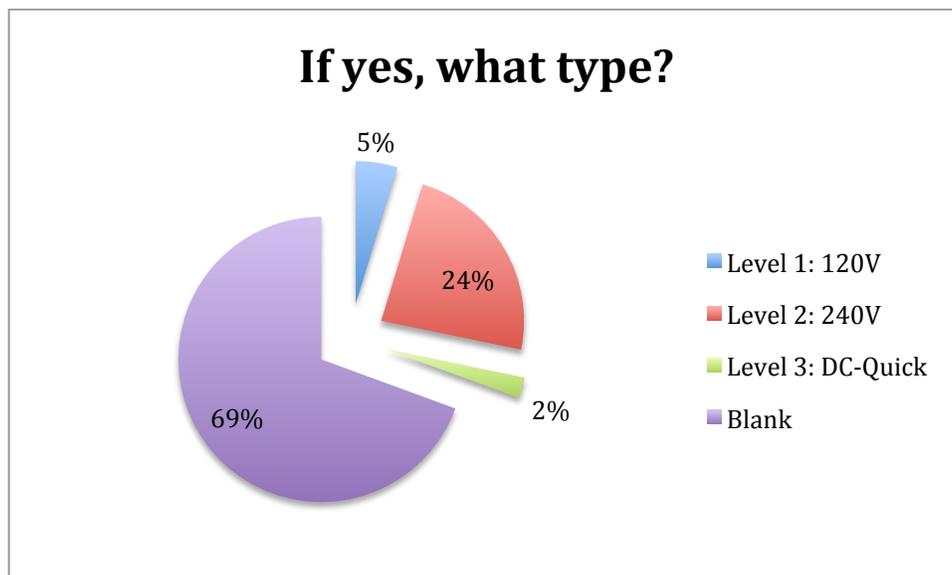


Based on the fact that 74% of the EV owners commute to work, it's possible to conclude that electric vehicles are continually moving around Metro Vancouver, and many are used on a daily basis.

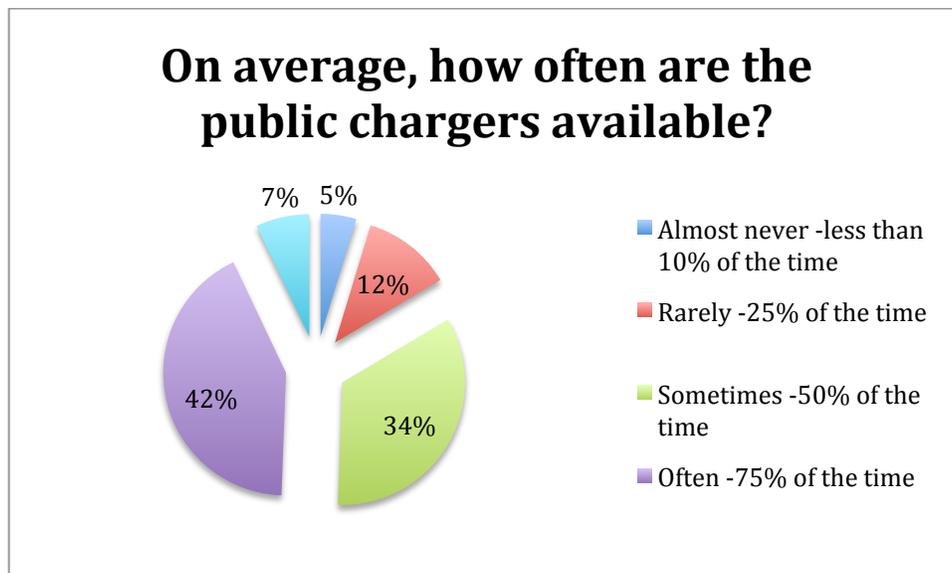
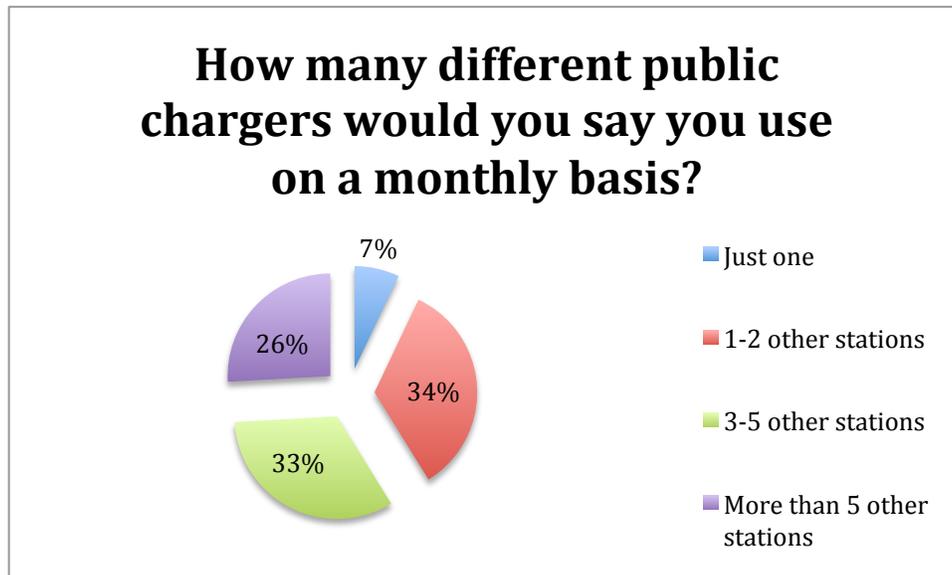


Due to the screening question included (question 7), 26% of the responses were blank, because the EV owners or another family member didn't commute by car to work, which aligns with the previous results (22% "No" and 4% "N/A").

However, for those who do commute, 43% don't have access to workplace charging. It seems like there is an opportunity for workplaces to consider the increasing trend of EV adoption.

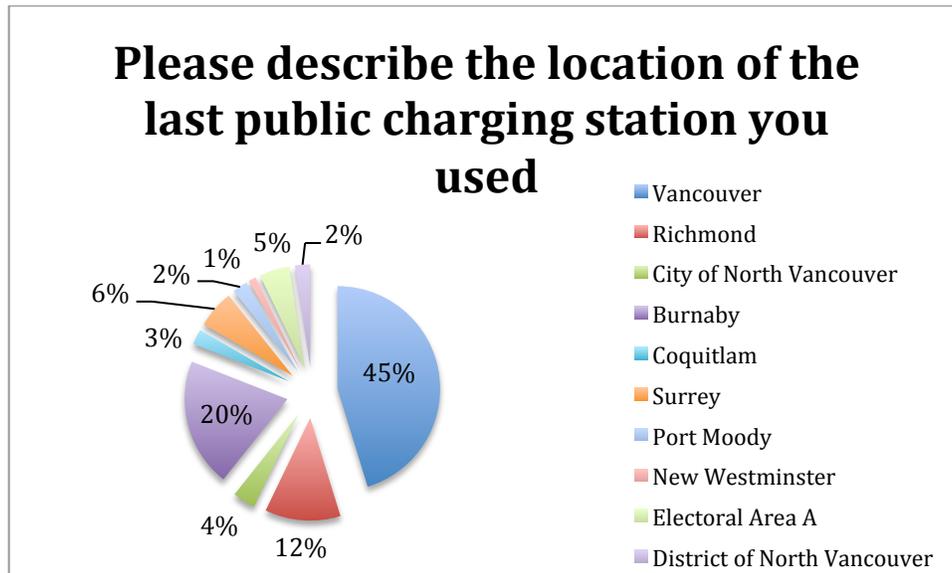


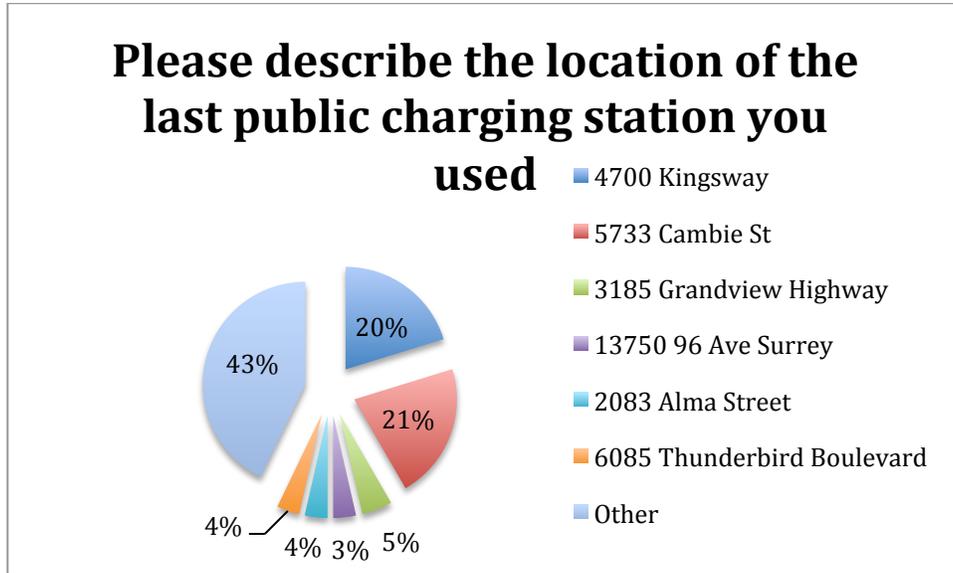
There were 69% blank responses, from which 38% were because of screening question 7 and 62% because, even though, they had charging at work, chose not to answer, indicating that creating an EV easy owner guide could be a great opportunity to make EV owners easier to understand the types of charging stations (ChargePoint, Flo, Greenlots, Sun Country, among others).



According to the survey, EV owners relied on more than one public charging station, with 69% of respondents indicating they use between 2 and 5 different stations in a given month.

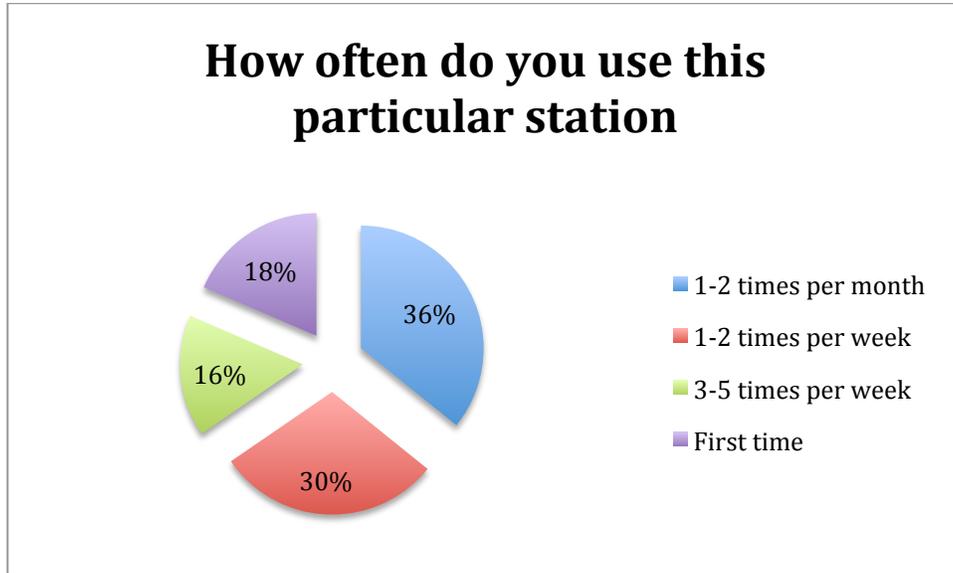
Most people find that public stations are available more than half of the time, with 49% indicating that they're available often or always, which indicates a satisfactory service of public charging stations in Metro Vancouver. However, some people who answered "always" mentioned that's due to the fact that they checked the availability on applications or they knew when the stations are more likely to be available.



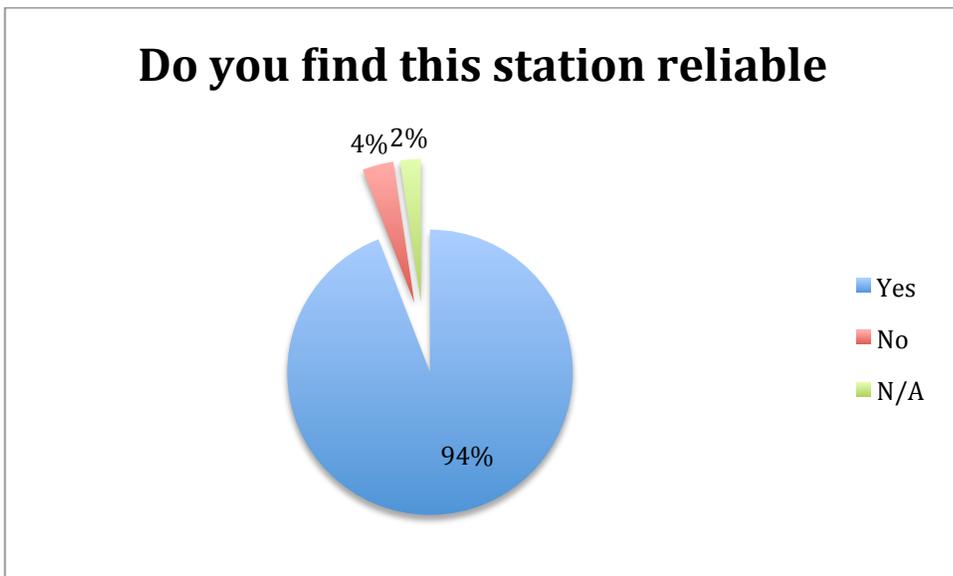


The survey was designed to get an understanding of why EV drivers were using the public charging station at the survey location (in the case of in-person intercept surveys), or the last public station they happened to frequent (in the case of online survey). Half of the surveys conducted took place in the City of Vancouver, which has the highest density of public chargers in Metro Vancouver.

Of the 85 surveys, 22% were done at Oakridge Mall (Vancouver), and 20% of the surveys were done at Metrotown (Burnaby). These two station locations are the most frequently visited public charging stations in Metro Vancouver. While a total of 27 sites were visited, high traffic in these locations allowed the surveyors to intercept more people on those visits.

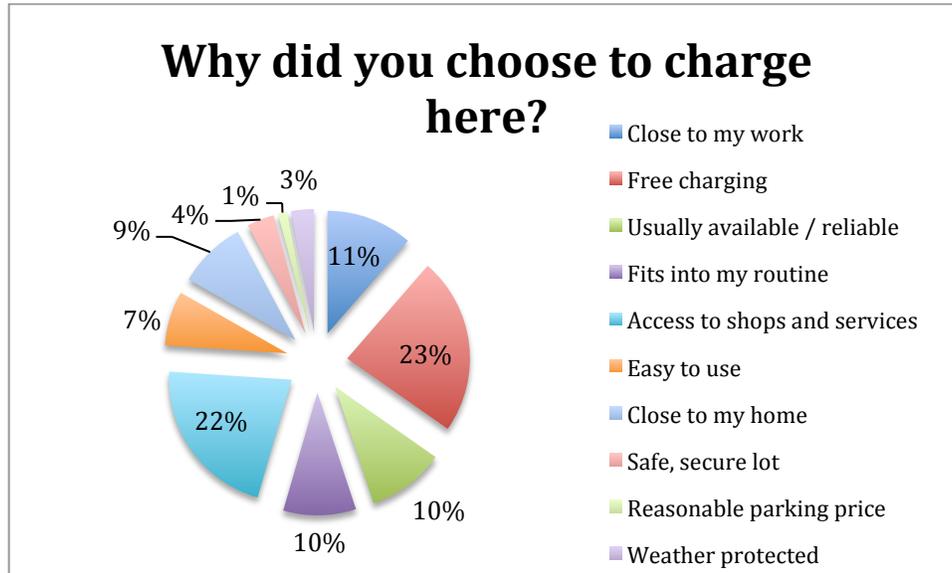


Of the 85 surveys, 35% of them use the surveyed station 1-2 times per month, and 27% of them use 1-2 times per week, indicating that most of them don't use the surveyed public charging stations very often, or as their primary charge.

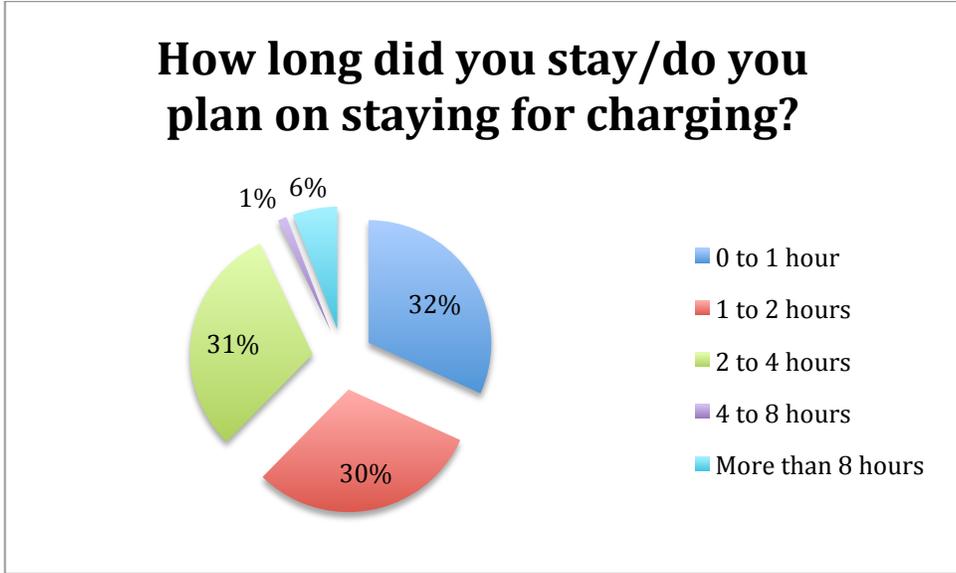


The three EV owners who answered "No" to this question, were referring to Metrotown (Burnaby), 1st Street East, between Lonsdale and St. Georges (North Vancouver) and Thunderbird Parkade (Vancouver). For the first case, the reasons include that there are not enough charging stations, EVs park without charging, or

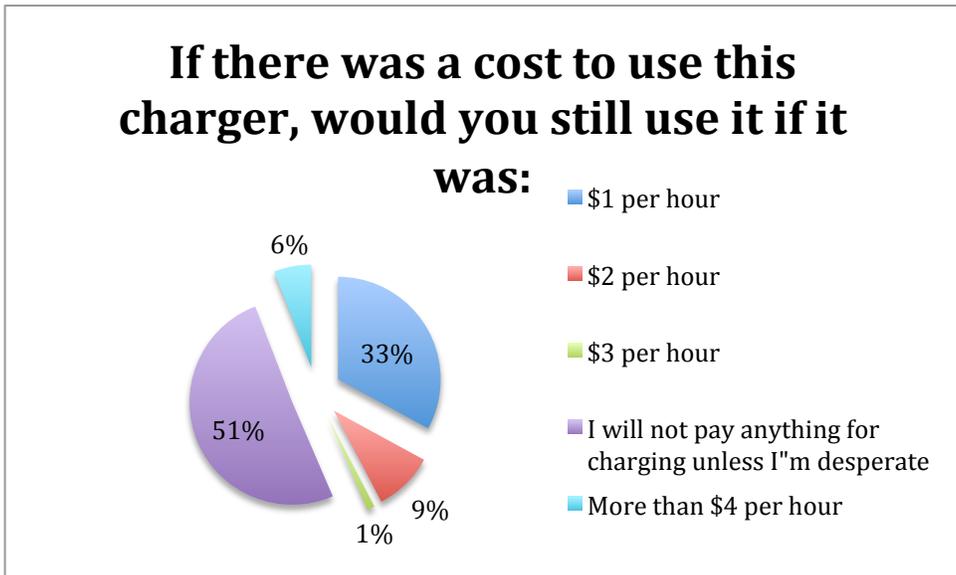
non-electric vehicles take the spot. For the second case, the station is constantly in use, probably because it is a Level 3 DC- fast charger. The last case is that there are not enough chargers for demand, and often cars aren't moved away from EV parking once charging is complete.



The most popular reasons to charge are “free charging” (23%) and “access to shops and services” (22%). Other popular answers are “close to work/home”, “usually available/reliable”, and “fits into my routine”. Most people who answered “fits into my routine” also indicated that the stations are close to their work/home.



A large portion of EV owners choose to charge for under 4 hours: 0-1 hour (32%), 1-2 hours (30%) or 2-4 hours (31%), which means that they do not need the station for the whole day or long periods of time. However, during the in-person survey, a couple of them mentioned that some owners do not move their vehicle away when their vehicles are fully charged.



More than half of the interviewees would not be willing to pay for charging (at the station in question) unless they were desperate. 33% of respondents were willing to pay \$1 per hour but very few more than this. This may be due to the fact that there

are currently many free options. If free charging alternatives didn't exist, the result might be different.

For the question, "Has the fact that this location provides EV charging changed your travel or shopping habits?" 62.4% (53/85) of the interviewees responded that public EV charging does change their travel or shopping habits. 37.6% (32/85) answered no. Among those who answered no, 23 people provided a specific reason.

When they were asked, "Please elaborate why or why not", over half of those who responded yes (22/43) mentioned an increase in shopping behaviour. Keywords include a shop, shopping, grocery, store, and retail.

For those who answered no and elaborated, 14 of them indicated the charger fit into their routine: close to their home/ where their family lives/ on the way to somewhere. 3 said there's no shopping nearby.

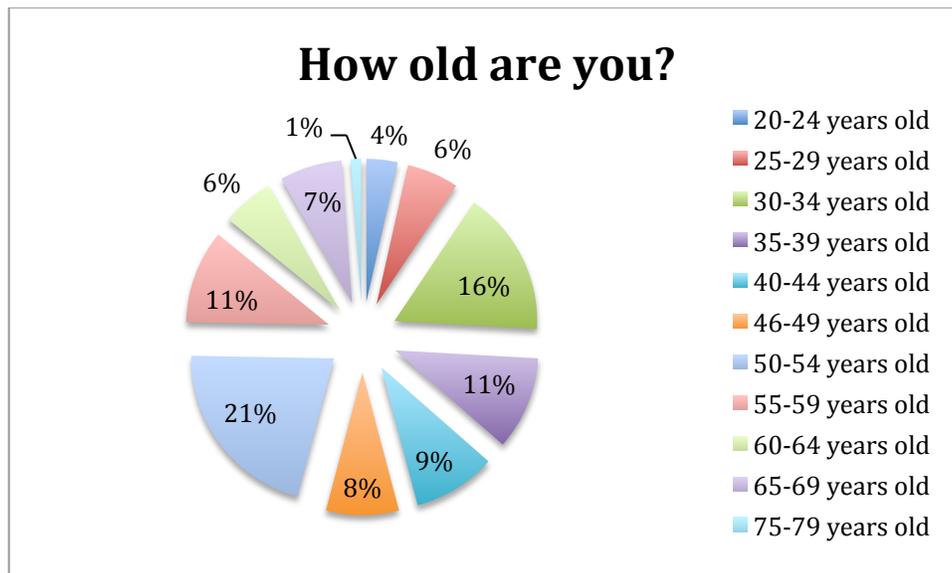


Figure 2 Some of the responses regarding the shop and shopping

In the case of the question “What changes or improvements would you like to see for public chargers in Metro Vancouver?” 88.1% (74/84) commented that they want to see more stations in general and 13.1% (11/84) mentioned more fast-charging stations.

For the question “Do you have additional comments that you would like to share?” additional comments were mostly related to improvements for public chargers in Metro Vancouver. For example, to have more public charging stations as well as DC fast-charging stations, to have lower rates for charging, and to have uniformed charging station availability information available to the public, to encourage customers to leave the spot when they don't need charge, to provide more incentives, to reduce the time it takes to maintain charging stations.

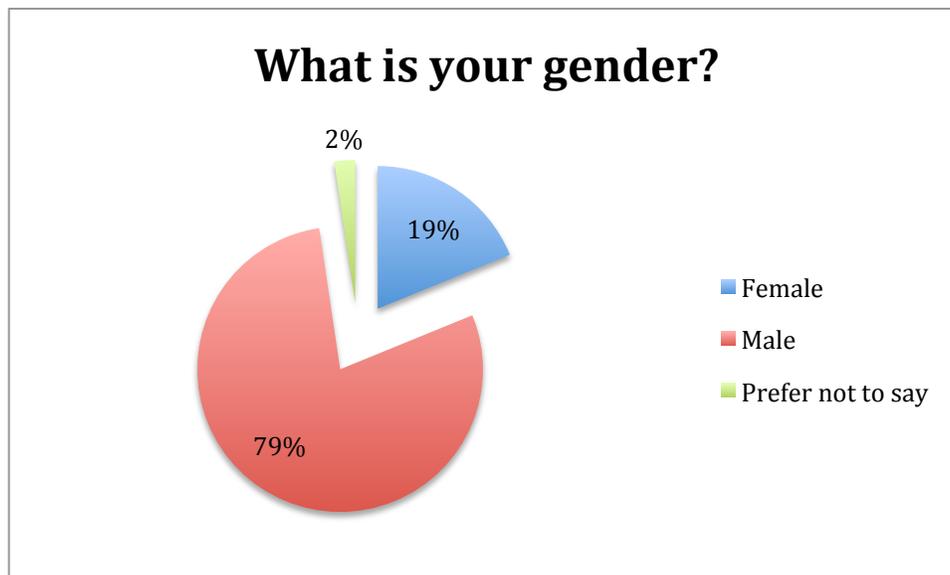
Finally, for the demographic data, the analysis was performed to understand how our audience, electric vehicles owners, differ from average British Columbians and Canadians.



There were more options that are not shown in this figure: 15-19 years old, 70-74 years old, 80-84 years old, 85-89 years old and, 90 and older. Because there are no interviewees from these age ranges, they are not displayed.

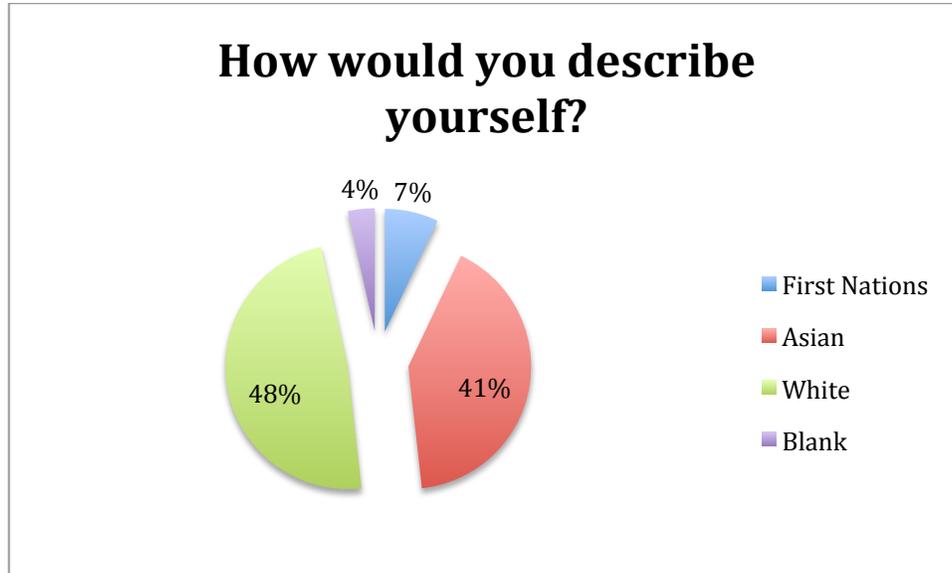
The age range of EV owners that was more representative was between 50 and 59 years old with 32%, followed by the range between 30 and 39 years old (27%). It seems to be a good strategy for automakers to set those as target age groups for potential EV owners to increase EV adoption in Metro Vancouver.

Additionally, it's important to add that both of these age ranges represent 14% of the 2017 Canada's population, as well as British Columbia's⁵.



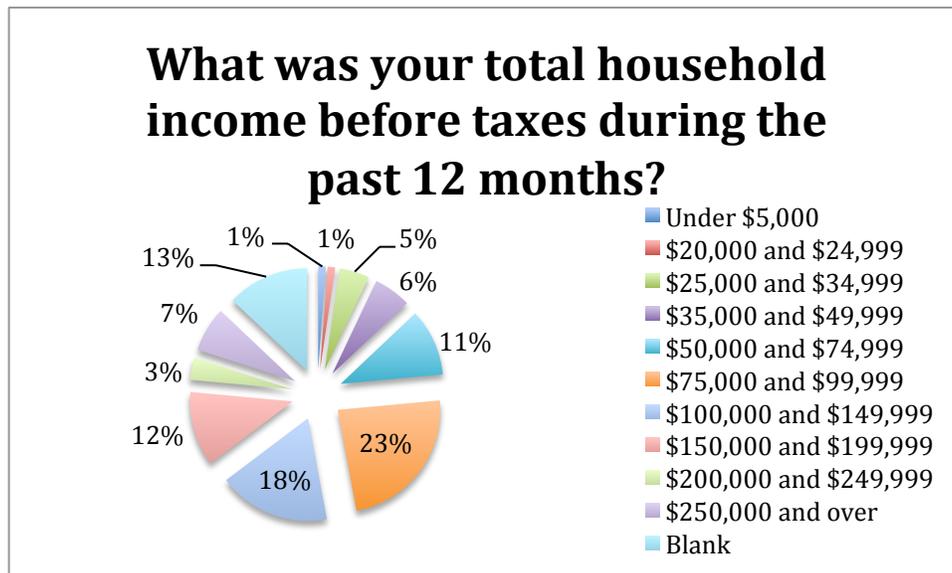
Of the 85 surveys, 79% of our interviewees were male.

⁵ <https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1710000501>
<https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1710000501&pickMembers%5B0%5D=1.11&pickMembers%5B1%5D=2.1>



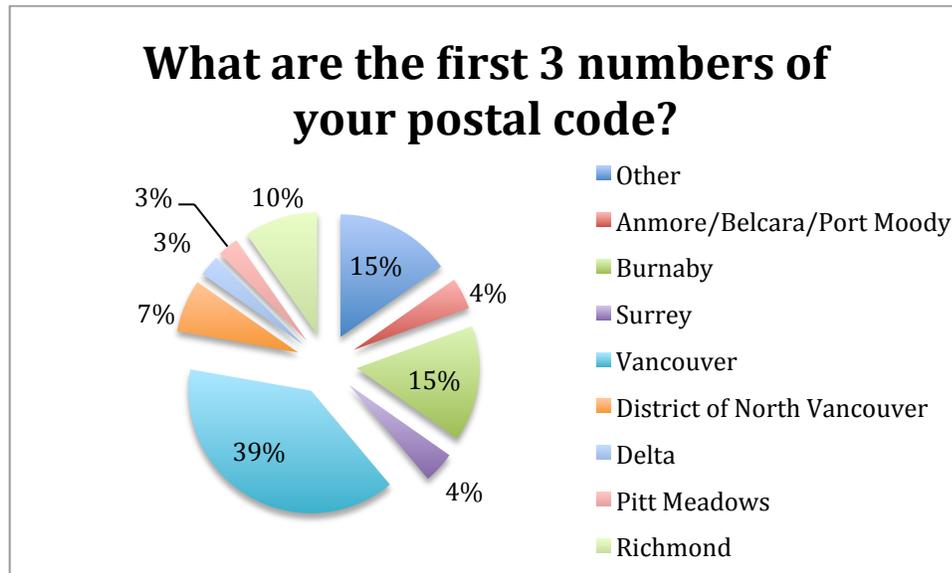
The two most representative racial groups in the EV owners interviewed were White and Asian. Only 4% didn't answer.

According to the 2016 Census, British Columbia population origins are 51% European, Asian 23%, and Other American 17%⁶.



⁶ <https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/details/page.cfm?Lang=E&Geo1=CMACA&Code1=933&Geo2=PR&Code2=59&Data=Count&SearchText=Vancouver&SearchType=Beginns&SearchPR=01&B1=Ethnic%20origin&TABID=1>

Of the 85 surveys, 87% answered, although, due to the sensitive nature of this final question, some interviewees during the in-person survey didn't feel comfortable providing a response.



Over one-third of the interviewees live in the City of Vancouver, followed by Burnaby and Richmond. This result complies with the surveyed locations. However, the responses suggest that some respondents live in interior BC and Vancouver Island and were visiting Metro Vancouver in their electric vehicles when they took this survey.

Discussions

Based on the survey data, some additional questions came up, which explored below.

1. Home Charger

Public Chargers Used Monthly	Percentage (Have Charging at Home)	Percentage (Have No Charging at Home)
Just one	6%	13%
1-2 other stations	35%	31%
3-5 other stations	32%	38%
More than 5 other stations	28%	19%

Table 1 Percentage of the number of public chargers used monthly for EV owners who have charging access at home and who don't.

The table shows that a larger portion of EV owners who have a charger at home use more than 5 public charging stations per month compared to those who do not have charging access at home. A smaller portion of EV owners who have a charger at home use just one public charging station per month compared to those who do not have charging access at home. The sample size of drivers who don't have charging at home was fairly small (16 drivers) compared with those who do (69 drivers), so it's hard to infer what these numbers might tell us.

2. EV owners knowledge

Among the 85 responses, 5 of them do not even know if their vehicles have DC fast charging port. However, if an electric vehicle is equipped with the fast charging port, the charging time can be cut by half with fast charging compared to level 2 charging.

3. Charging behaviour

Venue Type	0-20%	20-40%	40-60%	60-80%	80-100%
Retail	22.9%	29.2%	25.0%	22.9%	0.0%

Parking Lot/Garage	25.0%	37.5%	25.0%	12.5%	0.0%
Government	50.0%	16.7%	33.3%	0.0%	0.0%
Education	0.0%	60.0%	20.0%	20.0%	0.0%
Business/Commercial	0.0%	0.0%	80.0%	20.0%	0.0%
Leisure Destination	20.0%	40.0%	40.0%	0.0%	0.0%

Table 2 Venue type vs. State of charge upon arrival

There is no meaningful conclusion drawn from the data analysis.

No interviewee charged their vehicle when they had a 80-100% charge, which indicates that they had adapted good charging etiquette without using public charging stations when they do not actually need them.

However, around 40% of interviewees use charging stations when they had a 40-80% charge, in which case the owners don't necessarily need the charge.

Workplace, street parking, medical, and library locations are excluded because of the limited number of survey collected at those stations.

Venue Type	Have Home Charging
Retail	81.3%
Parking Lot/Garage	75.0%
Government	100.0%
Education	80.0%
Business/Commercial	60.0%
Leisure Destination	80.0%

Table 3 Venue types vs. Have some charging or not

According to the table, business/commercial has the lowest percentage of visitors who have home charging. However, all the EV owners surveyed at government locations have home charging (interestingly, this category had the highest number of drivers below 20% state of charge, which could mean they are driving further distances). It will be interesting to find out if these stations are less reliable or

available. Workplace, street parking, medical, and library locations are excluded because of the limited number of survey collected at those stations.

Venue Type	Backup Plan
Retail	62.5%
Parking Lot/Garage	87.5%
Government	100.0%
Education	80.0%
Business/Commercial	100.0%
Leisure Destination	100.0%

Table 4 Venue type vs. backup plan for public charging

All the EV owners surveyed at a government, business/commercial, and leisure destination locations have backup plans for public charging, from which government also has the highest percentage of customers who have a charger at home. That may also indicate low availability at those stations. Workplace, street parking, medical, and library locations are excluded because of the limited number of survey collected at those stations.

4. Shopping behaviour

Of the 85 surveys, 28 out of 48 (58.3%) interviewees at retail charging stations believed that use of that station changed their behaviour. 24 of them provided explanations, with 13 saying the station increased their patronization of the business in that location. 27% of the EV owners who visited retail locations for charging brought new business.

Based on the result and previous analysis in the data analysis section, it can be concluded that having charging significantly changed people's behaviour.

Venue Type	Total	Behaviour Changed	Percentage
Retail	48	28	58.3%
Parking Lot/Garage	8	6	75.0%
Government	6	6	100.0%
Education	5	4	80.0%
Business/Commercial	5	4	80.0%
Leisure Destination	5	1	20.0%

Table 5 Behaviour shift associated with the charger venue type

According to the table, it is interesting to find that all EV owners who charge at government stations have changed their behaviour. This conclusion might be caused by small sample size. Retail, parking lot/garage, education and business/commercial locations have also seen a large shift in behaviour. However, leisure destination locations have seen little shift in behaviour.

5. Willing to pay for public charging

According to the previous table, business/commercial locations have the highest percentage of people who didn't have access to home charging.

Have home charging	Would pay for charging	Would pay more than \$4 per hour
Yes	69.6%	2.9%
No	62.5%	12.5%

Table 6 Having home charging or not vs. would you like to pay for charging

Based on table 6, there is no clear trend showing that people who do not have home charging are more willing to pay for charging in general, but of those who would be willing to pay, there is a much higher percentage of those who would pay more than \$4 per hour compared to those who have home charging.

6. The link between owners' EV range and state of charge upon arrival

Charge upon arrival	Won't Pay unless Desperate	\$1 per hour	\$2 per hour	\$3 per hour	More than \$4 per hour
0-20%	41.2%	29.4%	17.6%	0.0%	11.8%
20-40%	46.2%	34.6%	15.4%	0.0%	3.8%
40-60%	54.2%	33.3%	4.2%	4.2%	4.2%
60-80%	58.8%	35.3%	0.0%	0.0%	5.9%
80-100%	100.0%	0.0%	0.0%	0.0%	0.0%

Table 7 Charge upon arrival at charging station vs. the willingness to pay for charging

According to table 7, there is a clear trend showing that there is an increasing percentage of people who would not like to pay for charging when they arrive at the charging station with a higher state of charge, and there is also a clear trend that people are more willing to pay more when they arrive at the station with less charge, which could be associated with their charging habits: some EV owners would not like to recharge unless they are running out of charge, while some EV owners are more conservative and charge when they can.

EV Type\state of charge	0-20%	20-40%	40-60%	60-80%	80-100%
PHEV	37.5%	18.8%	12.5%	25.0%	6.3%
BEV	16.2%	33.8%	30.9%	19.1%	0.0%

Table 8 State of charge vs. EV type

People who have a PHEV tend to charge at low battery compared to those who own a BEV, which might be due to the fact that PHEV can still run on fossil fuels when it is running out of electricity.

EV range (Km)	0-20%	20-40%	40-60%	60-80%	80-100%
51-100	17.9%	32.1%	32.1%	17.9%	0.0%

101-150	8.3%	50.0%	25.0%	16.7%	0.0%
151-200	0.0%	50.0%	50.0%	0.0%	0.0%
201-250	16.7%	0.0%	33.3%	50.0%	0.0%
251-300	20.0%	40.0%	40.0%	0.0%	0.0%
301-350	25.0%	75.0%	0.0%	0.0%	0.0%

Table 9 EV range and owners charging behaviour (state of charge upon arrival)

There is a weak trend indicating that owners who have larger EV range prefer to charge when the battery is low, and owners who have low EV range are more likely to charge when their battery is still high.

7. Stations demographics

There is no remarkable difference in demographics at any venue type.

Income\ Home Charging	Yes	No
Under \$5,000	0.0%	7.7%
\$5,000 and \$9,999	0.0%	0.0%
\$10,000 and \$14,999	0.0%	0.0%
\$15,000 and \$19,999	0.0%	0.0%
\$20,000 and \$24,999	1.6%	0.0%
\$25,000 and \$34,999	3.3%	15.4%
\$35,000 and \$49,999	4.9%	15.4%
\$50,000 and \$74,999	14.8%	0.0%
\$75,000 and \$99,999	24.6%	38.5%
\$100,000 and \$149,999	21.3%	15.4%
\$150,000 and \$199,999	16.4%	0.0%
\$200,000 and \$249,999	4.9%	0.0%
\$250,000 and over	8.2%	7.7%

Table 10 Home charging and income

There is no clear indication that people who have a charger at home have a higher income than those who do not. However, there is a greater portion of EV owners who have a charger at home earn a higher income (over \$100,000/year) compared to those who do not have.

Home Charging	Yes	No
20-24 years old	2.9%	6.3%
25-29 years old	4.3%	12.5%
30-34 years old	17.4%	12.5%
35-39 years old	11.6%	6.3%
40-44 years old	8.7%	12.5%
45-49 years old	10.1%	0.0%
50-54 years old	20.3%	25.0%
55-59 years old	8.7%	18.8%
60-64 years old	7.2%	0.0%
65-69 years old	7.2%	6.3%
70-79 years old	0.0%	0.0%
75-79 years old	1.4%	0.0%

Table 11 Home charging and age

According to the table above, it shows a weak trend that young people (<30 years old) tend to not have a charger at home, while people who are older (>60 years old) prefer to have home charging.

Limitations

- There are 23 member municipalities/electoral areas members located in Metro Vancouver Regional District, and 19 of them provide public electric vehicle charging stations. In the survey, only 10 regions are covered. A portion of the surveys was conducted online, and thus the authenticity of the information gathered cannot be guaranteed.

- This survey only focused on a limited number of charging stations and most were done near the shopping mall because those stations are most frequently visited, which might create bias. Future research should include more street parking and workplace locations, or lower frequented stations to provide comparison across a wider variety of public charging types and locations.
- In survey question 9: *“On average, how often are the public chargers available on your first attempt?”* some of them answered always due to the reason that they checked the availability on applications or they knew when the stations are more likely to be free.
- 85 survey responses are reasonable but not a large enough sample size considering there are currently over 3,000 electric vehicles in the Metro Vancouver region. As a consequence, the result might not be really representative of the entire region.

Future Considerations

- The charging station selection should be based on the different platforms that exist, such as Charge Point, Flo, and others; that mention if the charger is being used and the popular times. It is more effective to conduct surveys on sites where there are more charging ports and a venue type such as retail, due to the higher visitors' flow rate, unlike medical type.
- At the beginning of the in-person survey, a brief introduction explaining that the students are working for Plug In BC / Fraser Basin Council should be given to interviewees so that the interviewees will be more comfortable giving their answers because they will make a difference on the EV charging infrastructure.

- The survey should have fewer numbers of questions because the interviewees don't usually have more than 3 to 5 minutes to answer it.
- The open-ended questions, where the interviewees should describe even more of their answers, should be evaluated because there were not commonly answered.
- It's very important to take into account that surveys are more feasible when people arrive to charge compared to when they leave charging stations because when they are ready to go, the time that they have is reduced.
- Having a pamphlet/flyer designed to be placed on the windshield of those vehicles that were charging resulted to be effective. Some passionate EV owners that received it did the survey in their own time and greatly contributed to the 85 responses collected.
- Is also important to take into account that the following questions should be evaluated so that the answers will be easier to analyze and to understand even better what the EV owner meant. Some suggestions on survey questions for future consideration include:
 - *How many different public chargers would you say you use on a monthly basis?*
It will be better to modify this question by replacing monthly basis with weekly basis.
 - *Please describe the location of the last public charging station you used in Metro Vancouver? (Please provide address and/or detailed description)*

This question should be more specific for the in-person method, so that the interviewee would be able to indicate, exactly, at which charging station they received the flyer.

This will facilitate the identification of the effectiveness of the flyers.

- *Why did you choose to charge here? (Please check all the answers that apply)*

This question should be more specific. It was not very conclusive, because when the interviewee saw that many options, there were not very sure which 3 options to select.

- *If there was a cost to use this charger, would you still use it if it was:*

This question should be asked in a different way, such as a multiple choice, in the following way

“How much are you willing to pay to use this charger”

- \$1 per hour
- \$2 per hour
- \$3 per hour
- Other
- I will not pay anything extra for charging

- *What was your total household income before taxes during the past 12 months?*

This question should be modified to find out the total household income before tax during the last month to make it easier for the interviewee.

Additionally, it has to be taken into account that not everybody feels comfortable choosing the accurate option.

Conclusions

- Due to the limitations of this survey, the results provide some high-level insight to why people are using public charging stations, but no definitive conclusion should be made. It is the researchers' hope that these insights might generate additional questions to consider for future research and analysis, to better understand the relationship between EV drivers and public charging stations.
- In general EV owners agreed on the urgent need for more chargers, especially DC Fast charging that will be accessed freely at a different time. EV owners will like to find more chargers in the streets and to take less time during their charging time. Making these changes will increase EV adoption as well as customer satisfaction.
- There should be more enforcement for those owners that leave their vehicles at the station without requiring a charge. While this happens other electric vehicles that don't have enough charge are not able to use the station. The enforcement of a specific control will increase the number of cars charging at a specific station.
- The development of an EV User Guide seems to be an opportunity for those owners that don't know or are not sure of their charging possibilities (Level 1, Level 2, DC-fast charger). This Guide will facilitate the owners' understanding of their vehicle and will generate a viral marketing that will increase EV adoption and facilitate the charging process.
- There is a constant request to quickly deal with maintenance inconvenient for charging stations. When it is required, it causes a decrease in the chargers availability (e.g. Metrotown). This quickness will augment the chargers offer and the satisfaction and reputation towards the hosts' organizations.

Appendix A

Battery-electric vehicles

Make Model	Fuel type	Range (km)	Recharge time (h)
Specifications			
BMW i3			
S, 125 kW, A1	B	183	5
CHEVROLET BOLT EV			
WS, 150 kW, A1	B	383	9.3
FORD FOCUS ELECTRIC			
C, 107 kW, A1	B	185	5.5
HYUNDAI IONIQ EV			
M, 88 kW, A1	B	200	4
KIA SOUL EV			
WS, 81 kW, A1	B	179	5
NISSAN LEAF			
M, 110 kW, A1	B	242	8
TESLA MODEL 3 Long Range, AWD, AWD Performance			
M, 192 kW, 358 kW, A1	B	499	10
TESLA MODEL S 100D			
L, 386 kW, A1	B	539	12
TESLA MODEL X 100D			
UL, 386 kW, A1	B	475	12
VOLKSWAGEN e-GOLF			
C, 100 kW, A1	B	201	5.3

Table 12 Fuel consumption ratings BEVs

Plug-in hybrid vehicles

Make Model	Fuel type	Range (km)	Recharge time (h)
Specifications			
BMW 330e			
C, 65 kW, 2.0 L, 4 cyl, AS8	B/Z	23	2
BMW i3 Rex			
S, 125 kW, 135 kW, 0.6 L, 2 cyl, A1	B/Z	156	5
BMW X5 xDRIVE40e			
UL, 83 kW, 2.0 L, 4 cyl, AS8	B/Z	23	3
CHEVROLET VOLT			
C, 111 kW, 1.5 L, 4 cyl, AV	B/X	85	4.5
FORD FUSION ENERGI			
M, 68 kW, 2.0 L, 4 cyl, AV	B/X	35	2.5
KARMA REVERO			
S, 300 kW, 2.0 L, 4 cyl, A1	B/Z	60	3.75
KIA OPTIMA PLUG-IN			
M, 50 kW, 2.0 L, 4 cyl, AM6	B/X	47	2.7
HYUNDAI IONIQ ELECTRIC PLUS			
M, 32 kW, 1.6 L, 4 cyl, AM6	B/X	47	2.3
MITSUBISHI OUTLANDER PHEV AWD			
US, 60 kW, 2.0 L, 4 cyl, A1	B/X	35	3.5
TOYOTA PRIUS PRIME			
M, 71 kW, 1.8 L, 4 cyl, AV	B/X	40	2

Table 13 Fuel consumption ratings PHEVs

- Fuel type: X = Regular gasoline; Z = Premium gasoline; D = Diesel; E = E85; B = Electricity; N = Natural Gas.

- Range: For PHEVs and battery-electric vehicles (BEVs), the range is the estimated driving distance (in kilometers) on a fully charged battery or a full tank of fuel.
- Recharge time: For PHEVs and BEVs, recharge time is the estimated time (in hours) to fully recharge the battery at 240 volts.

Appendix B

Survey

a) Introduction

EVs make a continued difference! We are UBC Students conducting a survey on behalf of Plug In BC (an initiative that includes the Fraser Basin Council and Metro Vancouver). We would like to know more about your EV experience and how public charging stations are related to EV adoption to help non-profits and government better respond to current and future needs of EV owners. Additionally, we want to use the results to identify, what opportunities there are to encourage and engage even more current and potential EV owners.

Any information that you contribute through this survey will be anonymized in the final results to protect your privacy. If you have any additional questions about how this data will be used by UBC or its partners, please feel free to contact Karen Taylor, Program Manager of the UBC Sustainability Scholars Program, UBC (karen.taylor@ubc.ca) or Charlotte Argue, Program Manager, Plug In BC, Fraser Basin Council (cargue@pluginbc.ca).

Questionnaire UBC-FBC-MVC-001

b) Main body

▪ **Ownership knowledge**

Type: Open-ended

1) What make is your vehicle (e.g. Nissan)?

Type: Open-ended

2) What model is your vehicle (e.g. Leaf)?

Type: Open-ended

3) What year is your EV?

Type: Closed-ended - Selection among nominal categories

4) Does your EV have a DC Fast charging port (e.g. can you charge at fast charging stations or Superchargers?)

- Yes
- No
- I don't know

Type: Closed-ended - Selection among nominal categories

5) Do you have access to charging at home

- Yes - Level 1: 120V
- Yes - Level 2: 240V
- No

Type: Open-ended

a. If no, why don't you have a charge at home?

(E.g. Live in a condo, can't afford, no power, don't need one, etc.)

Type: Closed-ended - Selection among nominal categories

6) Do you or another family member commute by car to work?

- Yes
- No
- N/A

If the interviewer doesn't work or commute by car, skip questioning No. 8.

Type: Closed-ended - Selection among nominal categories

7) Do you have access to an EV charging at work?

- Yes
- No

b. If yes, what type?

- Level 1: 120V
- Level 2: 240V
- Level 3: DC-Quick

▪ **Charging Station Use**

Type: Closed-ended – Selection among ordinal categories

8) How many different public chargers would you say you use on a monthly basis?

- Just one
- 1-2 other stations
- 3-5 other stations
- More than 5 other stations

Type: Closed-ended – Selection among ordinal categories

9) On average, how often are the public chargers available (on your first attempt)?

- Always ~100% of the time
- Often ~75% of the time
- Sometimes ~50% of the time
- Rarely ~25% of the time
- Almost Never ~less than 10% of the time

Type: Open-ended

10) Please describe the location of the last public charging station you used in Metro Vancouver? (Please provide address and/or detailed description)

Type: Closed-ended – Selection among ordinal categories

11) How often do you use this particular station?

- On a daily basis
- 3-5 times per week
- 1-2 times per week
- 1-2 times per month
- First time

Type: Closed-ended – Selection among nominal categories and Open-ended

12) Do you find this station reliable?

- Yes
- No (please describe)
- N/A (please describe)

Type: Closed-ended – Selection among nominal categories and Open-ended

13) Do you have a backup plan for getting a charge if this station is unavailable?

- Yes (please describe)
- No
- Other

Type: Closed-ended – Selection among ordinal categories

14) What percentage charge did you have when you arrived at the station?

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

▪ **Trip behaviour in Metro Vancouver**

Type: Closed-ended – Checklist

15) Why did you choose to charge here? (Please check all the answers that apply)

- Access to shops and services
- Usually available/reliable
- Weather protected
- Easy to use / low barrier to access
- Safe, secure lot
- Reasonable parking price
- Free charging
- Fits into my routine
- Close to my home
- Close to my work

Type: Closed-ended - Selection among ordinal categories

16) How long did you stay/do you plan on staying for charging?

- 0 to 1 hour

- 1 to 2 hours
- 2 to 4 hours
- 4 to 8 hours
- More than 8 hours

Type: Closed-ended - Selection among ordinal categories

17) If there was a cost to use this charger, would you still use it if it was:

- \$1 per hour
- \$2 per hour
- \$3 per hour
- More than \$4 per hour
- I will not pay anything extra for charging

Type: Closed-ended - Selection among nominal categories

18) Has the fact that this location provides EV charging changed your travel or shopping habits?

- Yes
- No

Type: Open-ended

19) Please elaborate why or why not

Type: Open-ended

20) What changes or improvements would you like to see for public chargers in Metro Vancouver?

Type: Open-ended

21) Do you have additional comments that you will like to share?

▪ Demographic data

Type: Closed-ended - Selection among ordinal categories

22)How old are you?

- 15-19 years old
- 20-24 years old
- 25-29 years old
- 30-34 years old
- 35-39 years old
- 40-44 years old
- 46-49 years old
- 50-54 years old
- 55-59 years old
- 60-64 years old
- 65-69 years old
- 70-74 years old
- 75-79 years old
- 80-84 years old
- 85-89 years old
- 90 and older

Type: Closed-ended - Selection among nominal categories

23)What is your gender?

- Female
- Male
- Other
- Prefer not to say

Type: Closed-ended - Selection among ordinal categories

24) How would you describe yourself? (Choose one or more from the following racial groups)

- First Nation
(A person having origins in any of the original peoples of North and South America (including Central America), and who maintains a tribal affiliation or community attachment.)
- Asian
(A person having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent including, for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam.)
- Black or African Canadian
(A person having origins in any of the Black racial groups of Africa – includes Caribbean Islanders and other of African origin.)
- Native Hawaiian or Other Pacific Islander
(A person having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific Islands.)
- White
(A person having origins in any of the original peoples of Europe, the Middle East, or North Africa.)
- Other

Type: Closed-ended - Selection among ordinal categories

25) What was your total household income before taxes during the past 12 months?

- Under \$5,000
- \$5,000 and \$9,999
- \$10,000 and \$14,999
- \$15,000 and \$19,999
- \$20,000 and \$24,999
- \$25,000 and \$34,999

- \$35,000 and \$49,999
- \$50,000 and \$74,999
- \$75,000 and \$99,999
- \$100,000 and \$149,999
- \$150,000 and \$199,999
- \$200,000 and \$249,999
- \$250,000 and over

Type: Open-ended

26) What are the first 3 numbers of your postal code?

- **Thank you for your time and effort.**

Charging Stations

For the following addresses, we have identified what type of charging station there were using the following legend:

- **Level 1 (120 V)**
 - **Level 2 (240 V)**
 - **Level 3 (DC Quick) (CHAdeMO and CCS)**
 - **Level 3 (DC Quick) (Tesla)**
-
- **Burnaby**
 - Retail:
 1. 4700 Kingsway, Burnaby, BC V5H 4M1, Canada

 - **North Vancouver**
 - Street Parking:
 2. 140 1st St. E. North Vancouver, BC V7L 1B1, Canada

3. Civic Place Mews, North Vancouver, BC V7M 1P2, Canada

Business/Commercial:

4. 2300 Lonsdale Ave., North Vancouver, BC V7M 3L1, Canada

Medical:

5. 231 15th St. E., North Vancouver, BC V7L 2L7, Canada

▪ **Richmond**

Business/Commercial:

6. 3320 Jacombs Road, Richmond, BC V6V 1Z6 Canada

7. 9251 Alderbridge Way, Richmond, BC V6X 2K5, Canada

8. 7008 No 3 Rd, Richmond, BC V6Y 2C6, Canada

Street Parking:

9. 13091 Vanier Pl, Richmond BC V6V 2J1, Canada

10. 12800 Cambie Road, Richmond, BC

Parking Lots/Garages:

11. Templeton Station Rd, Richmond BC, Canada

12. 7373 Westminster Hwy, Richmond BC V6X, Canada

Government:

13. 6911 No. 3 Rd, Richmond, BC V6Y 2C1

▪ **Surrey**

Medical:

14. 13750 96 Ave Surrey, BC V3V 1Z2 Canada

Library:

15. 15288 105 Ave, Surrey, British Columbia, V3R 1R9

Parking Lots/Garages:

16. 15250 104th Avenue Surrey, BC V3X 6N8, Canada

Workplace:

17. 12388 88 Ave, Surrey, BC V3W 7R7, Canada

12388 88 Ave, Surrey, BC V3W 7R7, Canada

Business/Commercial:

18. 10355 152 St, Surrey, BC V3R 7C1, Canada

19. 10025 King George Highway Surrey, BC V3T 2W1, Canada

20. 13450 102 Ave, Surrey, BC V3T 0A3, Canada

▪ **UBC**

Business/Commercial:

21. 3335 Webber Ln, Vancouver, BC V6S 0H3, Canada

22. 3228 Ross Drive, Vancouver, British Columbia, V6S 0C6

Education:

23. 6085 Thunderbird Boulevard, Vancouver, BC V6T 1Z3

24. 6163/6133 University Blvd, Vancouver, BC V6T 1Z1, Canada

25. 6115 Student Union Boulevard, Vancouver, BC V6T 1Z1, Canada

▪ **Vancouver**

Leisure Destination:

26. 4915 W 16th Ave, Vancouver, BC V6T 2H2

Business/Commercial:

27. 5503 West Blvd, Vancouver, BC V6M 3W6, Canada

28. 3185 Grandview Hwy, Vancouver, BC V5M 2E9, Canada

29. 489 Interurban Way, Vancouver, BC V5X 0C7, Canada

30. 500 W. Cordova St., Vancouver, BC V6B 4N4, Canada

31. 900 W Cordova St, Vancouver, BC V6C 0A7, Canada

Retail:

32. 1077 Great Northern Way Vancouver, BC V5T 1E1, Canada

Parking Lots/Garages:

33. 999 Canada Place, Vancouver, BC V6C 0C3, Canada

34. 1661 Napier St, Vancouver, BC V5L 4X4, Canada

35. 596 W 16th Ave, Vancouver, BC V5Z, Canada

36. 2675 Oak St, Vancouver, BC V6H 3Z6, Canada

37. 1333 W Broadway, Vancouver, BC V6H 4C1, Canada

38. 1470 W Broadway, Vancouver, BC V6H 1H4, Canada

39. 3161 Arbutus St, Vancouver, BC V6K, Canada

40. 535 Richards St, Vancouver, BC, Canada

Medical:

41. 890 W 12th, Ave, Vancouver, BC V5Z 4S5, Canada

Government:

42. 1580 W Broadway, Vancouver, BC V6J 5K9, Canada

Street Parking:

43. 977 Mainland St, Vancouver, BC V6B 1A9, Canada

44. 310 West 4th Avenue, Vancouver, BC V5Y 1G9, Canada

Business/Commercial:

45. 1055 Eveleigh St, Vancouver, BC, Canada

46. 1050 W Pender St, Vancouver, BC, Canada

Government:

47. 455 W 10th Ave, Vancouver, BC V5Y, Canada

Retail:

48. 2083 Alma St, Vancouver, BC V6R 4N6, Canada

49. 5733 Cambie St, Vancouver, BC V5Z 2M9, Canada

5733 Cambie St, Vancouver, BC V5Z 2M9, Canada

▪ **West Vancouver**

Retail:

50. 964 Park Royal North West Vancouver, BC V7T, Canada

51. 2100 Park Royal South, West Vancouver, BC V7T 2W4, Canada

52. 901 Park Royal South, West Vancouver, BC V7T, Canada