Pollution Probe

Assessment of The Consumer Electric Vehicle Charging Experience in Canada

Final Project Report

Innovation, Science and Economic Development Canada, Office of Consumer Affairs

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About

Pollution Probe

Pollution Probe is a Canadian charitable environmental organization that is a leading agent of change at the intersection of communities, health and environment. Since 1969, we have been defining environmental problems through research, promoting understanding through education and pressing for practical solutions through advocacy. Pollution Probe has a proven track record of working in successful partnership with industry and government to develop practical solutions for shared environmental challenges.

Pollution Probe is one of Canada's leading independent transportation solution providers. Our work supports aggressive actions to address climate change and reduce air pollution while promoting job creation and economic growth. In addition to projects we actively contribute to expert transportation committees and working groups at local, regional, national and global levels. We are technology neutral and work collaboratively with a wide variety of stakeholders to develop transportation decarbonization solutions across all modes.

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Executive Summary

The current Canadian electric vehicle (EV) outlook is very strong as increased model availability and improved vehicle performance coupled with targeted political support is expected to accelerate EV market growth. While 2021 EV sales stood at 5.6%, sales are expected to reach 17% of all passenger vehicles sold in 2025, and 100% by 2035 as announced by the Government of Canada. Pollution Probe, one of Canada's leading not-for-profit low-carbon transportation solution providers, was contracted by the Office of Consumer Affairs at Innovation, Science and Economic Development Canada (ISED) to lead a first of its kind assessment of the consumer EV charging experience in Canada.

The existence of multiple public charging networks operated by a variety of different entities, as well as the uneven distribution of charging infrastructure, has greatly impacted the public charging experiences of EV users. Additionally, the charging behaviour of consumers varies depending on the range and charging capabilities of their EV as well as their travel patterns and access to chargers. In this context, this report summarizes and assesses the experience of Canadian EV owners with charging infrastructure to date.

The project team conducted interviews with more than 20 leading EV experts from both the public and private sectors to gather knowledge and perspectives on the current EV charging landscape. Based on their input and a review of the existing literature, a survey was designed and administered to a large sample of Canadian EV owners to evaluate their opinions on public charging infrastructure. The results of this study aim to identify gaps and weaknesses in current charging infrastructure as well as strengths that can be leveraged to maximize the benefits of future deployments.

Survey results are categorized under four categories, namely: charging behaviour, network coverage satisfaction, network service satisfaction, and network payment systems. Among the key findings of the study, EV owners that reside in MURBs are found to rely significantly more on public charging infrastructure than those in single detached homes, with 42% of MURB respondents indicating that more than half of their charging needs are addressed using public infrastructure. Additionally, 37% of survey respondents are not aware of any roaming agreements between network operators, and only about 6% of respondents had a clear understanding of the scope of these agreements. Lastly, EV owners indicate a high degree of interest in time-of-use pricing, smart charging, and bi-directional "vehicle-to-grid" charging technology. These demand management methods should be leveraged to avoid stressing local grids and to optimize existing electricity system infrastructure and capacity.

Many of the challenges identified through this work could be addressed simply by deploying a broader network of charging stations across the country, supported by both public and private entities. It is important that stakeholders remain focused on and committed to Canada's 2035 100% ZEV sales target, and deploy the number and type of stations commensurate with meeting it. Fast charging infrastructure should be strategically deployed with a focus on highway corridors and retail centers in urban areas with high concentrations of MURB occupants. There is a need to monitor the consumer EV charging experience in Canada on an ongoing basis. As solutions are implemented going forward, surveys such as this one should be consistently deployed to gauge the impacts of existing measures and highlight priority areas for future action.

1.0 Background

Electric vehicles (EVs), which include both battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs), have been rapidly gaining momentum as a more sustainable alternative to internal combustion engine passenger vehicles. This trend is fueled by recent improvements in battery range and cost that have reduced range anxiety and price barriers for Canadian consumers. [1] The current Canadian BEV outlook is positive as increased model availability and improved vehicle performance coupled with strong political support will keep the BEV market growing in the country. While 2021 EV sales stood at 5.6%,[2] they are expected to reach 335,000 in 2025, accounting for 17% of all new passenger vehicles sold in the country.[3]

The deployment of public charging infrastructure is essential to encourage consumers to make the transition to EVs. Public charging availability is consistently cited as one of the top three barriers to increased EV adoption, along with purchase prices and vehicle range.[4] However, investment in public charging infrastructure has been lacking to date due to low EV market penetration. This chicken and egg dilemma has resulted in the development of a decentralized public charging station ecosystem that consists of a wide variety of networks that are operated independently by provincial and local governments, private charging station operators, electrical utilities, and vehicle manufacturers. As of early 2022, Natural Resources Canada data indicates that there are over 14,000 EV chargers at 6,689 public locations across the country. Of these, approximately 18% consist of DC fast chargers that are capable of high-power charging with shorter wait times than lower voltage Level 2 stations.[5] The number of chargers deployed is expected to continue growing significantly in the short term due in part to various private sector commitments and government initiatives such as Natural Resources

[1] KPMG. (2021). Electric Vehicles to make up majority of new car purchases. Retrieved from: https://home.kpmg/ca/en/home/media/press-releases/2021/02/electric-vehicles-to-make-up-majority-of-new-car-purchases.html
[2] Electric Autonomy Canada. (2022). Over one in 20 new cars registered in Canada in 2021 were EVs. Retrieved from: https://electricautonomy.ca/2022/02/15/ihs-markit-zev-adoption-canada-2021/#:~:text=London%2Dbased%20consultancy%20IHS%20Markit's,cell%20(FCEVs)%E2%80%94%20making%20up
[3] Bloomberg NEF. (2021). Long term electric vehicle outlook. Retrieved from: https://about.bnef.com/electric-vehicle-outlook/
[4] Newmotion. (2020). EV Driver Survey Report 2020. Retrieved from: https://assets.ctfassets.net/ulfvrpf1itxm/3gNS3F5NPiiU2W7tA62QqH/f6269e4852bb147bc7e29709e2383989/EV_driver_survey_report_2020_EN.pdf
AlixPartners. (2019). International electric-vehicle consumer survey. Retrieved from: https://www.alixpartners.com/insights-impact/insights/international-electric-vehicle-consumer-survey/
KPMG. (2021). Electric Vehicles to make up majority of new car purchases. Retrieved from: https://home.kpmg/ca/en/home/media/press-releases/2021/02/electric-vehicles-to-make-up-majority-of-new-car-purchases.html
[5] Natural Resources Canada. (2022). Electric Charging and Alternative Fuelling Stations Locator. Retrieved from: https://www.nrcan.gc.ca/energy-efficiency/transportation-alternative-fuels/electric-charging-alternative-fuelling-stationslocator-map/20487#/find/nearest?country=CA&fuel=ELEC

Canada's Zero Emission Vehicle Infrastructure Program (ZEVIP) and its Electric Vehicle and Alternative Fuel Infrastructure Deployment Initiative (EVAFIDI).[6]

The existence of multiple public charging networks operated by a wide variety of different entities has an impact on the interaction of consumers with public charging infrastructure. Additionally, the charging behaviour of consumers varies depending on the range and charging capabilities of their EV as well as their travel patterns and access to chargers. Further, public charging infrastructure impacts consumer awareness of EVs as well as opinions on the feasibility of EV usage. Consumers are much more likely to buy an EV if charging is available at locations they visit frequently.[7]

In this context, this report summarizes and assesses the experience of Canadian EV owners with charging infrastructure to date.

The project team conducted interviews with more than 20 leading EV experts from both the public and private sectors to gather knowledge and perspectives on the current EV charging landscape. Based on their input and a review of the existing literature, a survey was designed and administered to a large sample of Canadian EV owners to evaluate their opinions on public charging infrastructure. The results of this study aim to identify gaps and weaknesses in current charging infrastructure as well as strengths that can be leveraged to maximize the benefits of future deployments.

Based on the results of the national survey, this report categorizes consumer interaction with charging infrastructure under four categories, namely: charging behaviour, network coverage satisfaction, network service satisfaction, and network payment systems. A descriptive analysis of the survey results attributed to each category is presented in the body of the report, while the appendices contain the survey itself and responses to each of its questions. A summary of key findings and associated recommendations are included in the report's final two sections.

[6] Natural Resources Canada. (2021). Zero Emission Vehicle Infrastructure Program. Retrieved from: https://www.nrcan.gc.ca/energy-efficiency/transportation-alternative-fuels/zero-emission-vehicle-infrastructure-program/21876
Natural Resources Canada. (2021). Electric Vehicle and Alternative Fuel Infrastructure Deployment Initiative. Retrieved from: https://www.nrcan.gc.ca/energy-efficiency/transportation-alternative-fuels/electric-and-alternative-fuel-infrastructure/electric-vehicle-alternative-fuels-infrastructure-deployment-initiative/18352

[7] Sandia National Laboratories (2017). Impact of Public Electric Vehicle Charging Infrastructure. Retrieved from: https://www.osti.gov/servlets/purl/1416695

2.0 Survey Respondent Characteristics

The online survey was hosted on dedicated webpages in both English and French, and Pollution Probe's extensive EV stakeholder network was leveraged to promote the survey and drive response rates. A total of 1,619 responses were collected from across Canada (**Figure 1**). The provinces with the highest number of responses were Quebec, Ontario, and British Columbia with 44%, 32% and 10% of the total, respectively.

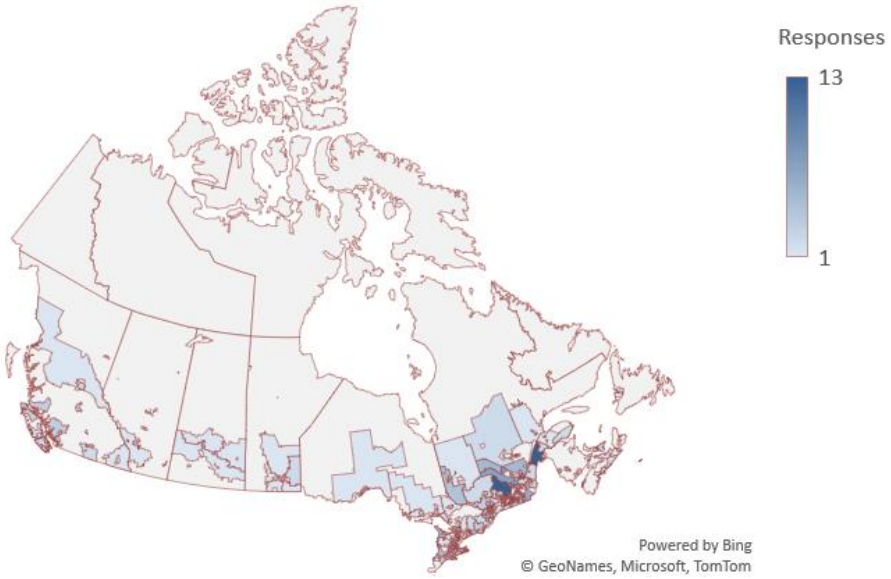


Figure 1: Postal code distribution of respondents across Canada (total of 1,619 responses)

92% of respondents were BEV users with the remaining 8% owning PHEVs. BEVs are powered only by a battery pack and current ranges on a single charge are generally between 110 and 560 km, depending on vehicle model and year. These vehicles rely entirely on access to a charging station or an electricity outlet to be recharged. On the other hand, PHEVs have much smaller battery packs that generally offer an electric driving range of between 16 and 80 km. Their batteries are coupled with an internal combustion engine (ICE) that is activated whenever the battery is depleted. The ICE of these vehicles is also sometimes used as a "range extender" to charge the battery.

Studies from North America and Europe show that early adopters of EV technology tend to have different charging behaviours than more recent adopters.[8] **Figure 2** shows the length of time that survey respondents have been EV owners for. Results indicate that 15% of respondents have owned an EV for more than 5 years and are considered early adopters. On the other hand, 58% of respondents have owned an EV for less than 3 years, representing more recent consumer growth in the Canadian EV sector.

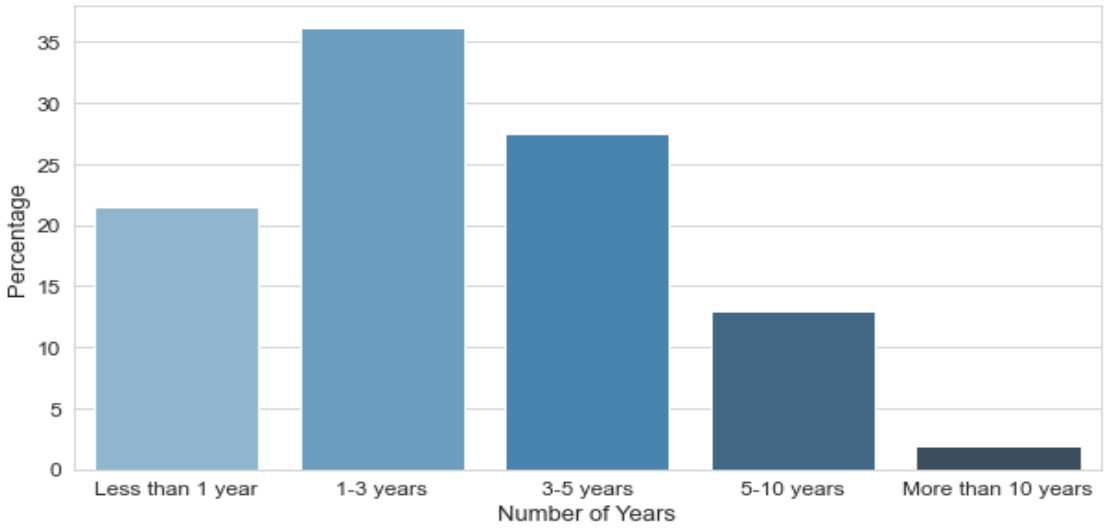


Figure 2: Respondent duration of EV ownership

Vehicle range tends to have a major impact on charging behaviour and the opinions of consumers related to public charging infrastructure. Canadian passenger vehicle owners drive an average of 42 km per day.[9] 71% of survey respondents indicate owning an EV with a range of at least 300 km, a distance that should be more than adequate to limit range anxiety concerns for daily travel. Additionally, 38% of respondents indicate going on a long-distance trip of more than 200 km one way at least once per month – a distance which in most cases would require the use of public charging infrastructure.

[8] Axsen, J., Goldberg, S., & Bailey, J. (2016). How might potential future plug-in electric vehicle buyers differ from current "Pioneer" owners? Transportation Research Part D: Transport and Environment, 47. https://doi.org/10.1016/j.trd.2016.05.015

[9] Statistics Canada (2019). Results from the 2016 Census: Commuting within Canada's largest cities. Retrieved from: https://www150.statcan.gc.ca/n1/pub/75-006-x/2019001/article/00008-eng.htm

2.1 Consumer Charging Behaviour

Charging stations in North America are divided into three different categories characterized as level 1, 2 and 3 (level 3 stations are commonly referred to as DC fast chargers, abbreviated as DCFC). Table 1 provides a synopsis of the key features of each type of charging.

Level 1 and level 2 charging are universally compatible with all EVs sold in North America. There are three types of DCFC connectors – SAE Combo/CCS, CHAdeMO, and Tesla Supercharger. The Supercharger network is exclusive to Tesla vehicles, and CCS and CHAdeMO adapters are also available to Tesla users. CHAdeMO used to be the favoured option for Japanese and Korean automakers, while CCS was used primarily for vehicles made in Europe and North America. In recent years, however, the use of CHAdeMO charging systems in all types of North American vehicles has declined rapidly, and CCS is becoming the de facto DCFC standard for non-Tesla EVs. Most non-proprietary public DCFCs have connectors for both CCS and CHAdeMO vehicles. Connector types are typically indicated in charging locator apps and maps.

Table 1: Summary of Charging Station Types

	Level 1 AC	Level 2 AC	DCFC
EVs supported	All PHEVs and BEVs	All PHEVs and BEVs	Most BEVs and some PHEVS
Requirements	120-volt AC (alternating current) standard electrical outlet	240-volt AC (alternating current) connection	480-volt DC (direct current) connection
Average BEV charging time	8 to 30 hours	4 to 10 hours	25 to 45 minutes (to 80% of full charge)
Power delivered	~1.6 kW	3.3 – 19.2 kW	50 – 450+ kW
Range added per hour (approximate)	5 – 8 km	30 – 40 km	240 – 400+ km
Hardware and installation costs	$1,000 in new build; $2,000 during renovation	$1,500 in new build; $5,000 during renovation	$50,000 - $120,000
Applications	Long-term parking (home, work, overnight, etc.)	Long- and short-term parking (home, work, retail, etc.)	Long-distance travel (highways) and retail

Source: Adapted from *Framework for Municipal Zero Emission Vehicle Deployment*[10]

Previous studies show that the four most common charging locations of EV users are their homes, their workplaces or commute destinations, public locations other than work, and rest stops on long distance travel corridors.[11] Yet, 50-80% of EV charging occurs at home and access to home charging has been shown to be one of the most influential factors in the decision to purchase an EV.[12] In this study, 85% of EV owners indicate residing in a single-family house/townhouse with dedicated parking, with only 12% residing in multi-unit residential buildings (MURBs).[13] This is notable given that

[10] Pollution Probe and The Delphi Group. (2019). Framework for Municipal Zero Emission Vehicle Deployment. Retrieved from: https://www.pollutionprobe.org/wp-content/uploads/Probe-Delphi-Municipal-ZEV-Framework-Report.pdf
[11] NewMotion. (2020). EV Driver Survey Report 2020. Retrieved from: https://assets.ctfassets.net/ulfvrpf1itxm/1Qid6yJBwkLoAoTSgr9kYt/9c11d5bdc97b994d1e8772e929e46f57/0729NM04_EV_driver_survey_report_2020_EN_FINAL.pdf
[12] Plug In America. (2021). Satisfied Drivers, Optimistic Intenders. Retrieved from: https://pluginamerica.org/wp-content/uploads/2021/02/2021-PIA-Survey-Report.pdf
[13] MURBs are defined in the survey as residents of condominiums/stata, and rental apartments in low-rise and high-rise buildings

approximately 33% of all Canadians live in MURBs.[14] Additionally, 91% of respondents indicate having access to home charging. EV consumers typically use level 1 overnight charging or install a level 2 charging station.[15]

81% of respondents use a level 2 charging station to charge from their home location while 13% use a level 1 standard wall electrical outlet. Only 5% of total respondents do not charge at home. However, in the case of MURB residents this number notably jumps to 32%. When asked about the percentage of charging conducted outside of their home location, 79% of total respondents indicate that less than one quarter of their charging needs are addressed using public charging infrastructure **(Figure 3).** On the other hand, 42% of respondents that live in MURBs indicate that more than half of their charging needs are addressed using public charging infrastructure, highlighting the need for more effective charging solutions for MURBs as well as better public charging infrastructure in MURB-heavy neighbourhoods.

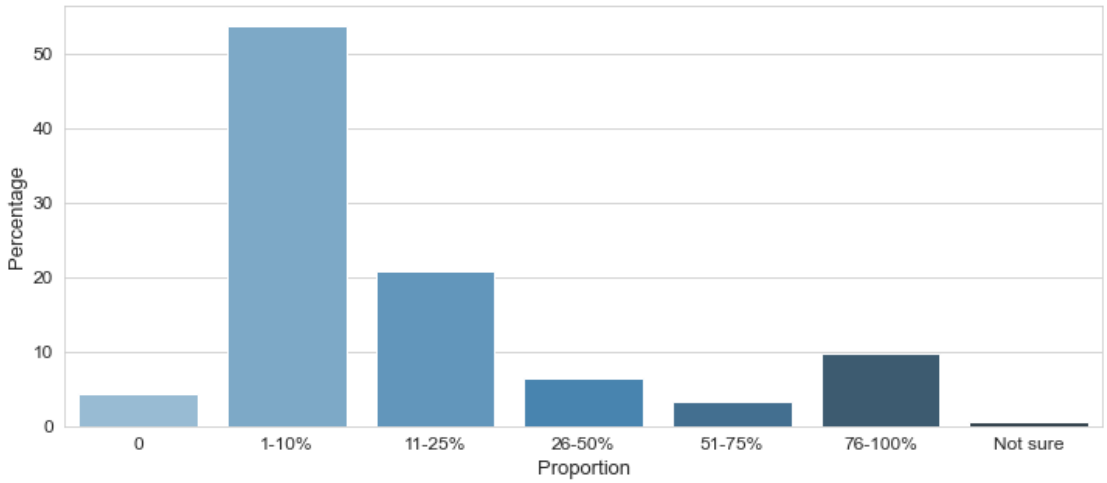


Figure 3: Total charging that occurs away from home

[14] Statistics Canada. (2017). Census in Brief: Dwellings in Canada. Retrieved from: https://www12.statcan.gc.ca/census-recensement/2016/as-sa/98-200-x/2016005/98-200-x2016005-eng.cfm
[15] Idaho National Lab. (2015). Plugged In: How Americans Charge Their Electric Vehicles. United States. Retrieved from: https://www.osti.gov/biblio/1369632-plugged-how-americans-charge-electric-vehicles

2.2 Network Coverage Satisfaction

As of 2020, the global average of the ratio of public charging stations per EV stock was 12 chargers for every 100 EVs. This ratio varies across countries mainly due to differences in regulations that dictate access to home charging. In countries like Norway and the United States where most people have access to home charging, there are respectively 4 and 6 public charging stations per 100 EVs. On the other hand, countries like China or the Netherlands which have limited access to home charging have 18 and 22 charging stations per 100 EVs respectively. There also exists significant variability across countries in the deployment of slow versus fast chargers (i.e., level 2 versus level 3) due to investment and population density discrepancies. As of 2020, Canada had 6 charging stations per 100 EVs with 17% of chargers consisting of level 3/DC fast chargers.[16]

Figure 4 presents the Likert scale responses to statements related to charging infrastructure coverage. 52% of respondents indicate that their EV purchasing decision was linked to charging infrastructure availability, in line with other findings on the role of charging infrastructure in promoting EV market penetration.[17] 59% of respondents disagree or strongly disagree that the existing number of charging stations available is adequate, with a slightly more pronounced dissatisfaction when respondents are asked about the availability of DC fast chargers specifically (**Figure 4**). Additionally, 43% of respondents indicate that they are often required to take indirect routes to access charging infrastructure during longer trips.

[16] International Energy Agency. (2021). Global EV Outlook 2021. Retrieved from: https://www.iea.org/reports/global-ev-outlook-2021/policies-to-promote-electric-vehicle-deployment#abstract
[17] KPMG. (2021). Electric Vehicles to make up majority of new car purchases. Retrieved from: https://home.kpmg/ca/en/home/media/press-releases/2021/02/electric-vehicles-to-make-up-majority-of-new-car-purchases.html

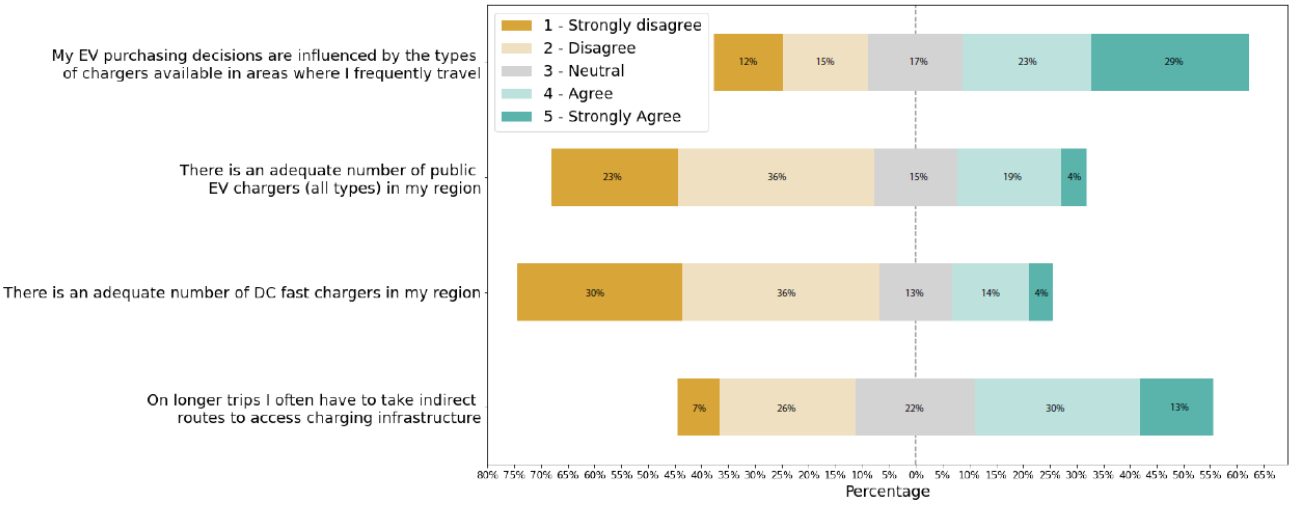


Figure 4: Network Coverage – Level of satisfaction

Figure 5 shows the distribution of types of DCFC connectors used by respondents in the survey. 45% of respondents use Tesla-specific Supercharger connectors, while 32% and 13% of respondents have vehicles that are CCS and CHAdeMO compatible respectively.

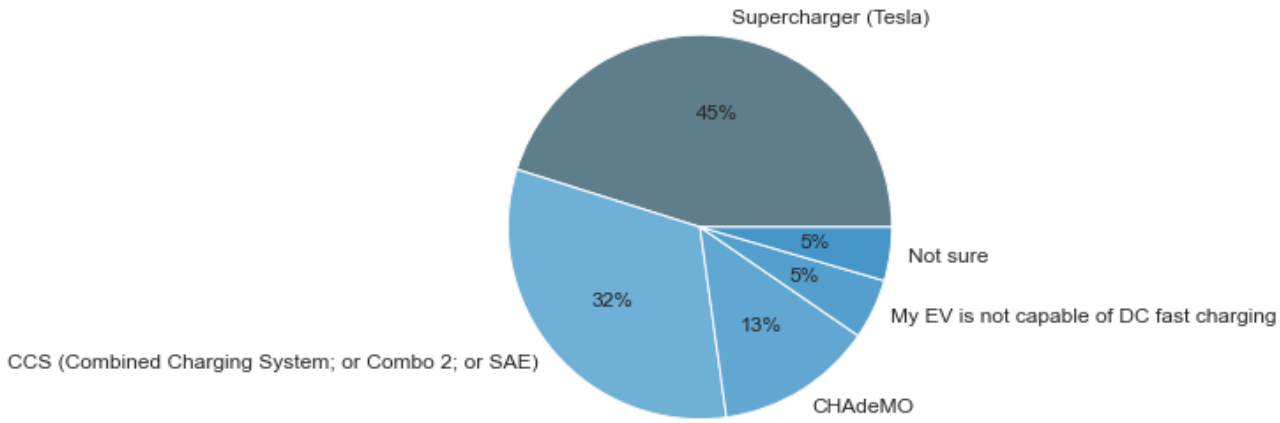
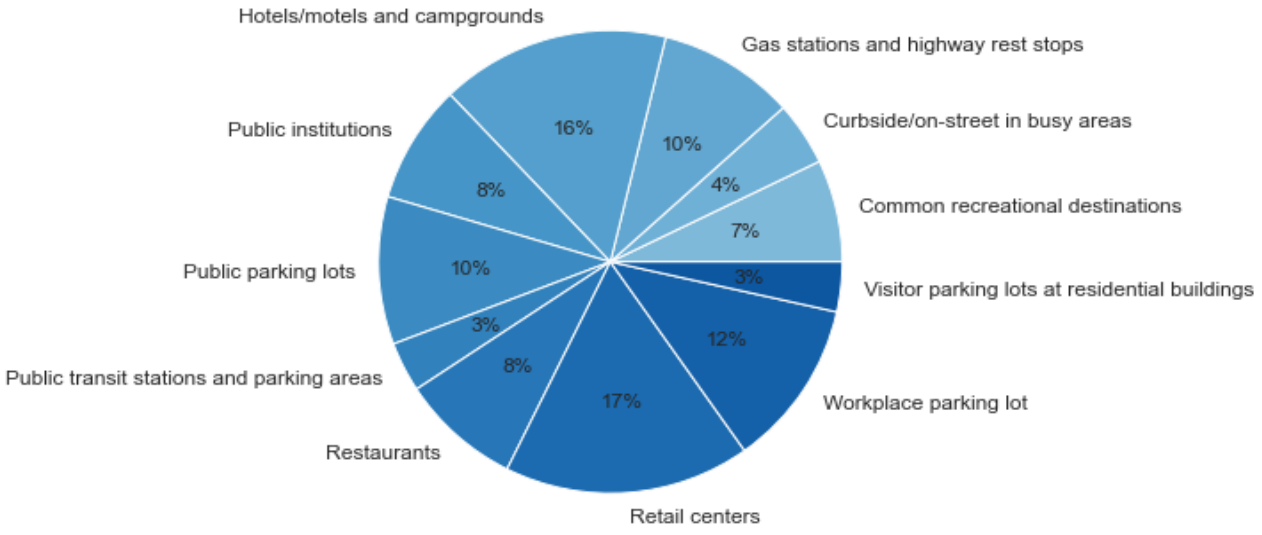


Figure 5: Respondent Vehicle DCFC Compatibility

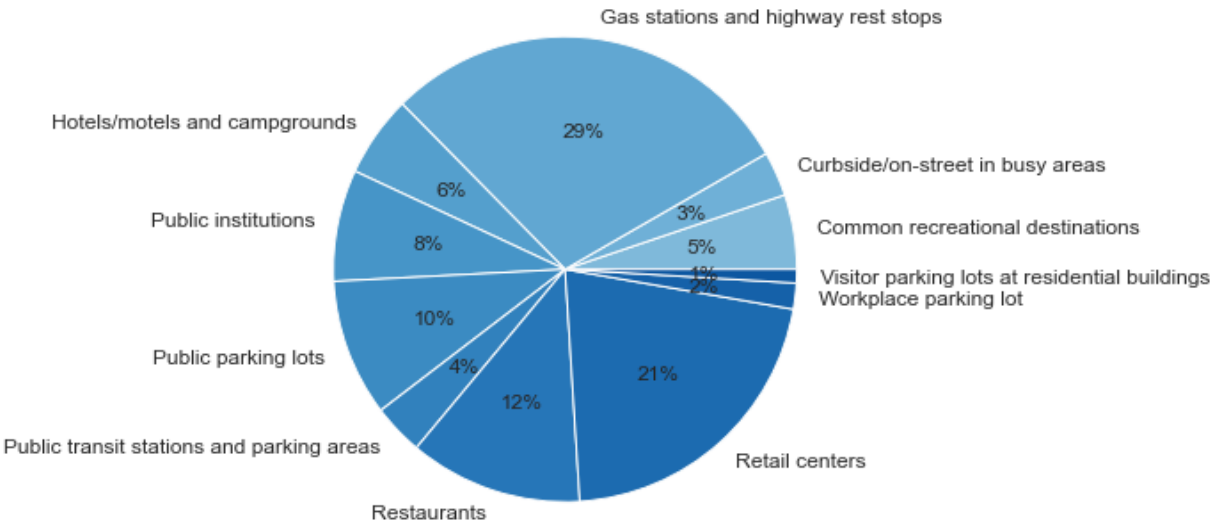
A variety of factors must be considered when determining the type and number of charging stations to install at different locations. DCFCs are optimal in scenarios where drivers would not be expected to remain parked for very long, while level 2 charging is appropriate for locations where drivers might remain parked for longer periods of time. Level 2 can also be useful for "top up" charging, or shorter periods of charging that give drivers enough range to get to a destination where they will be able to

charge more completely. Level 1 charging is particularly useful to PHEVs, which have smaller batteries that require less time and power to charge completely. It can also be used where no other options are available, or where EV users could remain parked for extended periods, even multiple days. Factors like cost (DCFCs cost roughly ten times more than level 2 stations, and often require local electrical upgrades) and power availability also influence the types of charging infrastructure used in different locations.

Figure 6 presents the location preference of respondents for the installation of (a) level 2 and (b) DC fast charging stations respectively. The figures represent the aggregate responses of EV owners that were asked to select their top three locations to deploy level 2 and DC fast charging stations. Retail centers, hotels/motels and campgrounds, and workplace parking lots are found to be the most preferable locations for level 2 charging stations with 17%, 16%, and 12% of counts respectively. Charging station location preferences are more pronounced for DC fast charging stations. Respondents indicate a preference for DC fast charging at gas stations and highway rest stops, retail centers, and restaurants with 29%, 21% and 12% of counts respectively. A strong preference can be observed for charging stations at gas stations and highway rest stops indicating the need of EV owners for high-speed charging on long distance trips. The retail center preference implies that EV users want fast charging at locations that they do not tend to stay at for very long yet visit regularly.



a) Level 2 charging preferred locations



b) DCFC preferred locations

Figure 6: Respondent location preferences for charging stations

2.3 Network Service Satisfaction

Figure 7 presents the Likert scale responses to statements related to wait time and charging impediments while using public charging infrastructure. 26% of EV owners agree or strongly agree that they often find themselves having to wait for others to charge before using a station, potentially indicating localized charging congestion. Additionally, 45% of respondents observe that the power provided by public chargers is not always consistent, leading to longer than expected charging times in some cases. This concern is often associated with the issue of power- versus time-based billing and was particularly highlighted by respondents through comments provided in addition to the survey questions. Respondents were typically of the opinion that power-based billing is preferable and fairer to billing based on length of time spent charging. Roughly half of respondents indicate that an acceptable wait time to gain 200 km of range is less than 20 minutes. Lastly, 22% of respondents are dissatisfied with the availability of amenities where public charging stations are located, potentially highlighting opportunities for charging station hosts to reconsider how best to accommodate their captive EV charging audiences in certain scenarios.

Regarding charging station maintenance, 21% of respondents agree or strongly agree that charging stations they attempt to use are often out of service. This proportion increases to 30% when focusing on Ontario specifically versus 12% for Quebec, suggesting the need for more effective maintenance regimens and oversight in Ontario. Relatedly, 43% of respondents agree or strongly agree that they have had concerns about being stranded due to charging stations being out of service, indicating that the reliability and maintenance of charging infrastructure has room for improvement, and that more stations may be required at certain locations. Lastly, 42% and 47% of respondents agree or strongly agree that people are often plugged-in to charging stations after they have fully charged and that there are often gas-powered vehicles parked in EV charging station parking spaces, respectively. This

suggests that a greater role could potentially be played by enhanced signage and parking enforcement at charging locations.

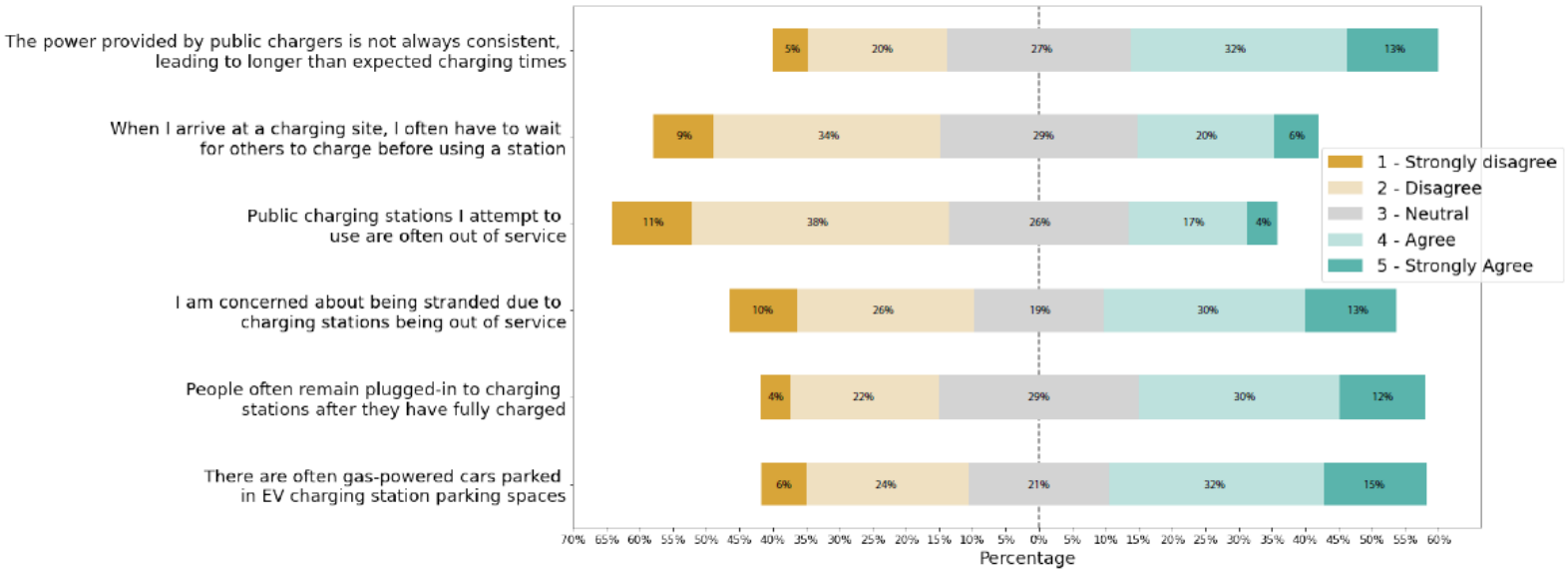


Figure 7: Network Service – Charging impediments and wait time

Figure 8 presents the Likert scale responses to statements related to the user friendliness of charging stations while being operated. The majority of respondents indicate satisfaction with the ease of use of stations, charging cable manipulation and winter access. Roughly half of respondents feel that signage at and around public charging stations is inadequate, and that stations should be easier to find. Regarding safety, 38% of respondents indicate that they have felt unsafe while using public charging infrastructure. The main reasons indicated for feeling unsafe include the remote, isolated location of stations and poor lighting.

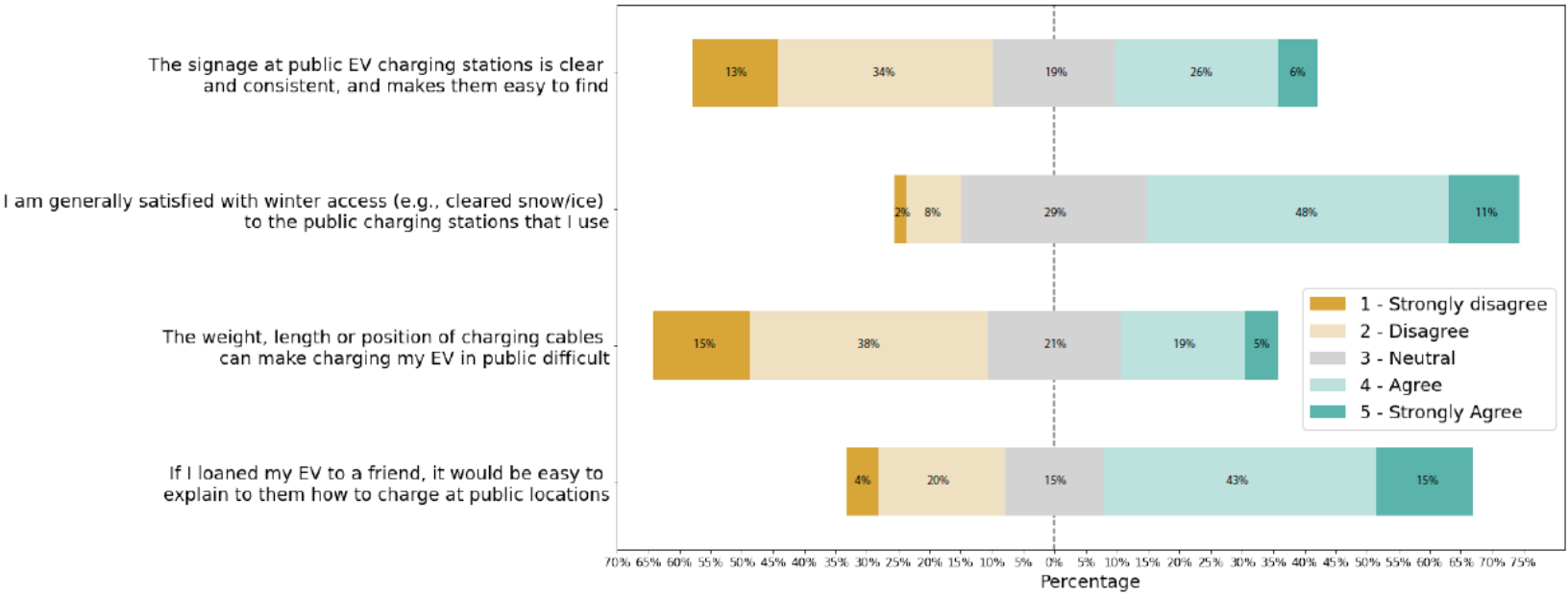
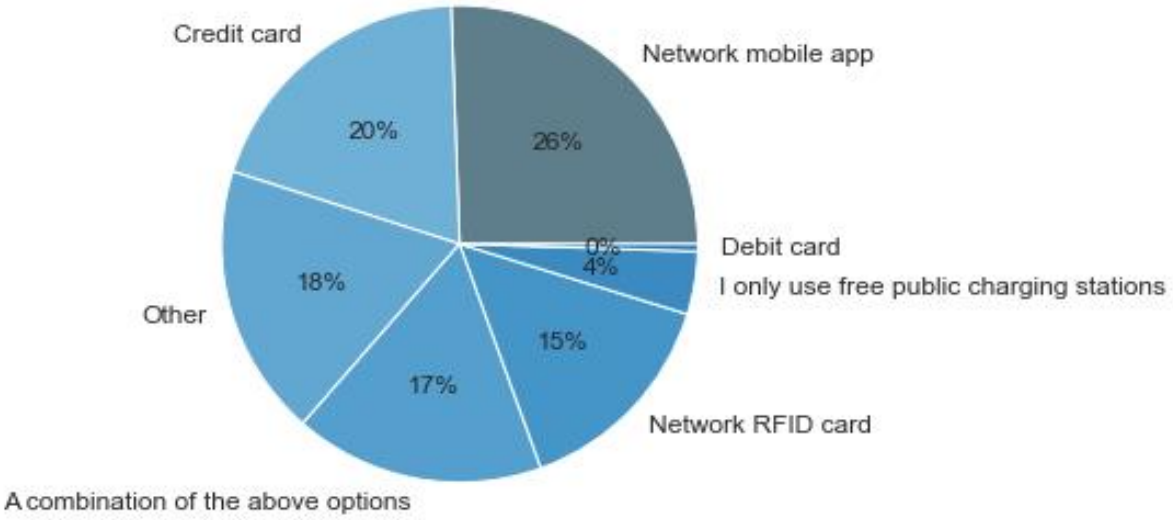


Figure 8: Network Service – Charging station user friendliness

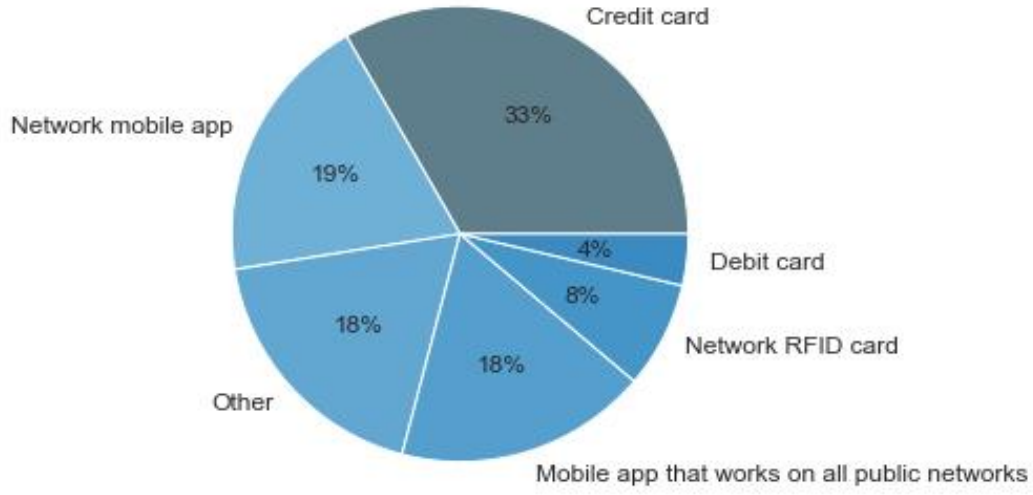
2.4 Network Payment Satisfaction

EV owners typically need to be a member of a charging network (or a partner network in the case of roaming agreements) to be able to access and pay for its charging stations. As mentioned earlier, the decentralized state of the Canadian charging ecosystem often requires consumers to register with multiple networks to gain access to adequate public charging infrastructure. In fact, 66% of survey respondents indicate being a member of at least two networks. Furthermore, 37% of survey respondents are not aware of any roaming agreements between network operators, and only about 6% of respondents had a clear understanding of the scope of these agreements. This suggests that more can be done to communicate to EV users details about the charging networks they already have access to. Multiple European countries (i.e., Netherlands, Portugal, United Kingdom) have passed legislation to guarantee payment interoperability for EV consumers. In Norway, the Norwegian EV Association introduced RFID cards that allow members to simultaneously register with all of the major charging providers and use their networks. Similar initiatives are being gradually implemented through agreements between major charging infrastructure providers in the Canadian context, and at the provincial level in British Columbia[18] and Quebec.[19] **Figure 9** presents the (a) existing and (b) preferred payment options of respondents.

[18] PluginBC (2022). Charging Card and Apps. Retrieved from: https://pluginbc.ca/charging/charging-cards-and-apps/
[19] CAA Quebec (2022). Public electric charging stations. Retrieved from: https://www.caaquebec.com/en/on-the-road/public-interest/sustainable-mobility/public-electric-vehicle-charging-stations/



a) Current payment methods



b) Preferred payment method

Figure 9: Respondent public charging payment options

The existing payment methods of respondents are diverse with no single payment option receiving a clear majority. The "Other" option was found to mainly consist of a vehicle-based billing approach associated with Tesla vehicles in which vehicles are identified by the charging stations and charging is automatically billed to the owner's credit card. Additionally, 46% of respondents indicate that they agree or strongly agree that the payment options for EV charging stations are adequate and convenient while 30% indicate the opposite. When given the option to select their preferred method

of payment, 33% of respondents indicate preferring to pay for charging directly with a credit card, followed by network mobiles apps and vehicle-based billing in the case of Tesla users.

Another concern related to charging is its costs. Lower operating and refueling costs are a major driver behind consumers' transition to EVs.[20] Relative to gasoline and diesel prices, the equivalent cost of charging an EV is typically about 75% lower.[21] Time-of-use pricing and smart charging can play roles in further reducing charging costs for consumers. **Figure 10** presents the Likert scale responses to statements related to charging cost. 21% of respondents feel that the cost of public charging is unreasonably high, while 53% feel that the cost of public charging is adequate. Notably, more than half of respondents indicate they would be willing to pay more to charge if faster methods of charging were available. Regarding demand management methods to reduce charging-related stress on local grids, respondents were almost equally divided on whether time-of-use pricing would encourage them to charge more frequently during off-peak hours. On the other hand, a clear majority of respondents indicate a willingness to participate in smart charging or vehicle-to-grid (V2G) charging programs that would offer them financial compensation, with favourable response rates of 79% and 62%, respectively.

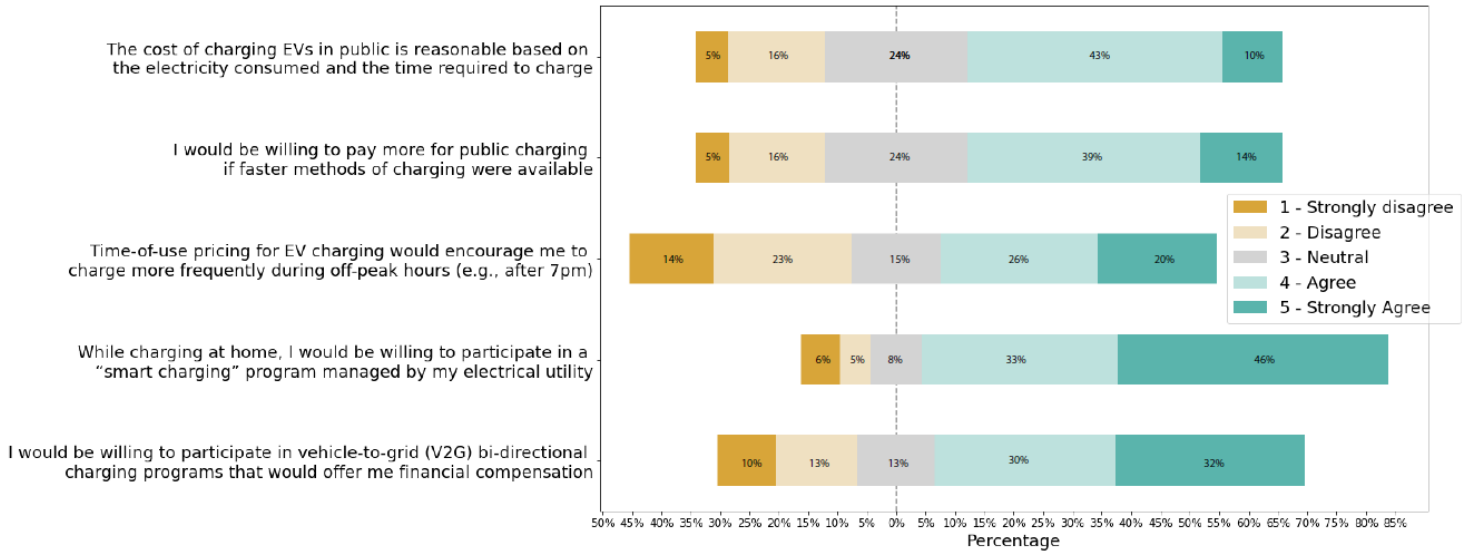


Figure 10: Network Charging – Costs and compensation

[20] Geotab Energy. (2020). EV driver insights: Understanding the experiences powering electric vehicle driver behaviour. Retrieved from: https://image.info.fleetcarma.com/lib/fe321171716404797c1674/m/1/14dc7fa3-567c-4b0b-85d9-a10e94a6b8fa.pdf

[21] CAA Quebec (2022). 5 frequently asked questions about electric cars. Retrieved from: https://www.caaquebec.com/en/on-the-road/advice/tips-and-tricks/tip-and-trick/show/sujet/5-frequently-asked-questions-about-electric-cars/

3.0 Key Findings

- EV owners that reside in MURBs rely significantly more on public charging infrastructure than those in single detached homes, with 42% of MURB respondents indicating that more than half of their charging needs are addressed using public infrastructure.

- The majority of current Canadian EV owners indicate that the existing number of public charging stations is insufficient, with a particular emphasis on DC fast chargers.

- Publicly accessible DC fast chargers facilitate longer journeys. As they are increasingly deployed, they will enable longer trips and will also encourage new adopters without access to private charging to purchase an EV.

- Canadian EV owners' location preference for level 2 charging is varied with interest in a multitude of location types. Consumer preference is more concentrated for DC fast charging stations, with a strong interest in station deployment at gas stations and highway rest stops, as well as retail centers.

- 37% of survey respondents are not aware of any roaming agreements between network operators, and only about 6% of respondents have a clear understanding of the scope of these agreements.

- Roughly half of respondents feel that signage at and around public charging stations is inadequate, and that stations should be easier to find. Additionally, 38% of respondents indicate that they have felt unsafe while using public charging infrastructure.

- Almost half of respondents indicate longer than expected charging times due to inconsistent or less-than-advertised charging power, with many respondents indicating concerns regarding time-based pricing systems associated with charging stations. A national review of time- versus power-based charging fees is being conducted by Measurement Canada to address billing options.[22]

[22] Measurement Canada. (2021). Consumer consultation: Electric Vehicle Chargers. Retrieved from: https://www.ic.gc.ca/eic/site/mc-mc.nsf/eng/lm04973.html

- Half of EV owners in the survey were satisfied with existing EV charging payment methods. When asked to select a preference, most respondents indicate an interest in payment by credit card.

- More than three quarters of EV owners are satisfied with or have no opinion on the current pricing of public charging, and more than half of respondents are even willing to pay a higher price for faster charging. These findings are important for building a business case for more private sector investment in charging infrastructure.

- Canadian EV owners indicate a high degree of interest in smart charging and V2G technology. 79% of EV owners surveyed would be willing to participate in a smart charging program managed by their electrical utility company. 62% of respondents indicated an interest in participating in a V2G program that offers financial compensation.

4.0 Recommendations

- There is a need to monitor the consumer EV charging experience in Canada on an ongoing basis. As solutions are implemented going forward, surveys such as this one should be regularly conducted to gauge the effectiveness of existing measures and highlight priority areas for future action. With minor refinements, the survey and summary report completed through this project could be used as a framework to facilitate the ongoing monitoring of the consumer EV charging experience in Canada.

- Future surveys similar to this one can be planned to attain a minimum threshold of responses from consumer segments such as: different provinces, different household types, different demographics of EV owners, etc. This will help stakeholders target solutions implemented to address specific barriers for specific areas and/or groups of EV users.

- Many of the challenges identified through this work could be addressed simply by deploying a broader network of charging stations across the country, supported by both public and private entities. It is important that stakeholders remain focused on and committed to Canada's 2035 100% ZEV sales target, and deploy the number and type of stations commensurate with meeting this target. Fast charging infrastructure should be strategically deployed with a focus on highway corridors and retail centers in urban areas with high concentrations of MURB occupants.

- The fact that such a high percentage of respondents indicated willingness to participate in demand management initiatives such as utility-led smart charging and V2G programs highlights the need for more utility involvement in EV charging management. Such programs have substantial potential to A) reduce the carbon intensity of EV charging, B) optimize the use of existing electricity system assets while minimizing the need for additional generation, transmission and distribution infrastructure, C) serve as new revenue streams for utilities, D) reduce demand charges at sites serving as charging hubs, and E) reduce the total cost of ownership of EVs for consumers. Given the substantial upside of these demand management practices, utility efforts in this space should be coordinated and focused, with the ultimate near-term goal of making smart charging an option to as many EV users as possible. While V2G solutions are still technologically immature, more EV models with bi-directional charging capabilities are being released every year. Responses suggest that as this option becomes more

mainstream there will be substantial consumer appetite to participate in V2G or vehicle-to-building (V2B) programs.

- The benefits of roaming agreements are not generally well-understood by EV users. This suggests that charging network operators can do more to communicate to clients that memberships can be used at multiple networks. There are likely opportunities to better incorporate partner networks into charging apps, network websites, and guidance and communications documents.

- Payment options and standards around dispensing power to EVs should be universalized to optimize the charging experience. Of all questions asked, the one related to universally accessible charging stations (question 38) received the highest degree of consensus. Almost all respondents agreed that it would be ideal to be able to charge at any publicly available station. Standardization could also benefit areas such as charging station signage, to make stations easier to find within specific sites.

Appendix A: Survey Questions

ASSESSMENT OF THE CONSUMER EV CHARGING EXPERIENCE IN CANADA

Section 1 – Personal Information

1. If you would like the project team to follow-up with you on the results of this study, please provide your email address (this will not be used for any purpose outside of this project):

_____

2. Please indicate the province/territory in which you reside.

[drop-down menu]

3. So we can gain a better sense of issues facing rural and urban EV owners, please provide the first three digits of your postal code.

---

4. How many years in total have you owned or leased an EV?

a) Less than 1 year
b) 1-3 years
c) 3-5 years
d) 5-10 years
e) More than 10 years

5. What type of EV do you own?

a) Battery EV (exclusively powered by a rechargeable battery)

b) Plug-in hybrid EV (powered by combination of rechargeable battery and gasoline engine or generator; includes range extenders)

6. What is the approximate all-electric range of your EV? Please indicate the longest range if multiple EVs are owned.

a) Less than 100 km
b) 100-200 km
c) 200-300 km
d) 300-400 km
e) 400-500 km
f) More than 500 km

7. What type of DC fast charger is your vehicle compatible with (excluding adapters)?

a) CCS (Combined Charging System; or Combo 2; or SAE)
b) CHAdeMO
c) Supercharger (Tesla)
d) My EV is not capable of DC fast charging
e) Not sure

8. What is the model year of your EV?

[dropdown menu with years 2011-2022]

9. Are you a member of an EV owner association?

a) Yes
b) No

10. What type of home do you live in?

a) Single family house/townhouse with dedicated parking
b) Single family house/townhouse without dedicated parking
c) Rental apartment in high-rise building
d) Rental apartment in low-rise building (e.g., duplex, triplex, basement apartment)
e) Condominium/strata
f) Other (please specify): _____

11. Do you have access to a charger at your home?

a) Yes
b) No

12. If you charge your EV at home, what method of charging do you use?

a) Standard wall electrical outlet (Level 1)
b) Fixed/hard-wired Level 2 charging station
c) Portable Level 2 charging station
d) Shared Level 2 charging station
e) Shared DC fast charger
f) I do not charge at home
g) Other (please specify): _____

13. Approximately what percentage of your EV charging occurs away from your home, in public?

a) 0%
b) 1-10%
c) 11-25%
d) 26-50%
e) 51-75%
f) 76-100%
g) Not sure

14. Approximately what percentage of your total EV charging consists of DC fast charging (sometimes referred to as Level 3 charging)?

a) 0%
b) 1-10%
c) 11-25%
d) 26-50%
e) 51-75%
f) 76-100%
g) Not sure

15. On average, do you go on long distance trips (more than 200 km one-way) in your EV at least once per month?

a) Yes
b) No

16. What is the approximate total mileage on your EV?

a) Less than 50,000 km
b) 50,000 – 100,000 km
c) 100,000 – 150,000 km
d) 150,000 – 200,000 km
e) 200,000 – 250,000 km
f) 250,000 – 300,000 km
g) 300,000 – 350,000 km
h) 350,000 – 400,000
i) More than 400,000 km
j) Not sure

Section 2 – Interaction with Public Charging Stations

17. How many public EV charging networks are you currently a member of?

a) 0
b) 1
c) 2
d) 3
e) 4
f) 5
g) More than 5
h) Not sure

18. Which method of payment do you most commonly use for public EV charging?

a) Credit card
b) Debit card
c) Network mobile app
d) Network RFID card
e) A combination of the above options
f) I only use free public charging stations
g) Other: _____

19. Which method of payment would you most **prefer** to use for public EV charging?

a) Credit card
b) Debit card
c) Network mobile app
d) Network RFID card
e) Mobile app that works on all public networks
f) Other: _____

20. While taking a long-distance trip, a reasonable amount of time to charge my EV so it gains at least 200 km of range is:

a) <10 minutes

b) 10-20 minutes
c) 20-30 minutes
d) 30-40 minutes
e) 40-50 minutes
f) >50 minutes

21. Please indicate your **top three** choices of types of locations where publicly accessible **Level 2** EV charging stations would be most useful to you.

a) The parking lot of my workplace
b) Visitor parking lots at residential buildings
c) Public institutions (e.g., schools, libraries, post offices, community centres, civic centers, fire stations, hospitals, etc.)
d) Public parking lots
e) Retail centres (e.g., grocery stores, shopping malls, pharmacies, hardware stores, car dealerships)
f) Restaurants
g) Hotels/motels and campgrounds
h) Common recreational destinations such as gyms, theatres, parks, museums, tourist destinations
i) Gas stations and highway rest stops
j) Curbside/on-street in busy areas
k) Public transit stations and parking areas, and other transport hubs such as airports

22. Please indicate your **top three** choices of types of locations where publicly accessible **Level 3 / DC fast charging** stations would be most useful to you.

a) The parking lot of my workplace
b) Visitor parking lots at residential buildings
c) Public institutions (e.g., schools, libraries, post offices, community centres, civic centers, fire stations, hospitals, etc.)
d) Public parking lots
e) Retail centres (e.g., grocery stores, shopping malls, pharmacies, hardware stores, car dealerships)
f) Restaurants
g) Hotels/motels and campgrounds

h) Common recreational destinations such as gyms, theatres, parks, museums, tourist destinations
i) Gas stations and highway rest stops
j) Curbside/on-street in busy areas
k) Public transit stations and parking areas, and other transport hubs such as airports

23. Have you ever felt unsafe while charging your EV in public, or waiting to charge? If so, please indicate why you felt unsafe (select all that apply).

a) I have never felt unsafe while charging my EV
b) Poor lighting
c) Remote, isolated location
d) Time of day
e) Cold or stormy weather
f) There were no open buildings or other people nearby
g) Lack of security cameras
h) Charging station or charging cable showed signs of damage
i) Other (please specify) : _____

Section 3 – Overall Impressions of the Charging Experience

On a scale of 1 to 5, please indicate your level of agreement with the following statements:

1 – Strongly disagree	2 – Disagree	3 – Neutral	4 – Agree	5 – Strongly agree	Not Applicable

NETWORK COVERAGE

24. There is an adequate number of public EV chargers (all types) in my region.

25. There is an adequate number of DC fast chargers in my region.

26. My EV purchasing decisions are influenced by the types of chargers available in areas where I frequently travel.

27. On longer trips I often have to take indirect routes to access charging infrastructure.

NETWORK SERVICE AND FUNCTIONALITY

28. People often remain plugged-in to charging stations after they have fully charged.

29. There are often gas-powered cars parked in EV charging station parking spaces.

30. When I arrive at a charging site, I often have to wait for others to charge before using a station.

31. Public charging stations I attempt to use are often out of service.

32. I am concerned about being stranded due to charging stations being out of service.

33. I am generally satisfied with winter access (e.g., cleared snow/ice) to the public charging stations that I use.

34. The power provided by public chargers is not always consistent, which can lead to longer than expected charging times.

35. I am concerned about the impact of DC fast charging (Level 3) on battery degradation.

36. Useful amenities tend to be available where public charging stations are located.

37. The signage at public EV charging stations is clear and consistent, and makes them easy to find.

38. It would be ideal if I could charge my EV using any charging network or app.

39. I tend to use the same public charging network most of the time.

40. The weight, length or position of charging cables can make charging my EV in public difficult.

41. If I loaned my EV to a friend, it would be easy to explain to them how to charge at public locations.

NETWORK PAYMENT AND COSTS

42. The payment options for public EV charging stations are adequate and convenient.

43. The cost of charging EVs in public is reasonable based on the electricity consumed and the time required to charge.

44. I would be willing to pay more for public charging if faster methods of charging were available.

45. I am aware of roaming agreements between charging network providers and use these to simplify my charging experience.

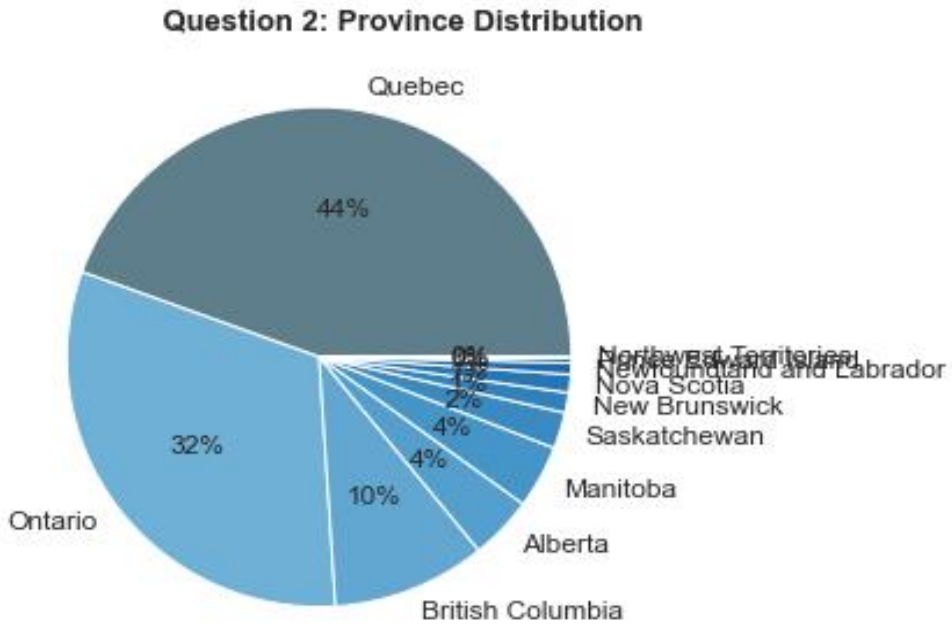
46. Time-of-use pricing for EV charging would encourage me to charge more frequently during off-peak hours (e.g., after 7pm).

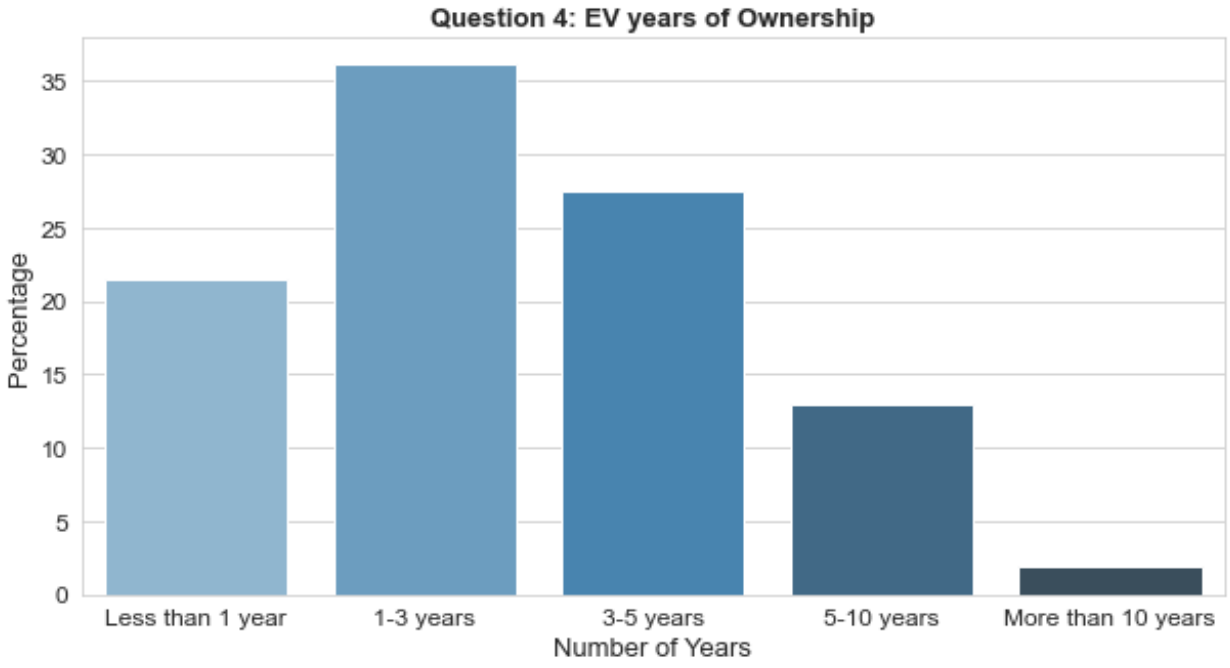
47. While charging at home, I would be willing to participate in a "smart charging" program managed by my electrical utility. This program would allow my utility to increase or decrease the power delivered to my EV, as long as it charges to a certain level by a certain time daily, as determined by me. I would receive financial compensation for my participation.

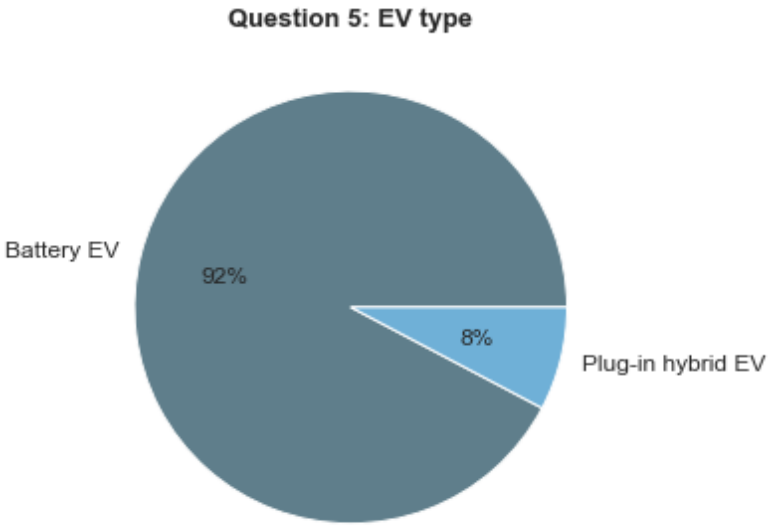
48. If my EV was capable of vehicle-to-grid (V2G) bi-directional charging, I would be willing to participate in programs that would offer me financial compensation to allow my electrical utility to draw power from my battery when my vehicle is plugged in at home (as long as battery state of charge never falls below a level indicated by me).

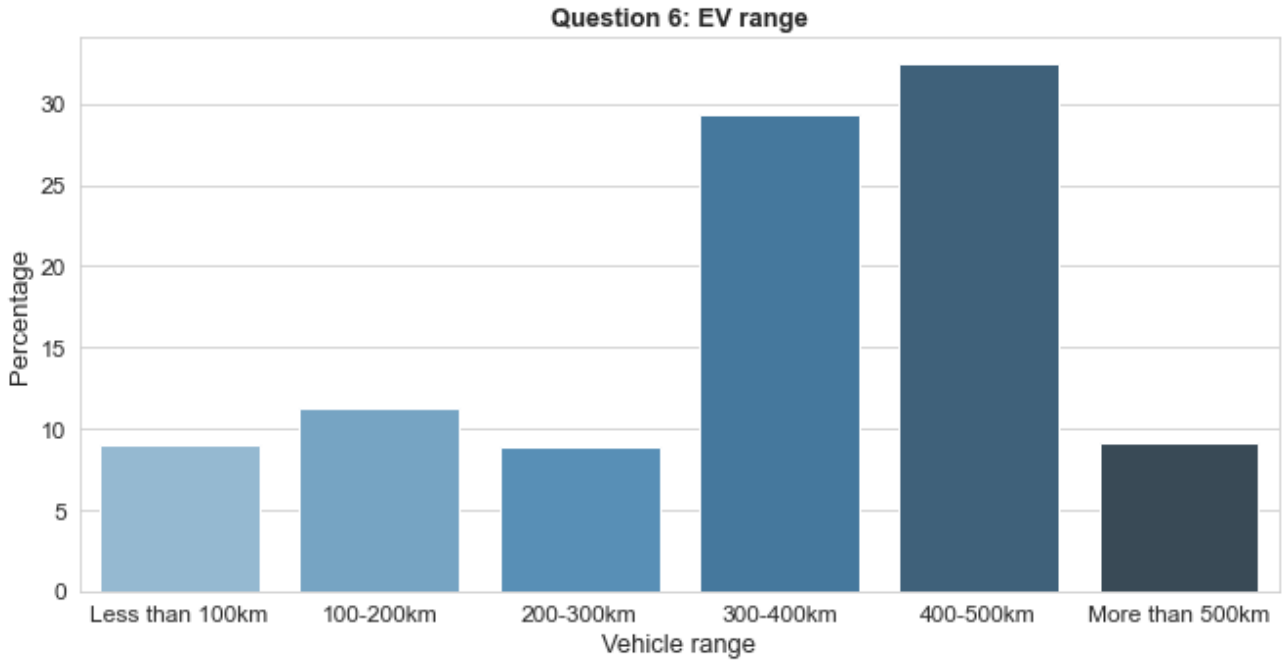
49. Please provide any comments related to your EV charging experience which were not captured by the questions in this survey (e.g., areas of strength or weakness in public charging infrastructure from the perspective of user experience, location, power, availability, functionality, cost, or other factors).

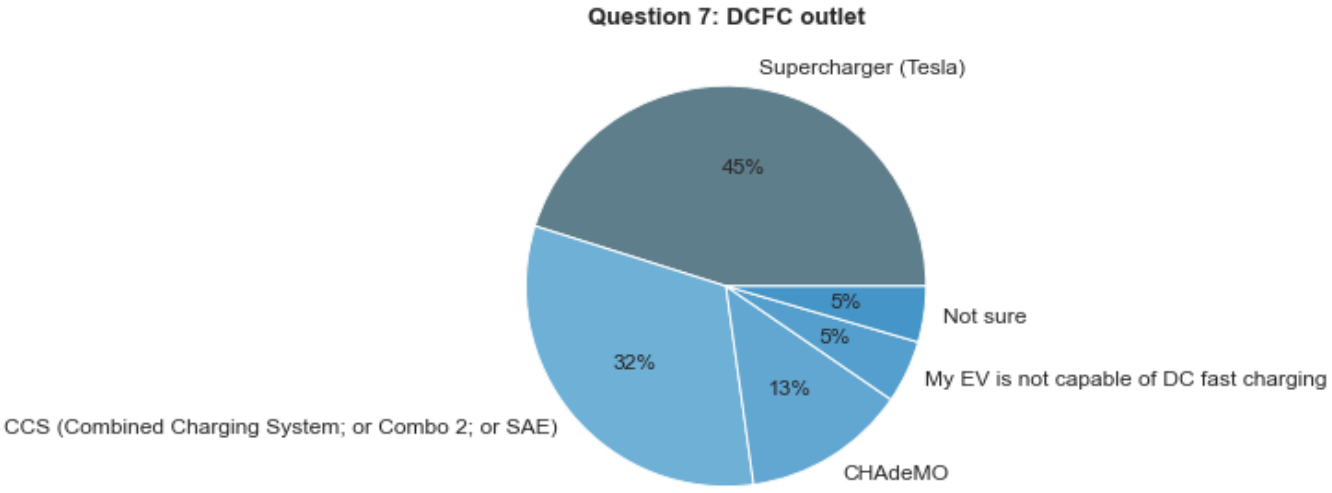
Appendix B: Survey Responses

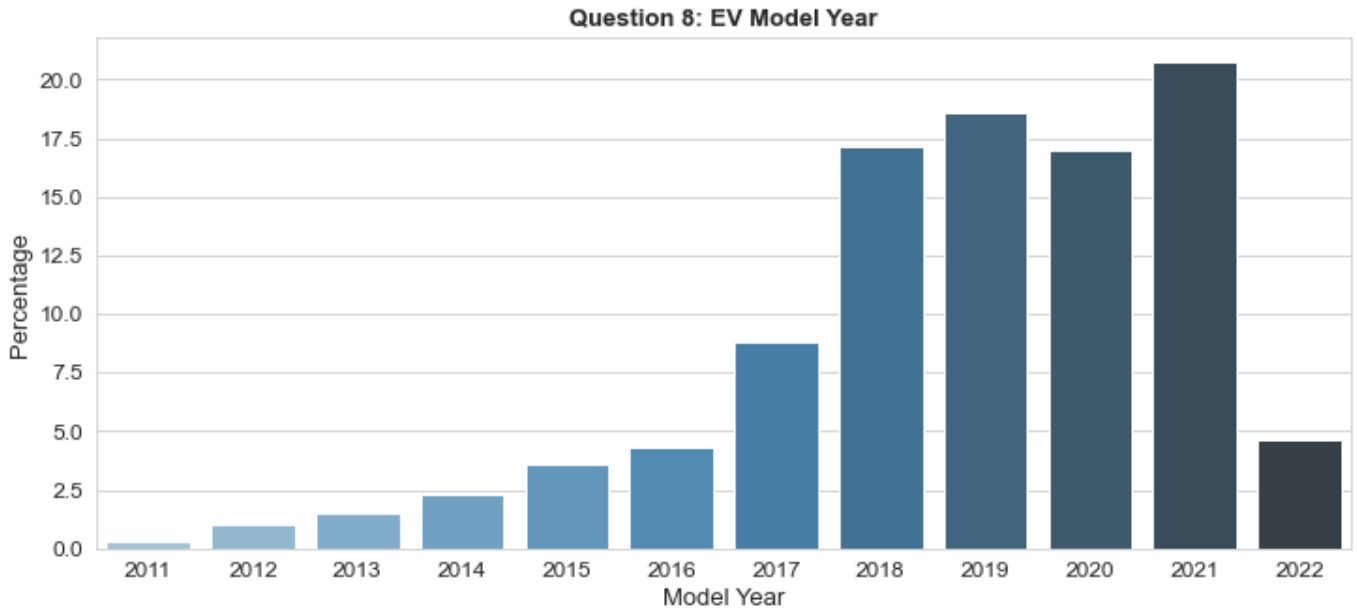


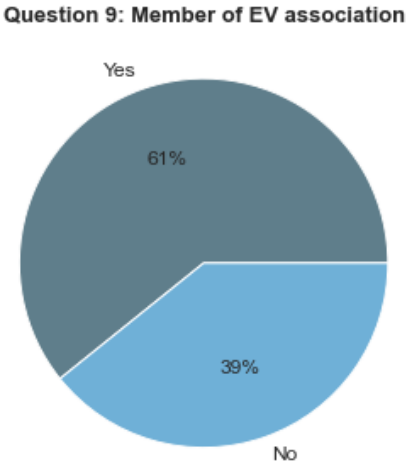

Question 4: EV years of Ownership
Percentage
0
5
10
15
20
25
30
35
Less than 1 year
1-3 years
3-5 years
5-10 years
More than 10 years
Number of Years


Question 5: EV type
Battery EV
92%
8%
Plug-in hybrid EV

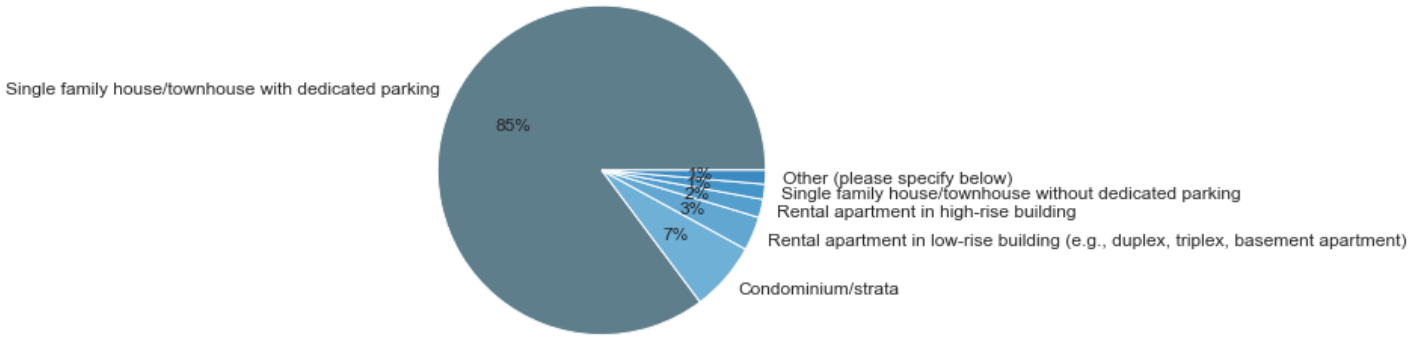

Question 6: EV range
Percentage
0
5
10
15
20
25
30
Less than 100km
100-200km
200-300km
300-400km
400-500km
More than 500km
Vehicle range


Question 7: DCFC outlet
Supercharger (Tesla)
45%
5%
Not sure
5%
My EV is not capable of DC fast charging
13%
CHAdeMO
32%
CCS (Combined Charging System; or Combo 2; or SAE)

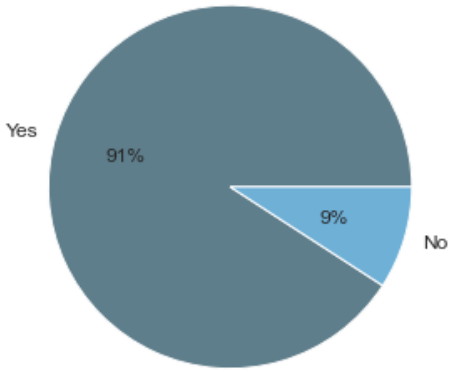

Question 8: EV Model Year
Percentage
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
Model Year


Question 9: Member of EV association
Yes
61%
39%
No

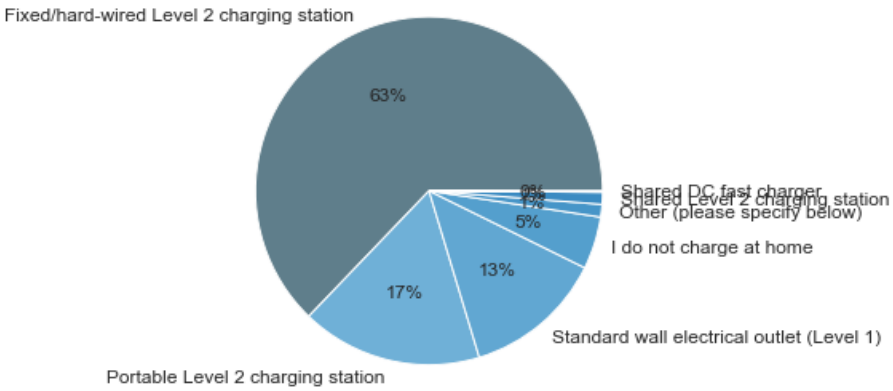
Question 10: Type of Home

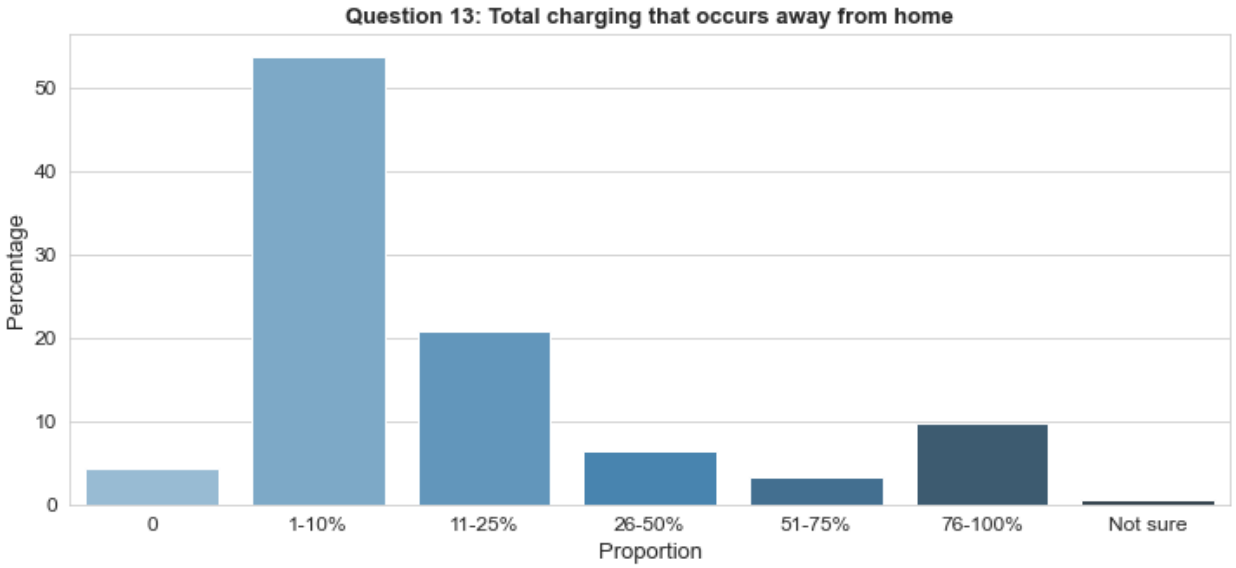


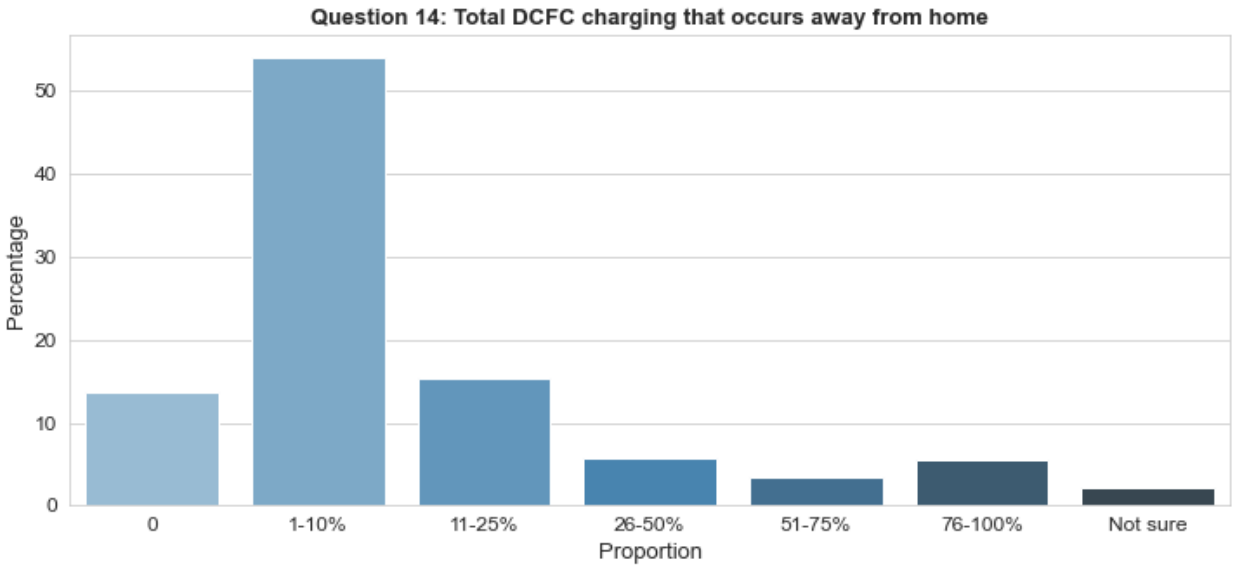
Question 11: Access to Home charging

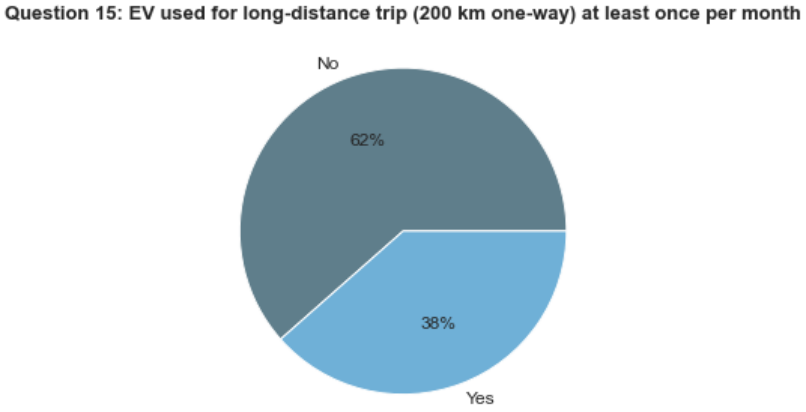


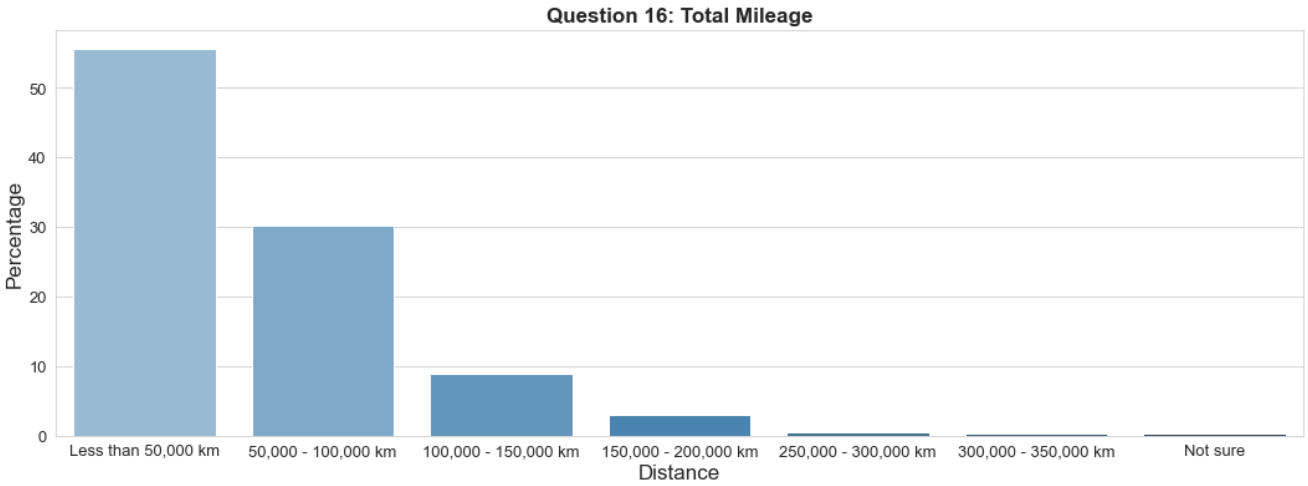
Question 12: Home Charging Type

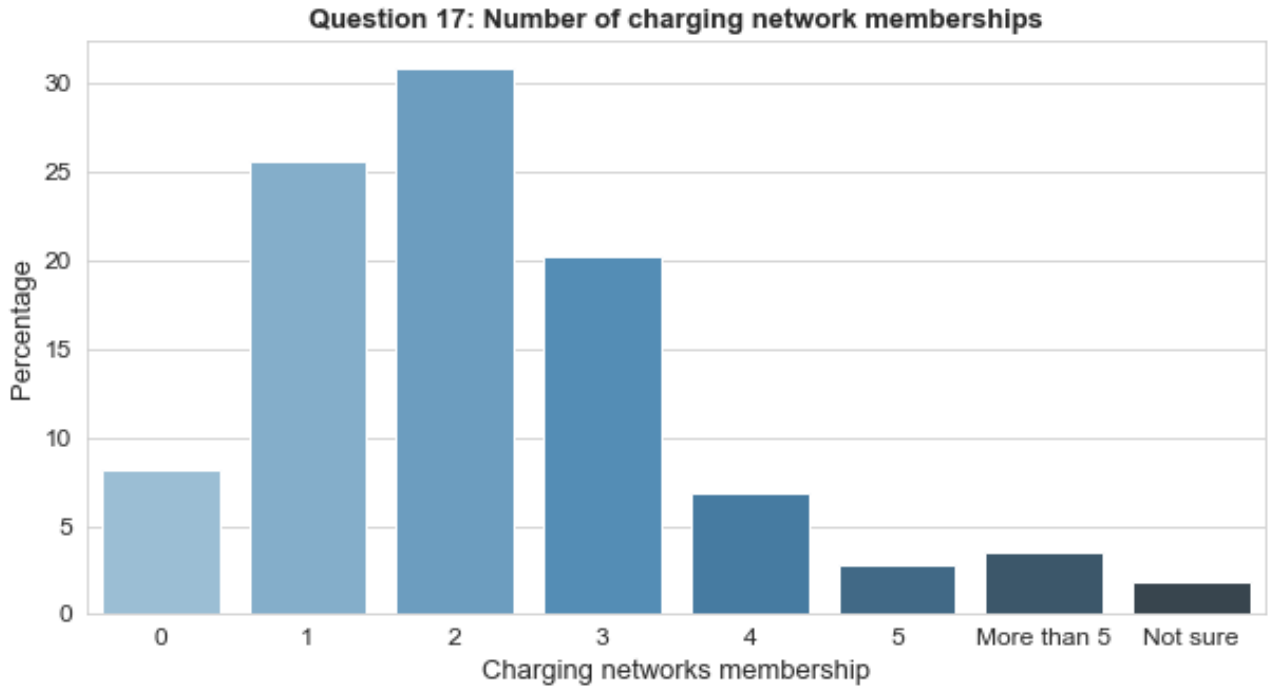


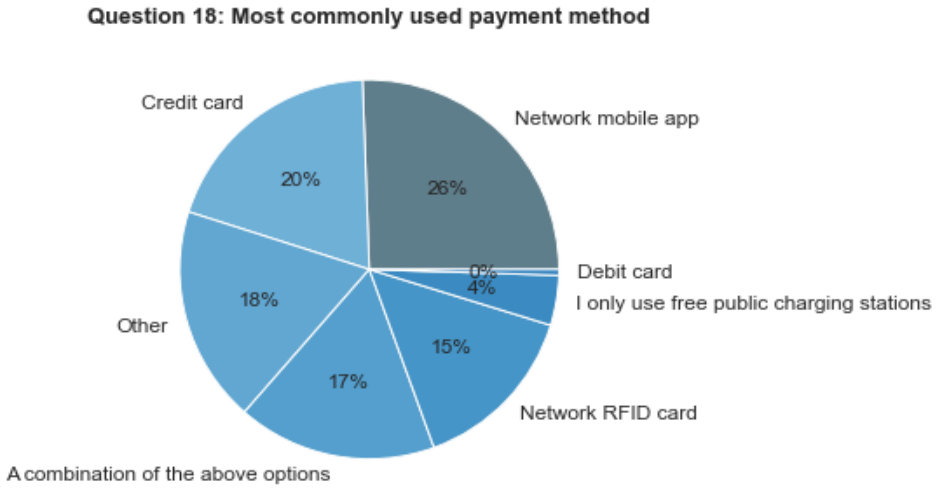

Question 13: Total charging that occurs away from home
Percentage
0
10
20
30
40
50
0
1-10%
11-25%
26-50%
51-75%
76-100%
Not sure
Proportion


Question 14: Total DCFC charging that occurs away from home
Percentage
0
10
20
30
40
50
0
1-10%
11-25%
26-50%
51-75%
76-100%
Not sure
Proportion


Question 15: EV used for long-distance trip (200 km one-way) at least once per month
No
62%
38%
Yes

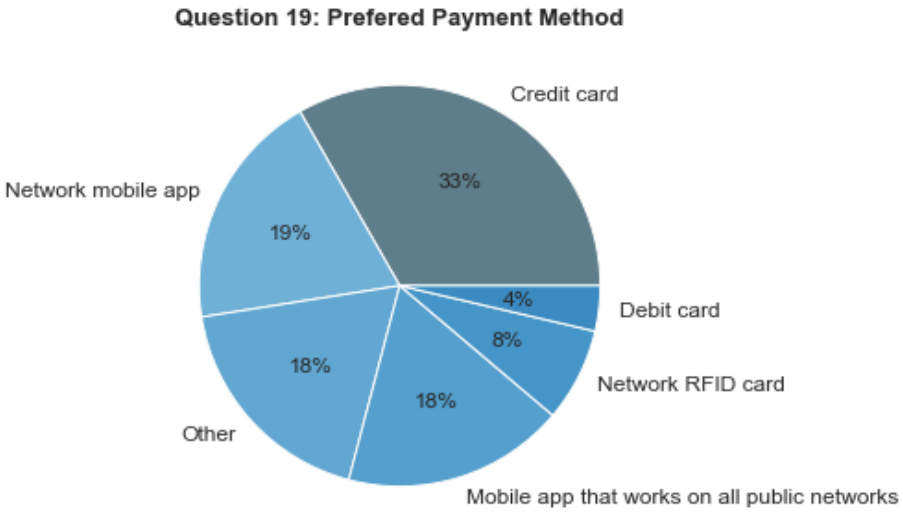

Question 16: Total Mileage
Percentage
0
10
20
30
40
50
Less than 50,000 km
50,000 - 100,000 km
100,000 - 150,000 km
150,000 - 200,000 km
250,000 - 300,000 km
300,000 - 350,000 km
Not sure
Distance

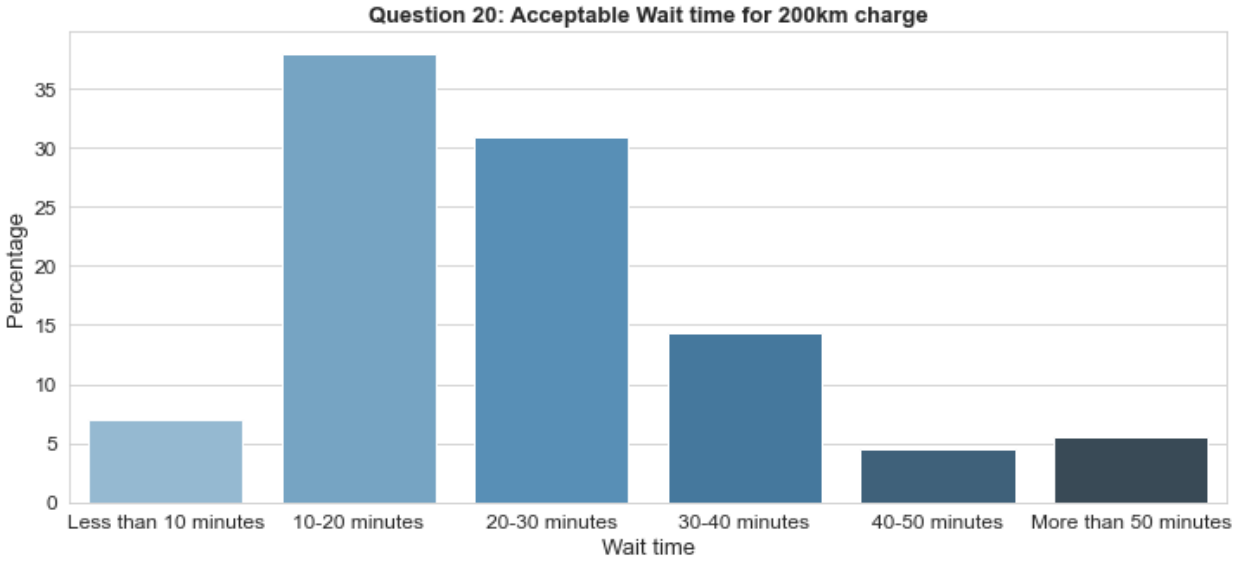




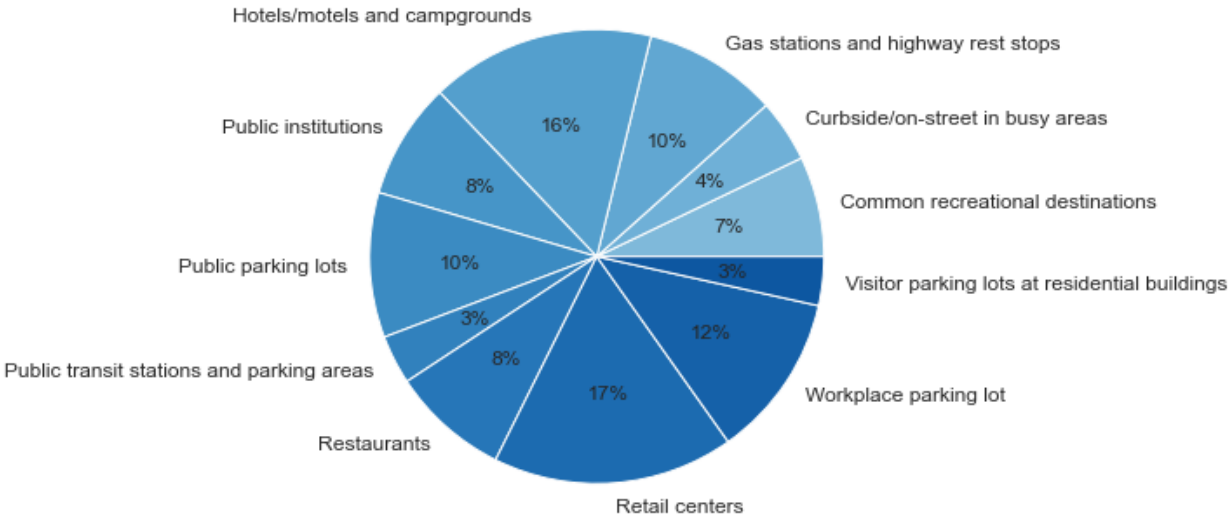
[23]

[23] The 'Other' payment method was found to mainly consist of 'vehicle-based billing' associated with Tesla vehicles

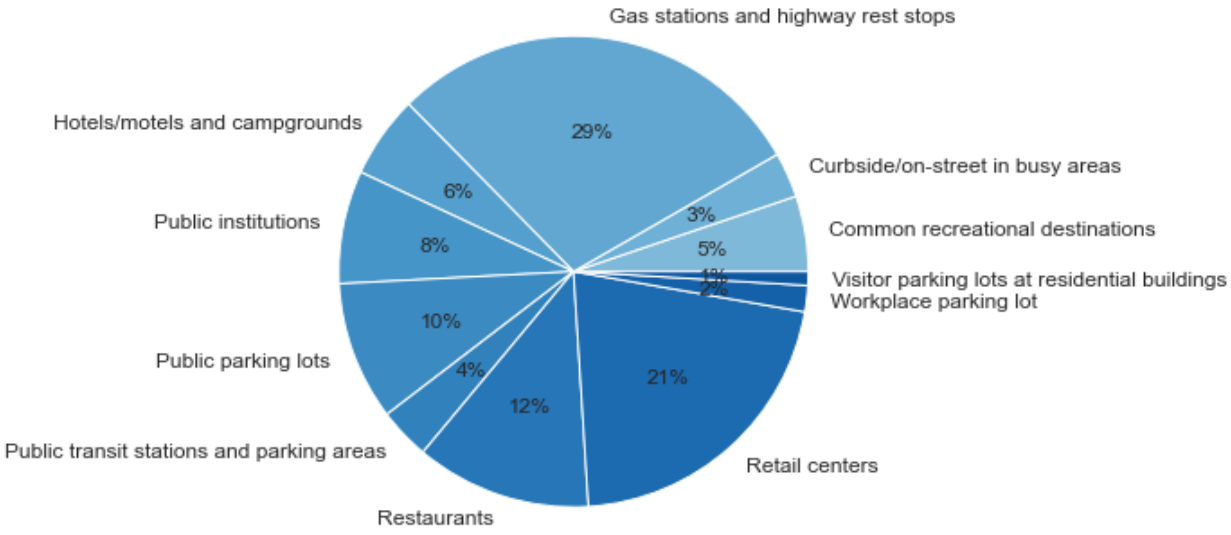

Question 19: Prefered Payment Method
Credit card
33%
Network mobile app
19%
4%
Debit card
8%
Network RFID card
18%
18%
Other
Mobile app that works on all public networks

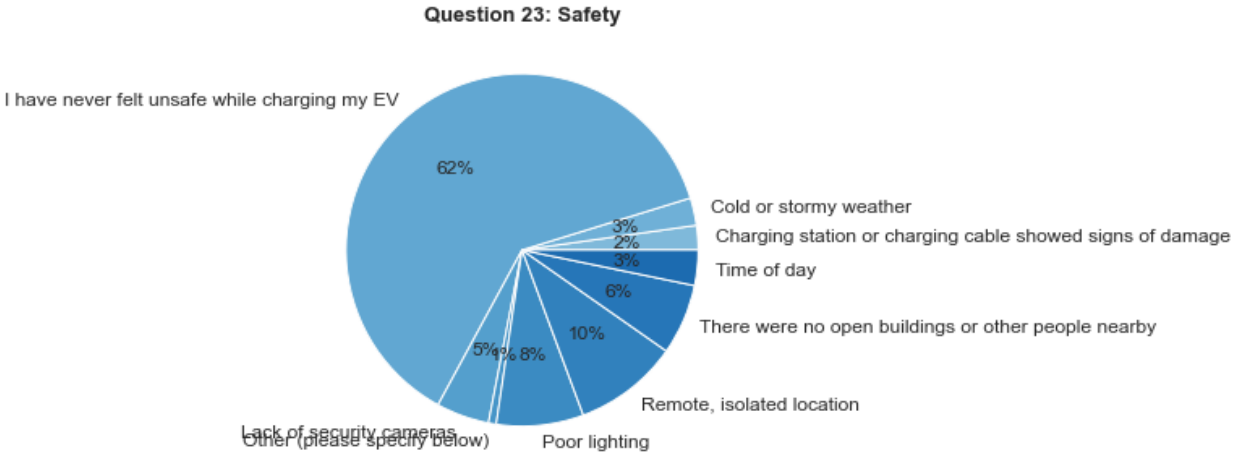

Question 20: Acceptable Wait time for 200km charge
Percentage
0
5
10
15
20
25
30
35
Less than 10 minutes
10-20 minutes
20-30 minutes
30-40 minutes
40-50 minutes
More than 50 minutes
Wait time

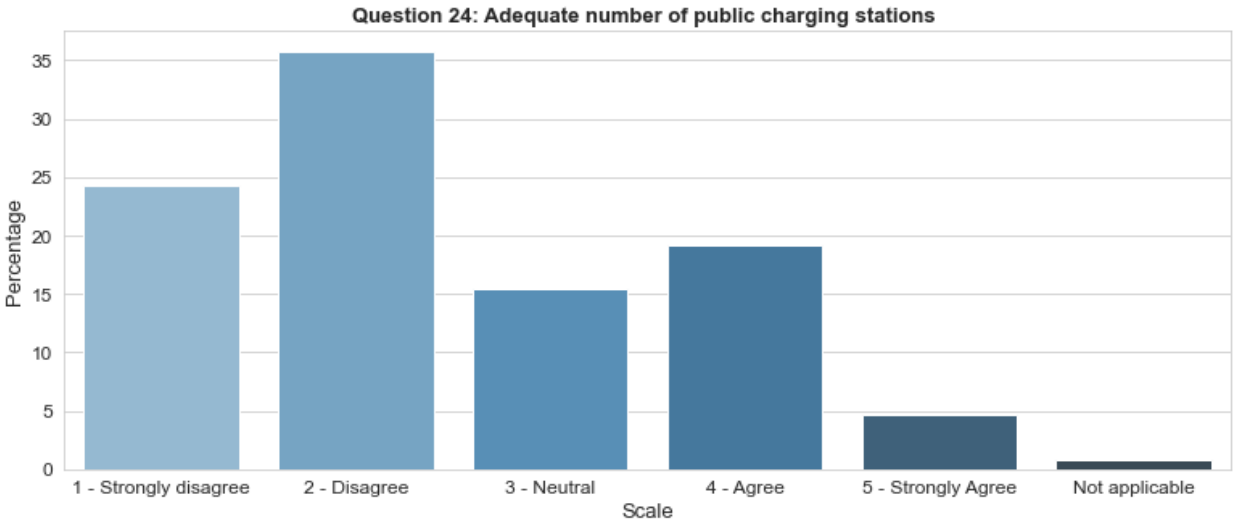
Question 21: Level 2 chargers preferred location

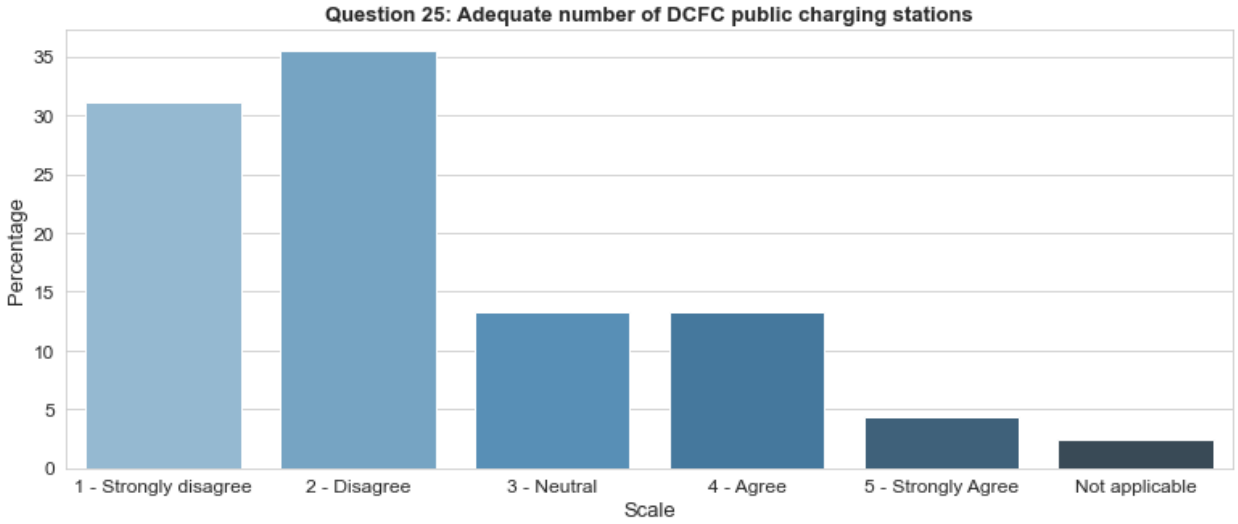


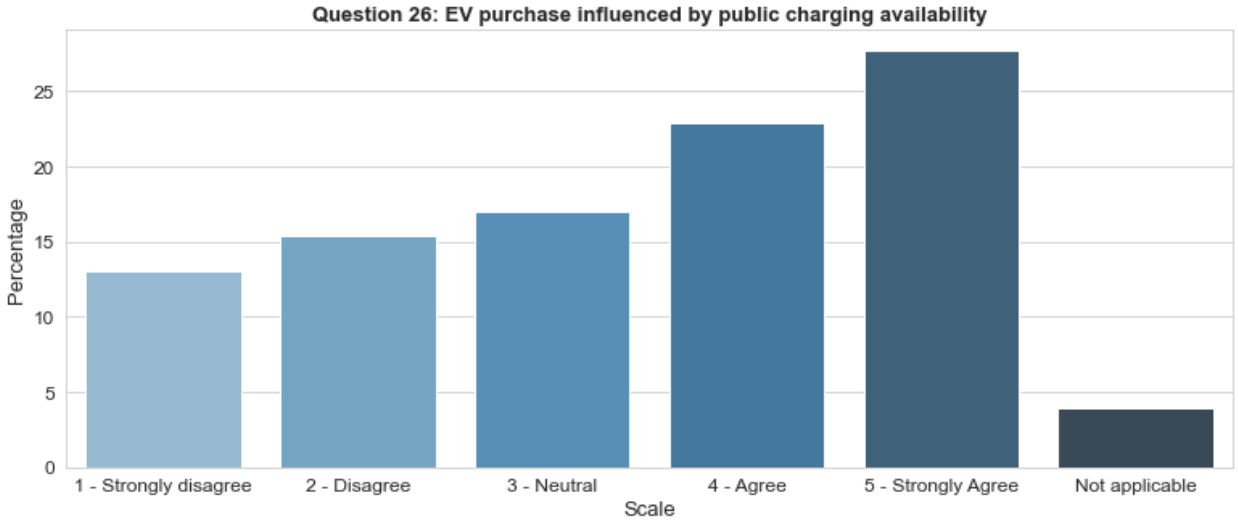
Question 22: DCFC preferred location

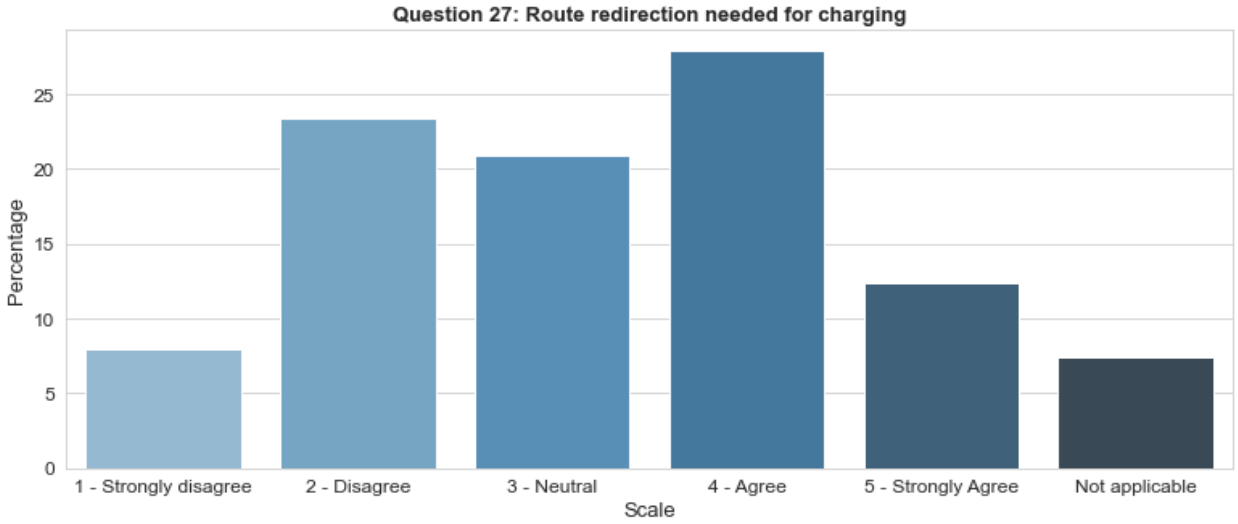


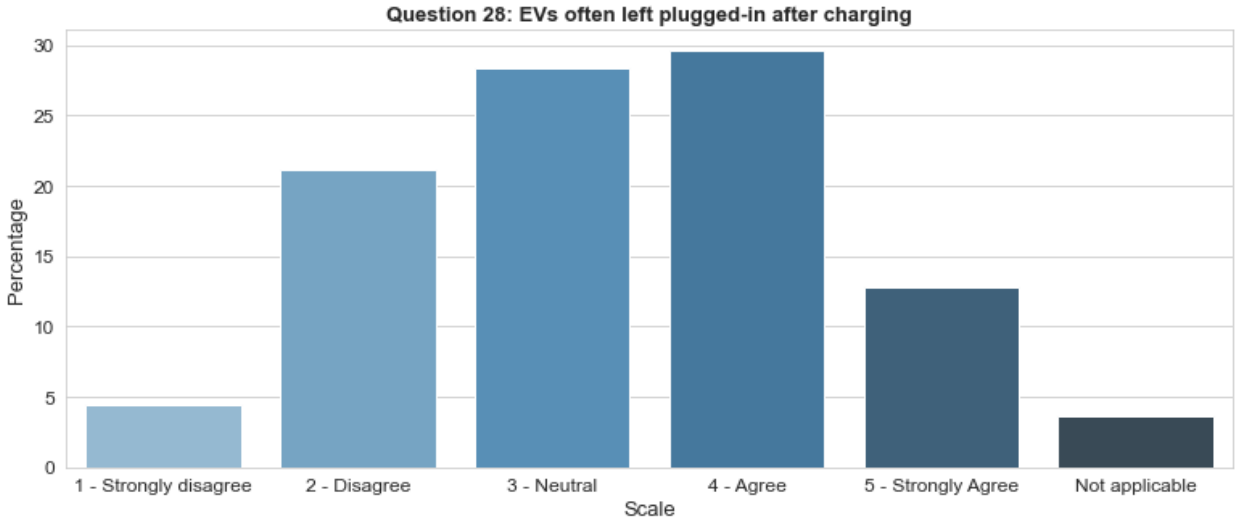

Question 23: Safety
I have never felt unsafe while charging my EV
62%
Cold or stormy weather
3%
Charging station or charging cable showed signs of damage
2%
Time of day
3%
There were no open buildings or other people nearby
6%
Remote, isolated location
10%
Poor lighting
8%
Lack of security cameras
5%
Other (please specify below)

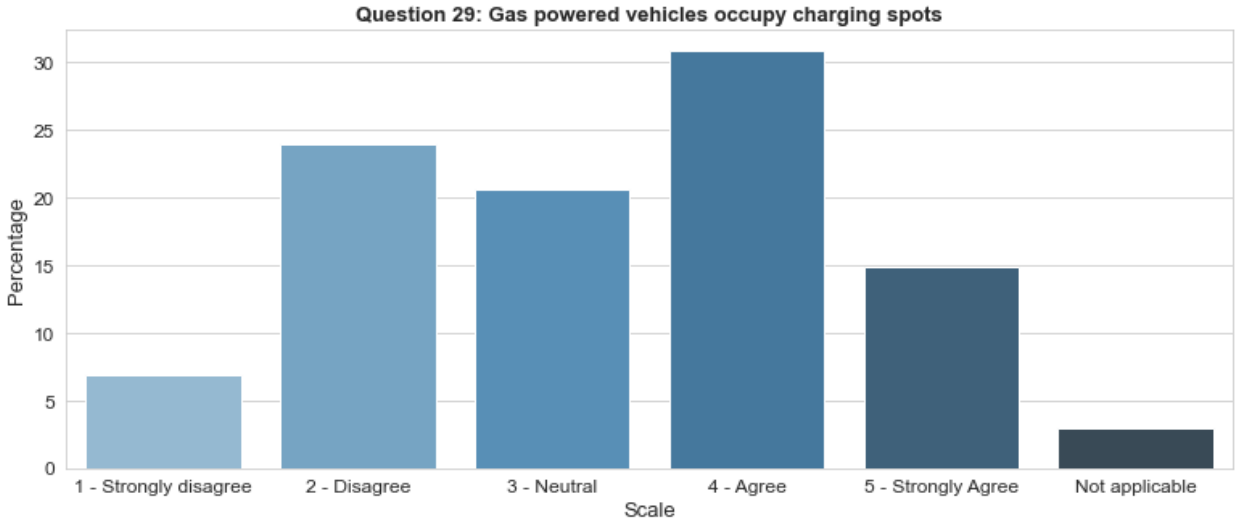

Question 24: Adequate number of public charging stations
Percentage
0
5
10
15
20
25
30
35
1 - Strongly disagree
2 - Disagree
3 - Neutral
4 - Agree
5 - Strongly Agree
Not applicable
Scale

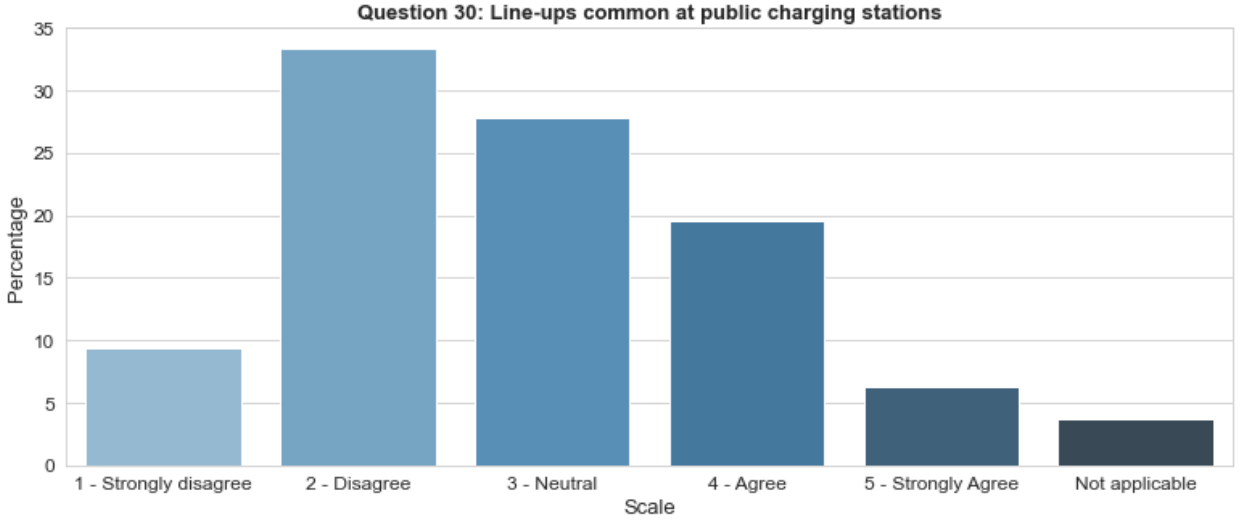

Question 25: Adequate number of DCFC public charging stations
Percentage
0
5
10
15
20
25
30
35
1 - Strongly disagree
2 - Disagree
3 - Neutral
4 - Agree
5 - Strongly Agree
Not applicable
Scale

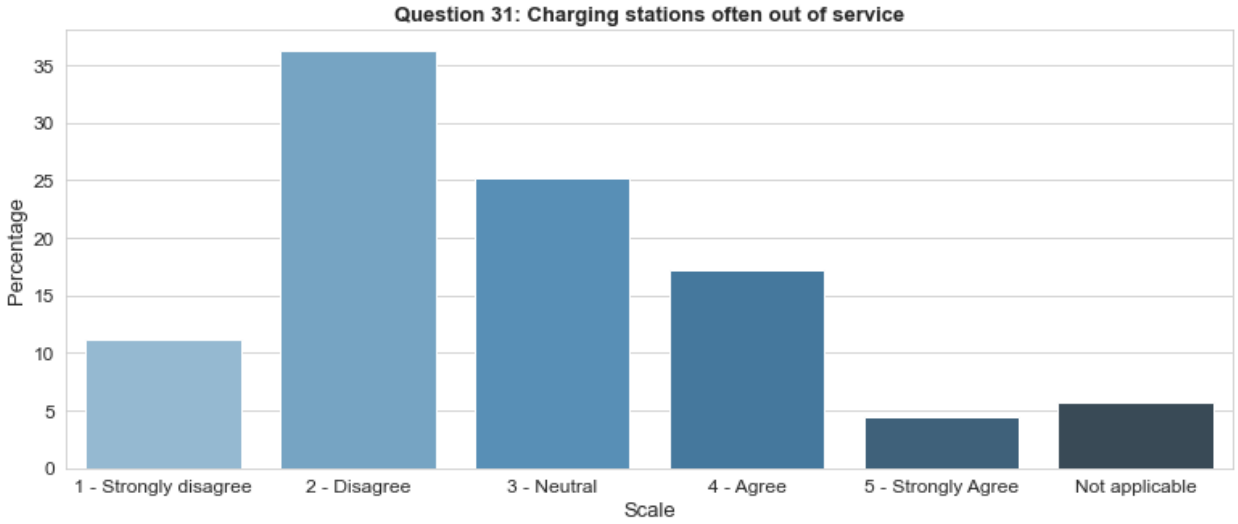

Question 26: EV purchase influenced by public charging availability
Percentage
0
5
10
15
20
25
1 - Strongly disagree
2 - Disagree
3 - Neutral
4 - Agree
5 - Strongly Agree
Not applicable
Scale

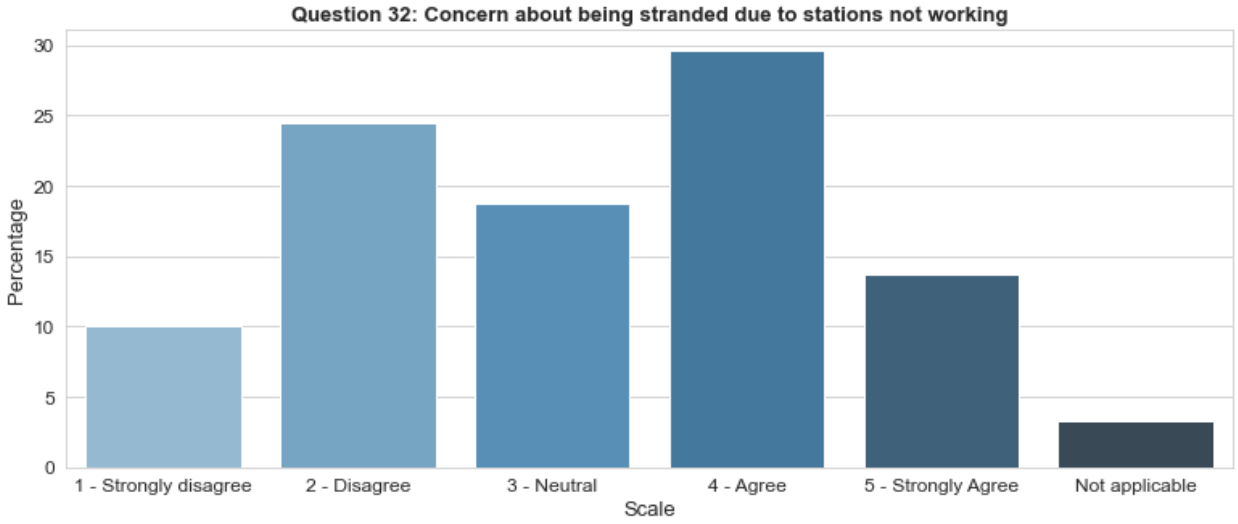

Question 27: Route redirection needed for charging
Percentage
0
5
10
15
20
25
1 - Strongly disagree
2 - Disagree
3 - Neutral
4 - Agree
5 - Strongly Agree
Not applicable
Scale

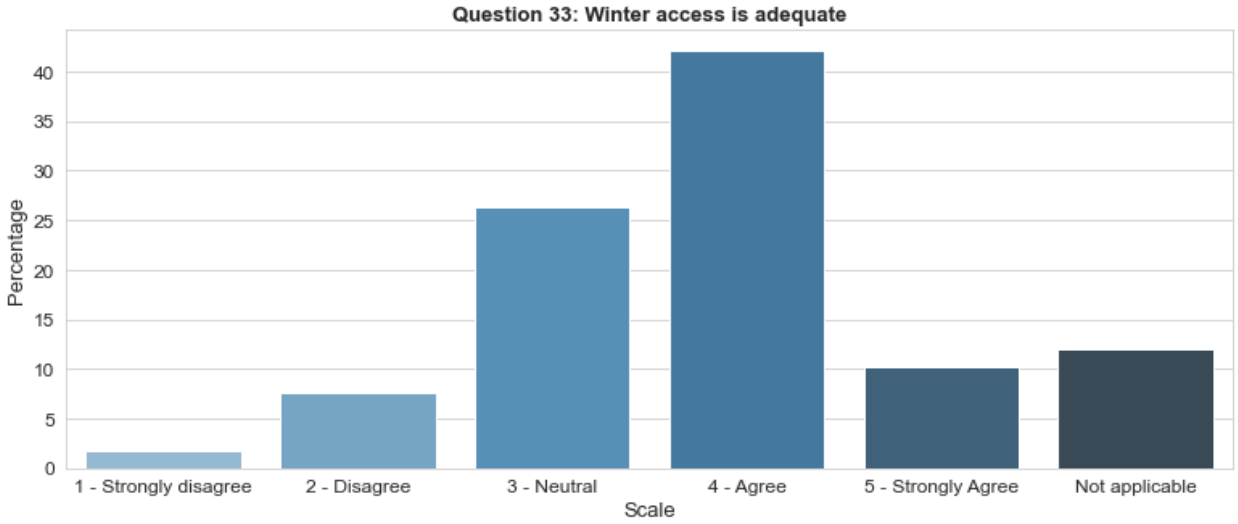

Question 28: EVs often left plugged-in after charging
Percentage
0
5
10
15
20
25
30
1 - Strongly disagree
2 - Disagree
3 - Neutral
4 - Agree
5 - Strongly Agree
Not applicable
Scale

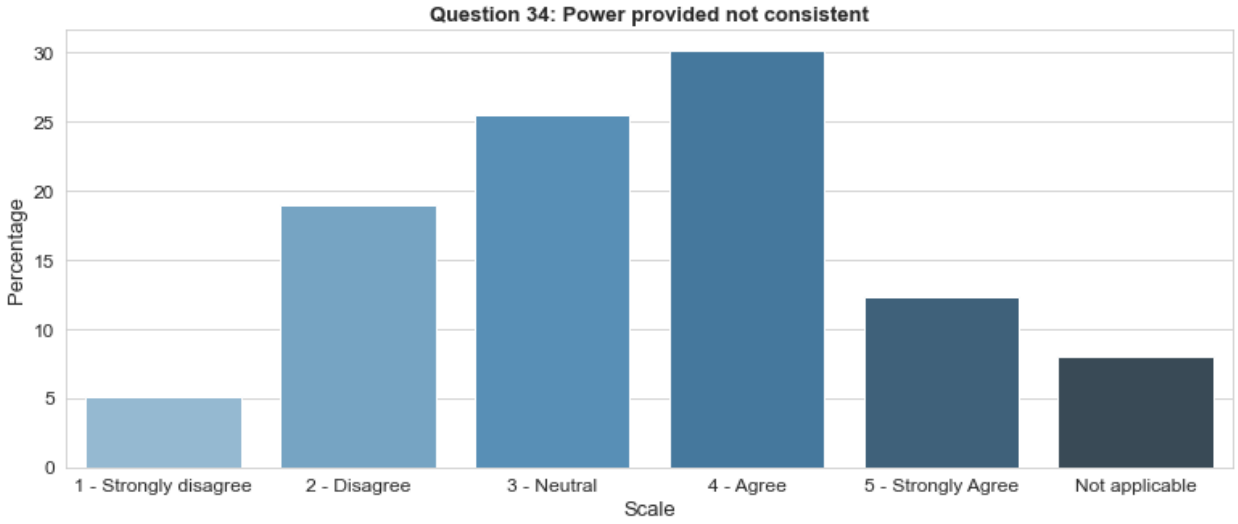

Question 29: Gas powered vehicles occupy charging spots
Percentage
0
5
10
15
20
25
30
1 - Strongly disagree
2 - Disagree
3 - Neutral
4 - Agree
5 - Strongly Agree
Not applicable
Scale

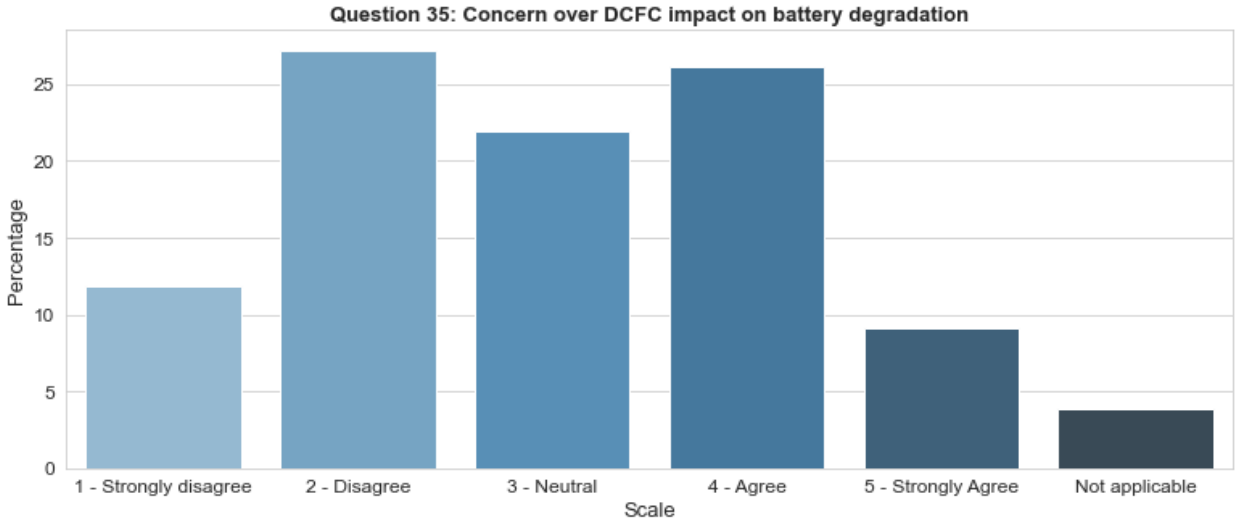

Question 30: Line-ups common at public charging stations
Percentage
0
5
10
15
20
25
30
35
1 - Strongly disagree
2 - Disagree
3 - Neutral
4 - Agree
5 - Strongly Agree
Not applicable
Scale

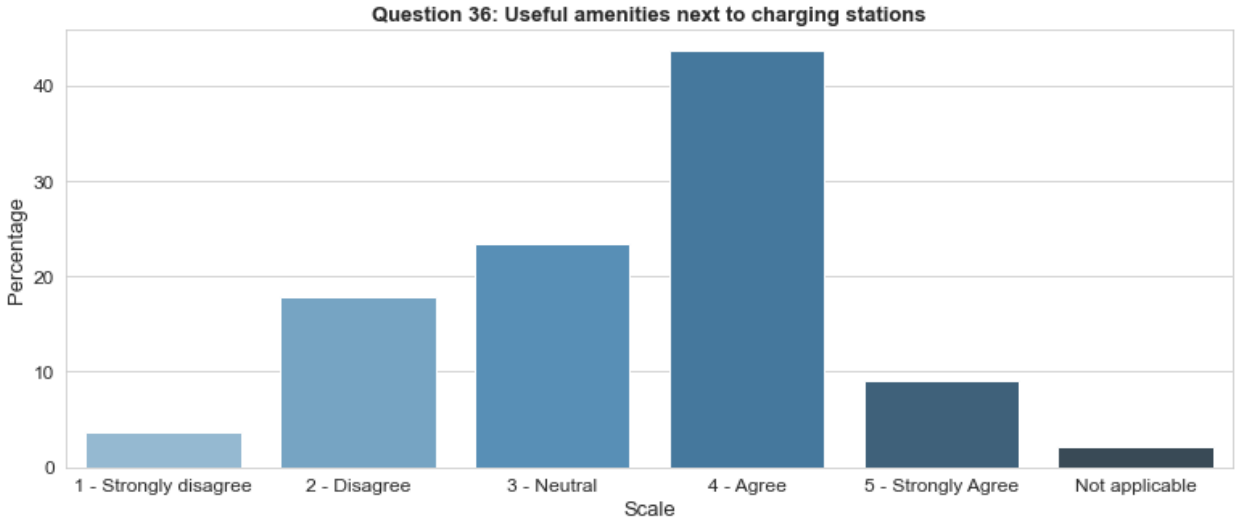

Question 31: Charging stations often out of service
Percentage
0
5
10
15
20
25
30
35
1 - Strongly disagree
2 - Disagree
3 - Neutral
4 - Agree
5 - Strongly Agree
Not applicable
Scale

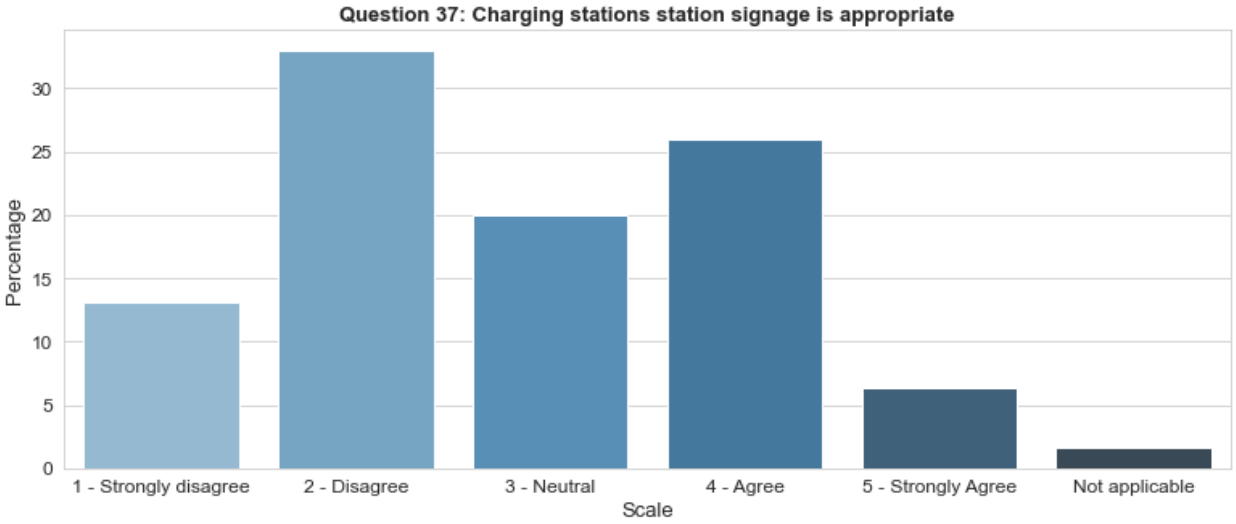

Question 32: Concern about being stranded due to stations not working
Percentage
0
5
10
15
20
25
30
1 - Strongly disagree
2 - Disagree
3 - Neutral
4 - Agree
5 - Strongly Agree
Not applicable
Scale

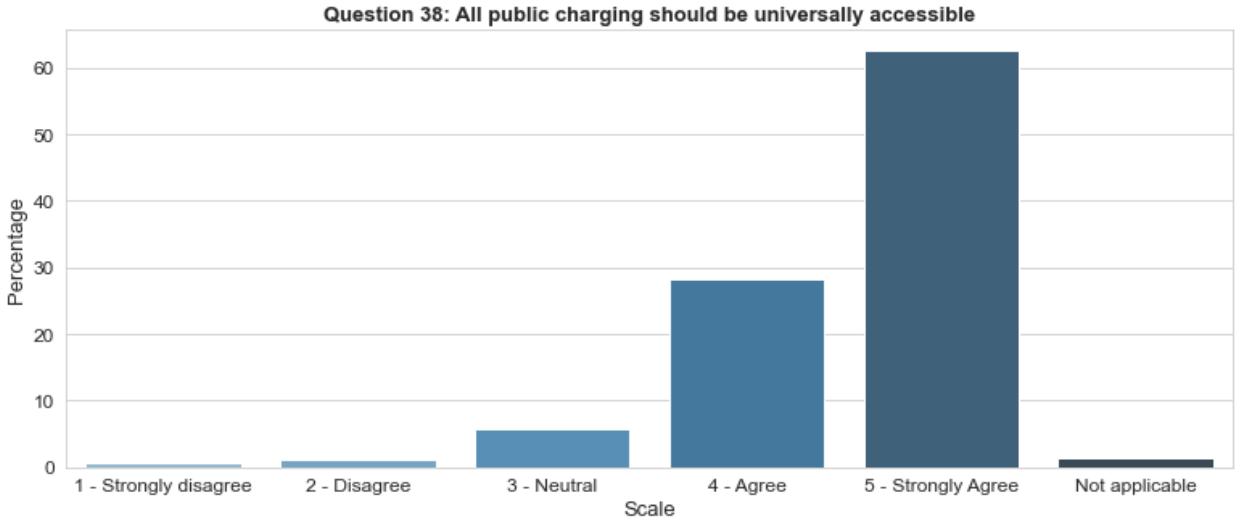

Question 33: Winter access is adequate
Percentage
0
5
10
15
20
25
30
35
40
1 - Strongly disagree
2 - Disagree
3 - Neutral
4 - Agree
5 - Strongly Agree
Not applicable
Scale

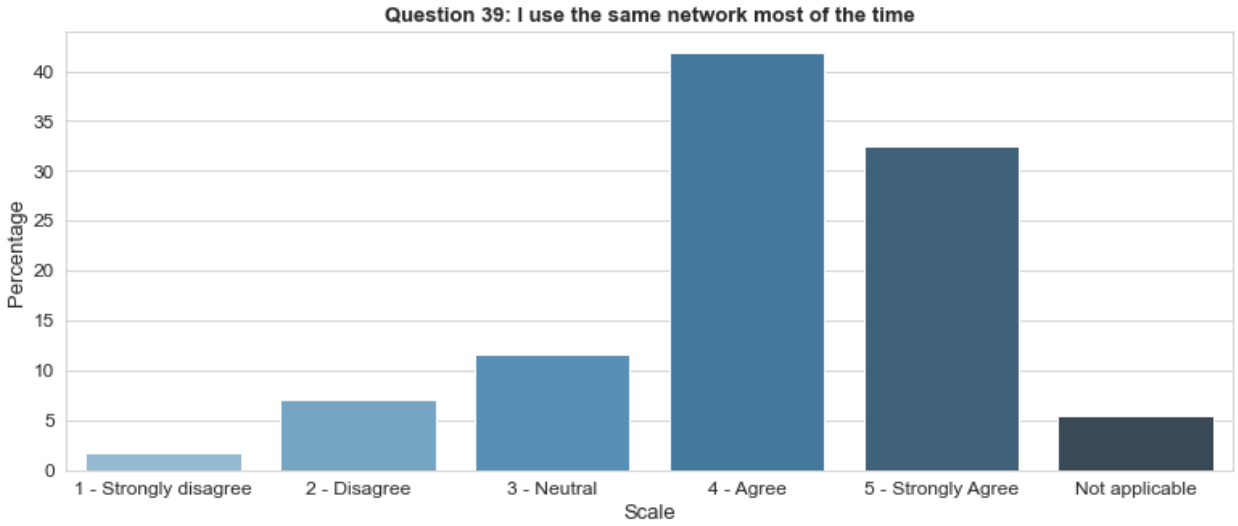

Question 34: Power provided not consistent
Percentage
0
5
10
15
20
25
30
1 - Strongly disagree
2 - Disagree
3 - Neutral
4 - Agree
5 - Strongly Agree
Not applicable
Scale

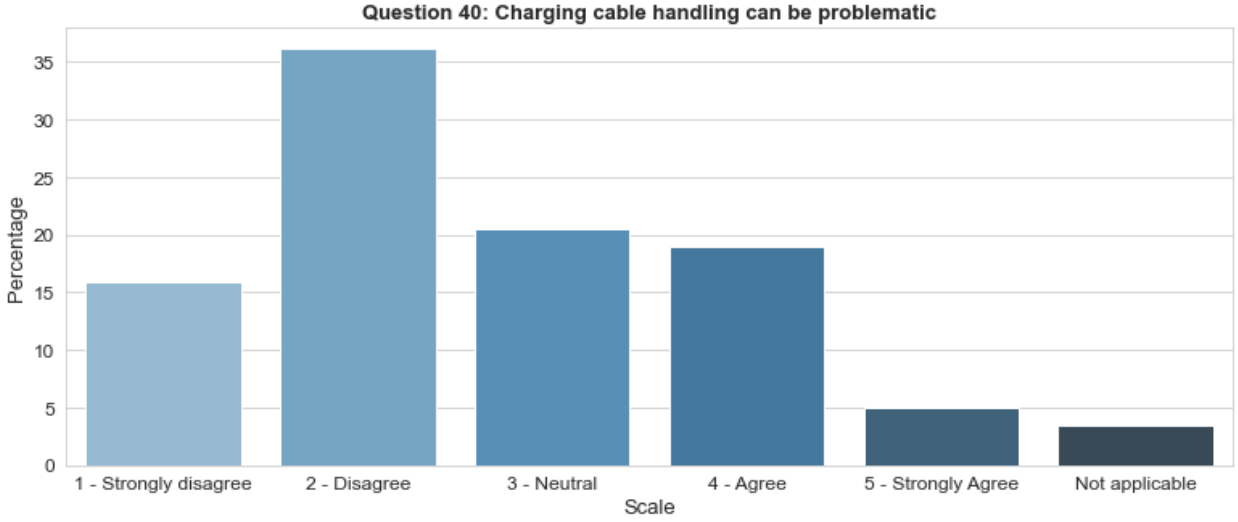

Question 35: Concern over DCFC impact on battery degradation
Percentage
0
5
10
15
20
25
1 - Strongly disagree
2 - Disagree
3 - Neutral
4 - Agree
5 - Strongly Agree
Not applicable
Scale

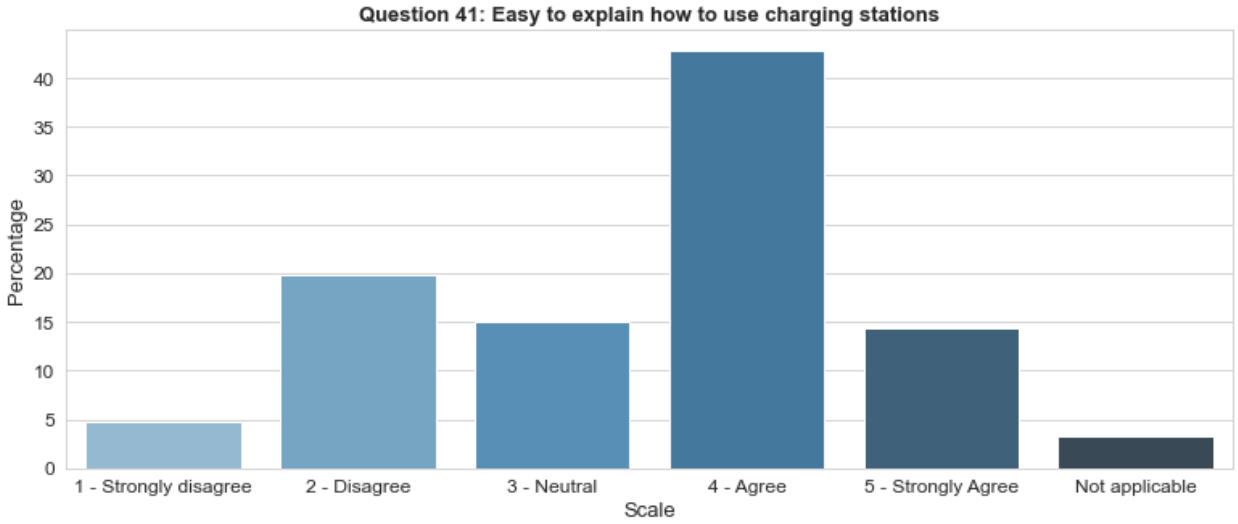

Question 36: Useful amenities next to charging stations
Percentage
0
10
20
30
40
1 - Strongly disagree
2 - Disagree
3 - Neutral
4 - Agree
5 - Strongly Agree
Not applicable
Scale

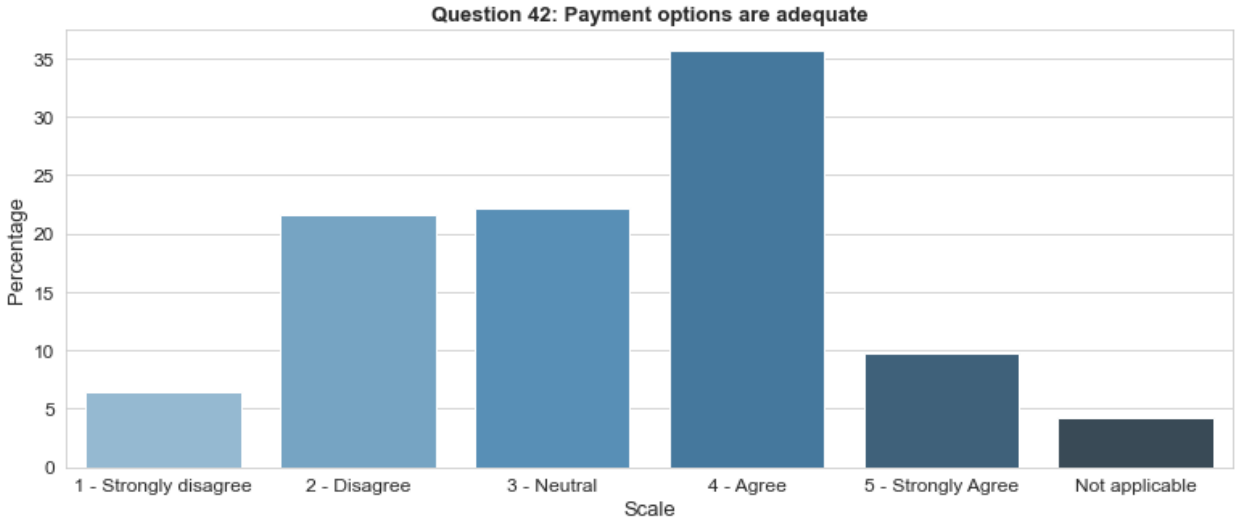

Question 37: Charging stations station signage is appropriate
Percentage
0
5
10
15
20
25
30
1 - Strongly disagree
2 - Disagree
3 - Neutral
4 - Agree
5 - Strongly Agree
Not applicable
Scale

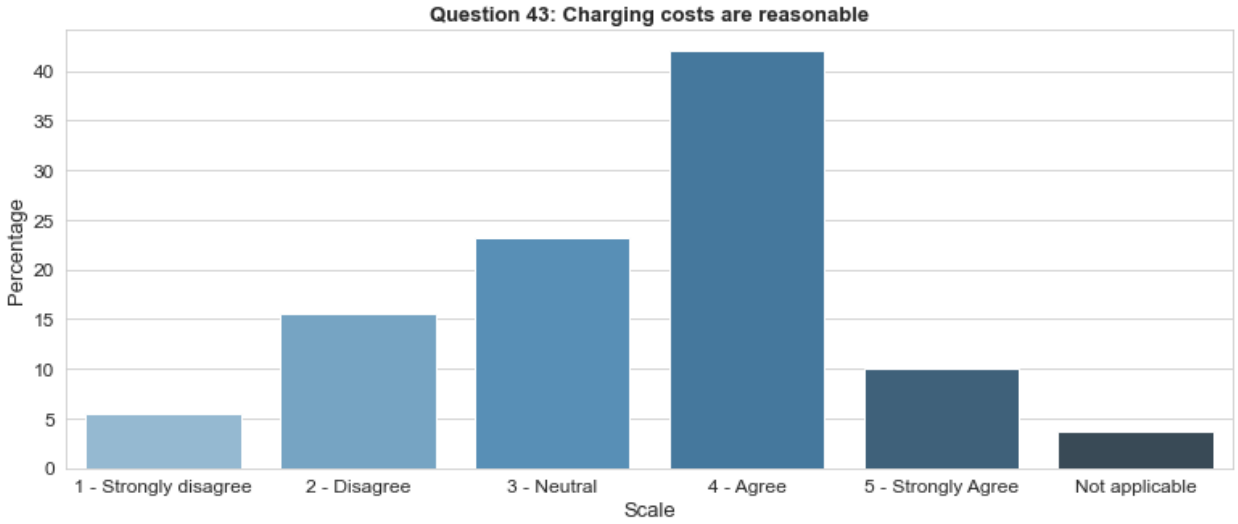

Question 38: All public charging should be universally accessible
Percentage
0
10
20
30
40
50
60
1 - Strongly disagree
2 - Disagree
3 - Neutral
4 - Agree
5 - Strongly Agree
Not applicable
Scale

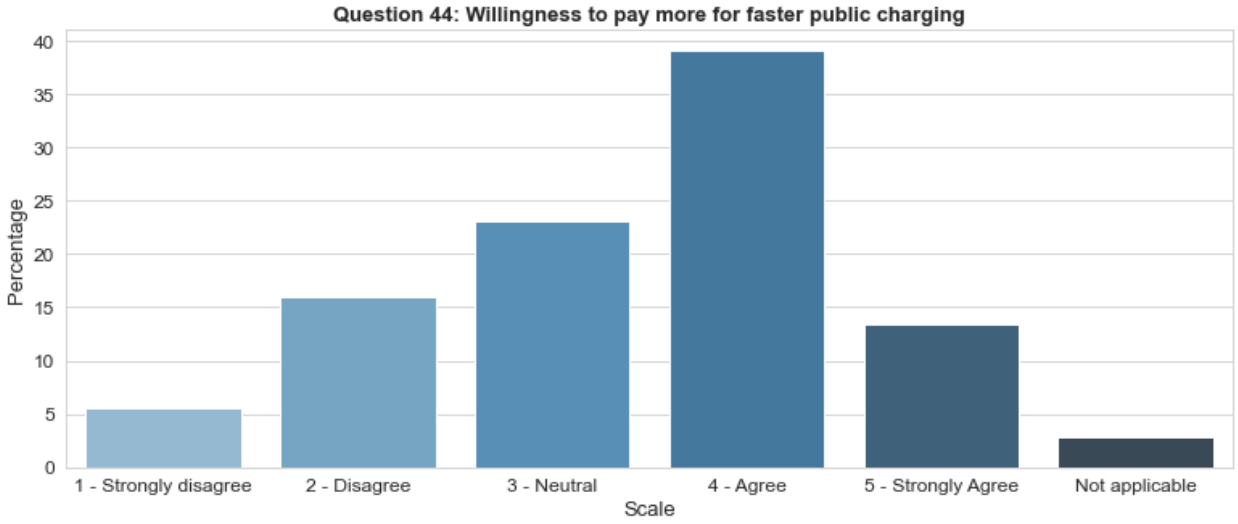

Question 39: I use the same network most of the time
Percentage
0
5
10
15
20
25
30
35
40
1 - Strongly disagree
2 - Disagree
3 - Neutral
4 - Agree
5 - Strongly Agree
Not applicable
Scale

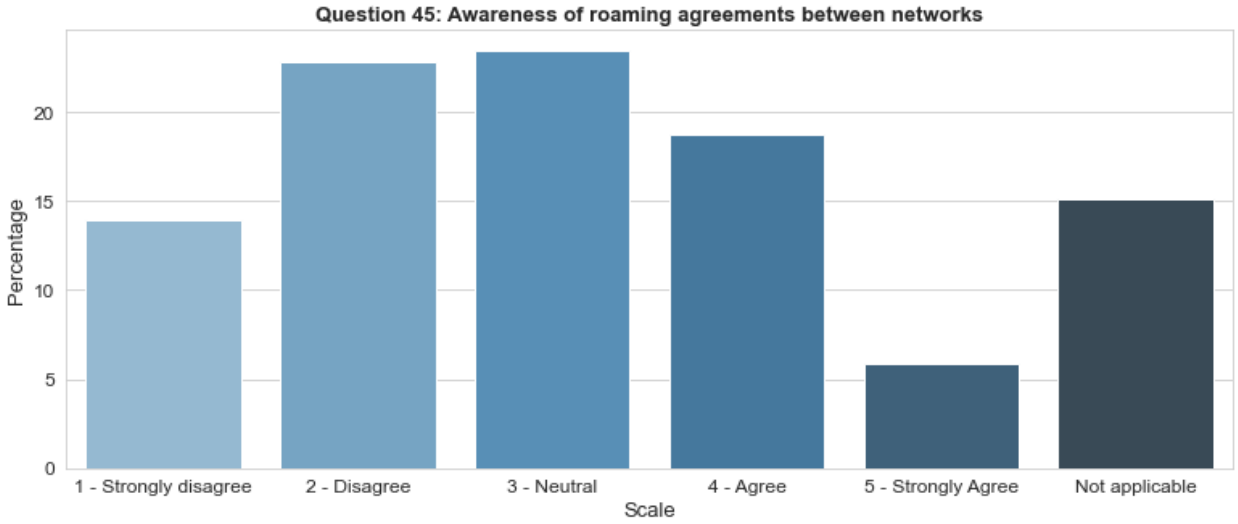

Question 40: Charging cable handling can be problematic
Percentage
0
5
10
15
20
25
30
35
1 - Strongly disagree
2 - Disagree
3 - Neutral
4 - Agree
5 - Strongly Agree
Not applicable
Scale

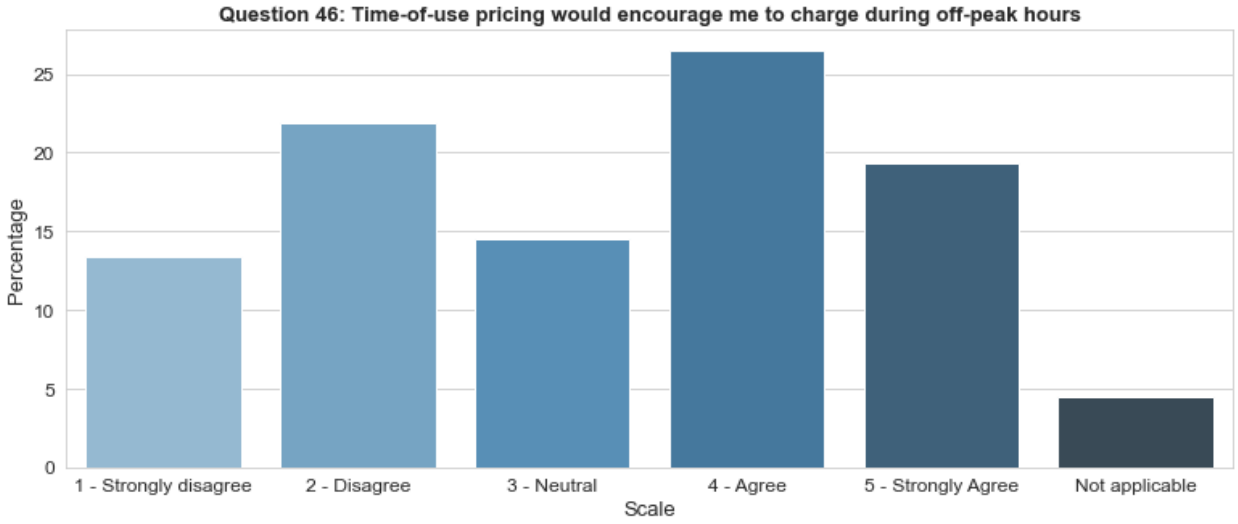

Question 41: Easy to explain how to use charging stations
Percentage
0
5
10
15
20
25
30
35
40
1 - Strongly disagree
2 - Disagree
3 - Neutral
4 - Agree
5 - Strongly Agree
Not applicable
Scale

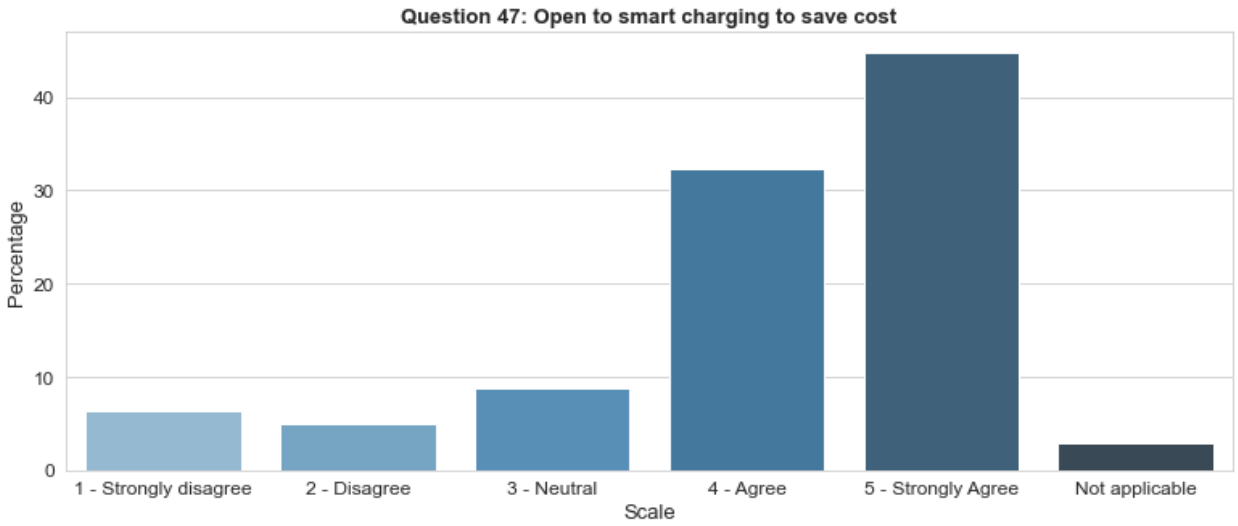

Question 42: Payment options are adequate
Percentage
0
5
10
15
20
25
30
35
1 - Strongly disagree
2 - Disagree
3 - Neutral
4 - Agree
5 - Strongly Agree
Not applicable
Scale

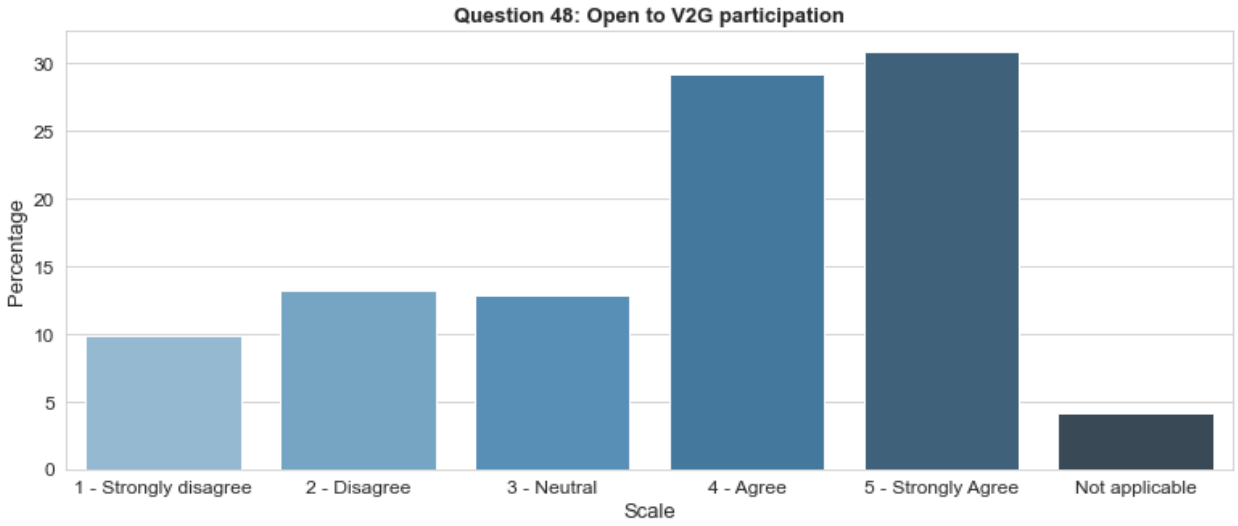

Question 43: Charging costs are reasonable
Percentage
0
5
10
15
20
25
30
35
40
1 - Strongly disagree
2 - Disagree
3 - Neutral
4 - Agree
5 - Strongly Agree
Not applicable
Scale


Question 44: Willingness to pay more for faster public charging
Percentage
0
5
10
15
20
25
30
35
40
1 - Strongly disagree
2 - Disagree
3 - Neutral
4 - Agree
5 - Strongly Agree
Not applicable
Scale


Question 45: Awareness of roaming agreements between networks
Percentage
0
5
10
15
20
1 - Strongly disagree
2 - Disagree
3 - Neutral
4 - Agree
5 - Strongly Agree
Not applicable
Scale


Question 46: Time-of-use pricing would encourage me to charge during off-peak hours
Percentage
0
5
10
15
20
25
1 - Strongly disagree
2 - Disagree
3 - Neutral
4 - Agree
5 - Strongly Agree
Not applicable
Scale


Question 47: Open to smart charging to save cost
Percentage
0
10
20
30
40
1 - Strongly disagree
2 - Disagree
3 - Neutral
4 - Agree
5 - Strongly Agree
Not applicable
Scale


Question 48: Open to V2G participation
Percentage
0
5
10
15
20
25
30
1 - Strongly disagree
2 - Disagree
3 - Neutral
4 - Agree
5 - Strongly Agree
Not applicable
Scale