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Swedish EV users' routines and behaviors without home charging availability

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This paper presents the results of an online survey addressed to current EV users in Sweden. The aim of the paper is to improve knowledge of a previously overlooked group in the electric vehicle adoption literature – households that lack the possibility to install their own home charger. Of specific interest in this investigation is revealing the charging needs, behaviors, and perceptions of this group. The results of the study are based on an online survey with 250 EV users, the majority of whom were in Gothenburg. EV users were divided into two groups: a group with home charging availability and a group without home charging availability. Linear regression models comparing the two groups showed that users without home charging availability perceive public charging as less convenient, further from their homes, and they have a lower perception of freedom to charge.
Keywords: Electric Vehicles; Consumer behaviour; Social equity; Optimal charging locations

1 Introduction

Adoption of electric vehicles has thus far predominantly taken place in households residing in single-family houses [1]. One plausible explanation for this phenomenon is that single-family houses generally have the technical and physical possibilities to install a home charger at their property, and that the households possess the legal mandate to initiate such an installation. The importance and intense use of home chargers have been highlighted in several previous studies [2,3].

For electric vehicles to reach a larger share of vehicle-owning households, more emphasis needs to be placed on understanding how to overcome barriers for households that do not possess the necessary conditions to install their own home charger. Although this group is likely not homogeneous, it is reasonable to assume that many reside in multi-dwelling units and rely on on-street parking. It is also likely that there are significant geographical differences between and within countries. An investigation in Denmark revealed that 80 percent of Danish households have parking situated at their residence, but the corresponding share in the capital city Copenhagen was only 20 percent [4]. Currently, little is known about this group of households that lack their own parking and thus the mandate to install a home charger. The case from Denmark highlighted above gives a broad overview of the size of the group. More research is needed to estimate the size of this group of households and their geographical and demographic characteristics.

The Swedish project "El för ännu fler" (Electricity for more), funded by the Swedish Innovation Agency Vinnova, was initiated in 2023 with the specific aim to explore the group of existing and potential users of electric vehicles that do not have access to parking and thus lack the possibility to install a home charger.

This paper focuses on current electric vehicle users that lack their own parking and home charging. A group which, to our knowledge, has not previously been investigated in the literature. This study aims to improve the understanding of the behaviors, routines, and perceptions of charging of this group. Knowledge that could provide valuable insights into the challenges that need to be addressed, as well as in the ongoing commercial and policy work in planning for charging infrastructure expansion.

1.1 Research questions

RQ1. Do EV owners who do not have home charging availability differ from EV owners who have home charging in terms of sociodemographic variables, behavioral patterns, attitudes, and perceptions of public charging?

RQ2. What are the main needs of Swedish EV owners who do not have home charging availability?

RQ3. What are the charging behavior patterns of this group?

RQ4. What are the perceptions of public charging of this group?

2 Method

An online survey was sent out by parking and charging operators to EV users, the majority of whom were in Gothenburg. The survey covers overall evaluations of routines for charging, such as charging location, possibility to charge at work, and overall evaluation of public charging. An appendix with the survey questions is available upon request to the authors.

A sample of 250 respondents completed 80% of the survey's questions. The majority of the respondents are men (N = 195; 78%), with no children in the household (N = 161; 64.4%), living in an apartment owned (N = 106; 42.4%) or rented (N = 90; 36%). They mostly own/lease one car (N = 195; 78%), the majority of the cars are BEVs (N = 179; 71.6%), and a total of 119 respondents (47.6%) reported not having home charging availability.

The survey comprised 27 questions, divided into three main blocks: 1) driving and charging behavior (frequency of charging, charging availability, types of charging), 2) attitudes and perceptions of EV owners (perceptions of public charging infrastructure, availability, comfort, price), and 3) sociodemographic characteristics (household characteristics, amount and types of cars in the household, presence of children in the household, gender, and age).

3 Results

This section is organized by the four research questions stated in the introduction. The results focus on the group of interest in this study – EV users who do not have home charging availability. Therefore, the respondents were divided into two groups based on the question: "*Think about your routine at home, do you have access to a charger when you park at home?*". The options for answers were: "No", "Yes", "Yes, but it is rarely available when I want to charge", "I don't know", and "Not applicable". For the purpose of the analyses, two groups were formed: the Group without home charging availability (those who answered "No") and the Group with home charging availability (those who answered "Yes" and "Yes, but it is rarely available when I want to charge"). The other answers were not considered for analyses. The two groups accounted for 80% of the respondents to the survey.

3.1 RQ1 - Do EV owners who do not have home charging availability differ from EV owners who have home charging in terms of sociodemographic variables, behavioral patterns, attitudes, and perceptions of public charging?

Table1 shows the sociodemographic differences between both groups, addressing the first research question RQ1. There were no substantial differences between the groups, except that the group without home charging availability tend to live in apartments.

1.1 RQ2 - What are the main needs of Swedish EV owners who do not have home charging availability? RQ3 - What are the charging behavior patterns of this group?

The results that address research question RQ2 are interconnected, as they both show the needs and current behavioral patterns of EV users. These results are also reported with comparisons between the two groups – users with and without home charging availability.

Distance to public charging: Respondents were asked to report the distance to the most used public charger. The median for the group without home charging was 500 meters (SD = 3893.9), and for the group with home charging availability, the median distance was 400 meters (SD = 45796.28). When asked for the distance to the closest public charging to their homes, both groups reported a median distance of 300 meters (SD = 4995.19 for the group with home charging availability and SD = 750.53 for the group without home charging availability).

Table1. Sociodemographic characteristics of EV users with and without home charging availability.

	Home charging not available (N=119)	Home charging (N=129)	Overall (N=248)
Gender			
Female	24 (20.2%)	27 (20.9%)	51 (20.6%)
Male	95 (79.8%)	99 (76.7%)	194 (78.2%)
Prefer not to say	0 (0%)	1 (0.8%)	1 (0.4%)
Missing	0 (0%)	2 (1.6%)	2 (0.8%)
Age			
21-29	6 (5.0%)	3 (2.3%)	9 (3.6%)
30-39	21 (17.6%)	20 (15.5%)	41 (16.5%)
40-49	26 (21.8%)	33 (25.6%)	59 (23.8%)
50-59	35 (29.4%)	33 (25.6%)	68 (27.4%)
60 or older	27 (22.7%)	32 (24.8%)	59 (23.8%)
Missing	4 (3.4%)	8 (6.2%)	12 (4.8%)
Children			
No	82 (68.9%)	79 (61.2%)	161 (64.9%)
Yes	36 (30.3%)	49 (38.0%)	85 (34.3%)
Missing	1 (0.8%)	1 (0.8%)	2 (0.8%)
Housing			
A house (villa/radhus)	7 (5.9%)	42 (32.6%)	49 (19.8%)
Apartment (that I own)	57 (47.9%)	49 (38.0%)	106 (42.7%)
Apartment (that I rent)	55 (46.2%)	35 (27.1%)	90 (36.3%)
Other	0 (0%)	1 (0.8%)	1 (0.4%)
Missing	0 (0%)	2 (1.6%)	2 (0.8%)
Number of cars			
1 car	102 (85.7%)	93 (72.1%)	195 (78.6%)
2 cars	15 (12.6%)	29 (22.5%)	44 (17.7%)
3 cars or more	2 (1.7%)	7 (5.4%)	9 (3.6%)
Car types			
BEV	87 (73.1%)	92 (71.3%)	179 (72.2%)
PHEV	29 (24.4%)	33 (25.6%)	62 (25.0%)
Missing	3 (2.5%)	4 (3.1%)	7 (2.8%)
Car ownership time			
Less than 1 year ago	38 (31.9%)	41 (31.8%)	79 (31.9%)
1 year ago	27 (22.7%)	25 (19.4%)	52 (21.0%)
2 years ago	25 (21.0%)	29 (22.5%)	54 (21.8%)
>= 3 years ago	17 (14.3%)	24 (18.6%)	41 (16.5%)
Missing	12 (10.1%)	10 (7.8%)	22 (8.9%)

Minimum State of Charge (minimum SoC): Both groups with and without home charging availability reported a median value of 20% SoC (SD = 16.73 for the group with home charging availability and SD = 11.32 for the group without home charging availability).

Charging frequency: The median frequency of charging is twice per week for both groups (SD = 1.7 for the group with home charging availability and SD = 1.42 for the group without home charging availability) (see Fig. 1).

Charging triggers: To identify potential charging triggers, respondents were asked to select from a set of options the main determinants of when and where they charge their vehicles. Respondents could choose several options. The goals of this question were to: 1) identify potential differences between the groups in terms of charging triggers; and 2) identify a potential pattern of triggers for charging. Therefore, some of the options were more goal-oriented, such as "*I have a routine that I follow*" while others reflected a more spontaneous approach, such as "*When I pass by a charging station*" The complete list of options was:

- “When I reach a certain percentage/km left in the battery.”
- “When I pass by a charging station.”
- “Convenience.”
- “Low price.”
- “When I have free time.”
- “I have a routine/strategy that I follow.”

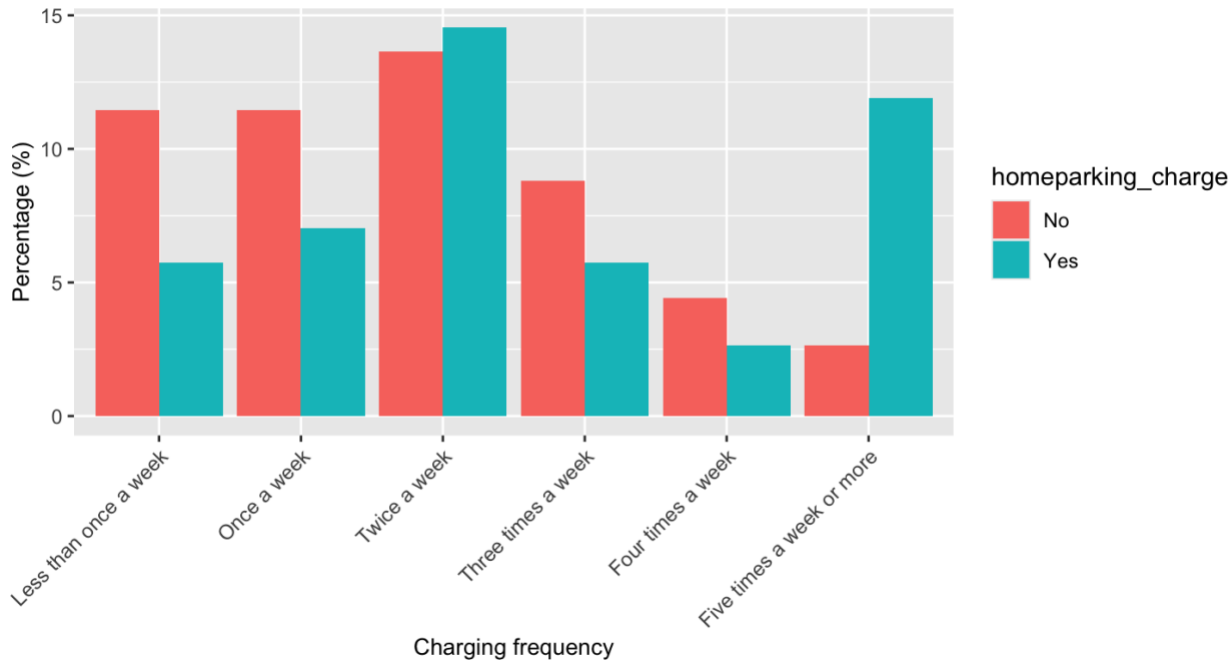

Figure 1: Charging frequencies for EV users with and without home charging availability.

For both groups, minimum SoC was the main charging trigger. Additionally, for both groups, the more spontaneous triggers “*When I have free time*” and “*When I pass by a charging station*” were the least selected options, indicating that charging is rather a goal-oriented behavior than spontaneous.

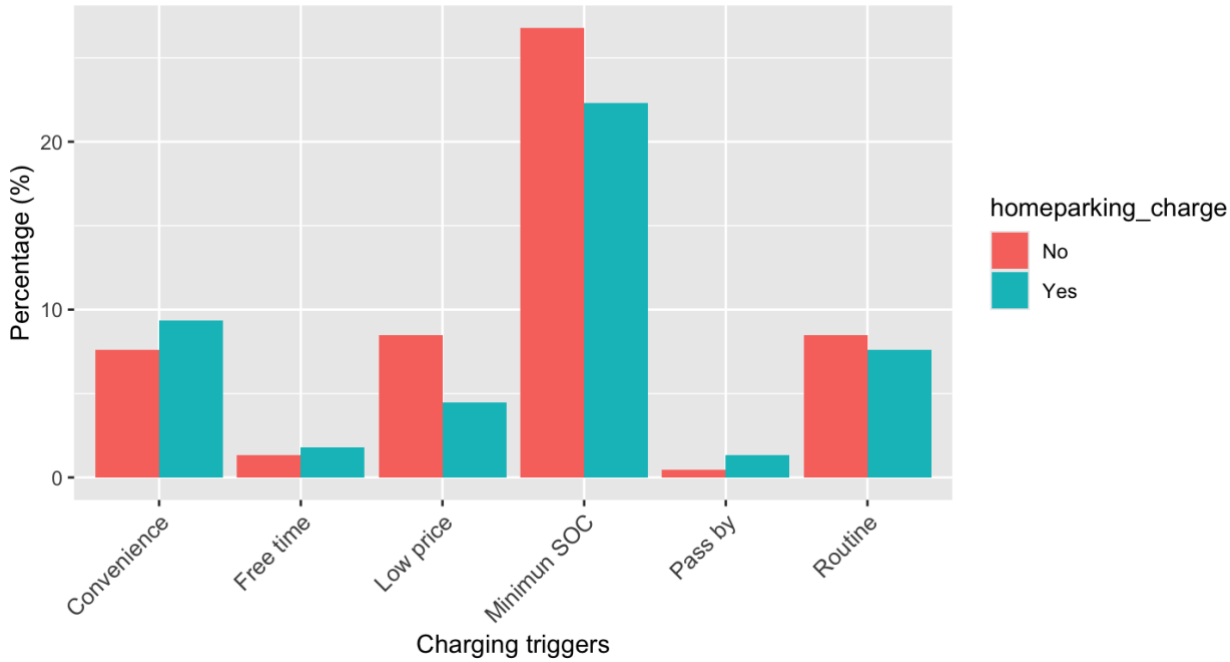

Figure 2: Charging triggers for EV users with and without home charging availability.

Work charging availability: The group without home charging availability also reported having less availability for charging at work, if compared to the group with home charging availability (see Figure 3).

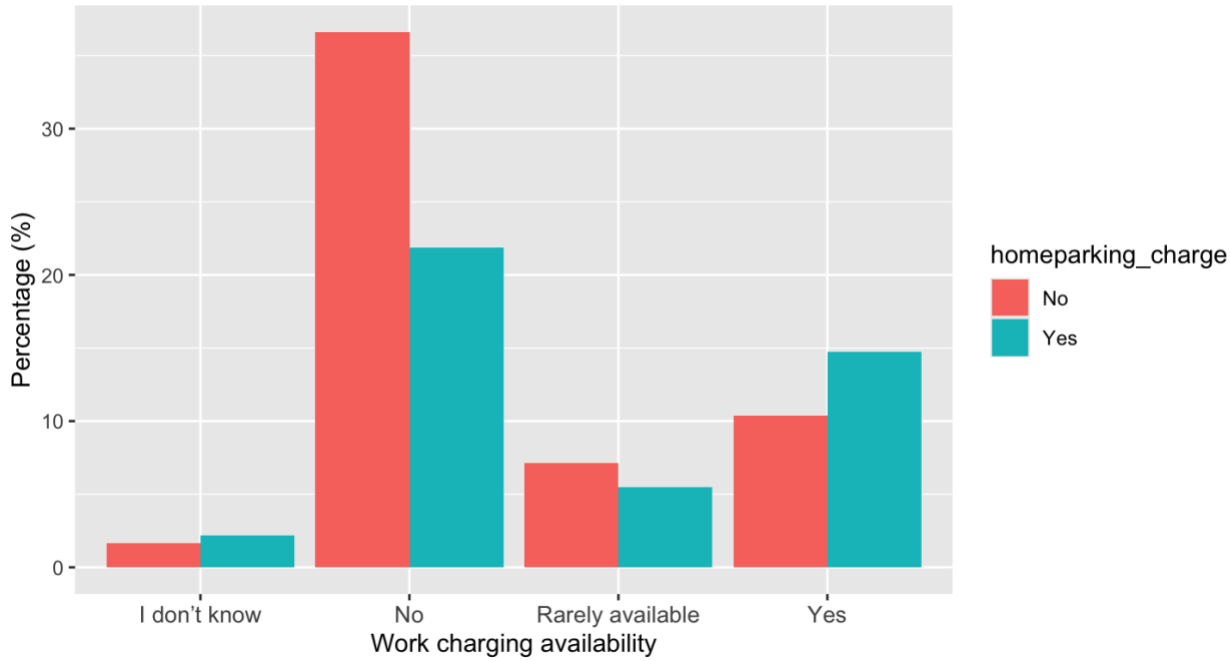

Figure 3: Work charging availability for EV users with and without home charging availability.

Work charging frequency: For those that reported having some availability for charging at work, the group with home charging availability reported charging less than once a week at work (Median = 2; SD = 1.77) and the group without home charging availability reported charging once a week at work (Median = 3.5; SD = 2.03).

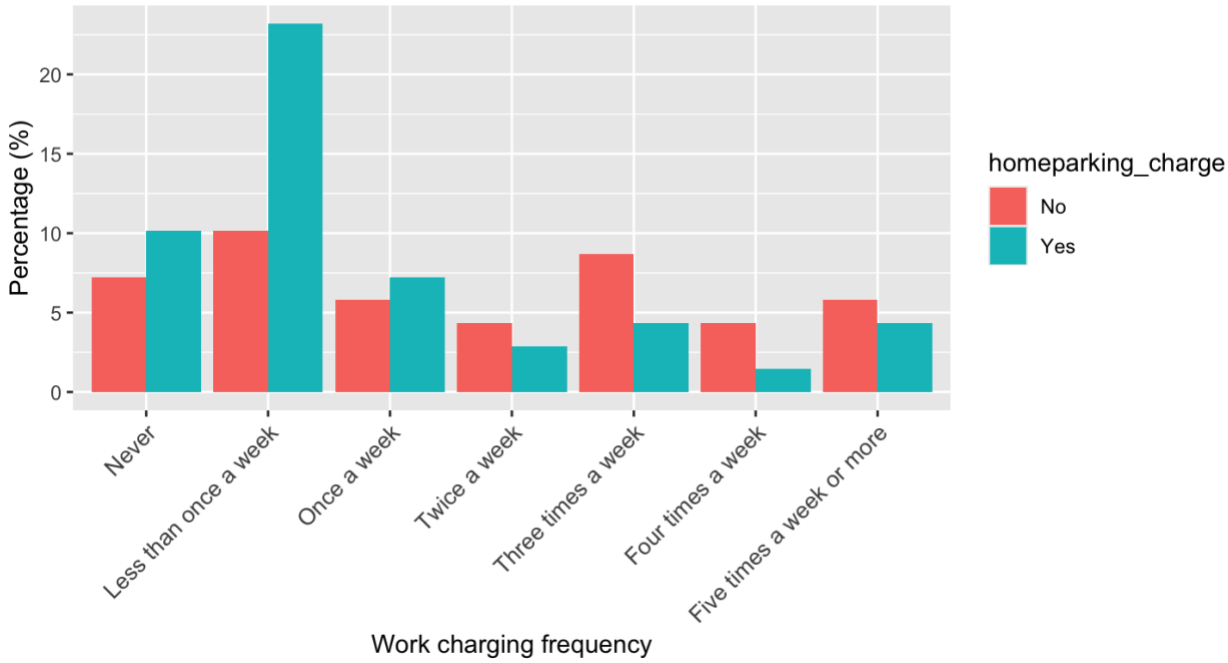

Figure 4: Work charging frequency for EV users with and without home charging availability.

1.2 RQ4 - What are the perceptions of public charging of EV users without home charging availability?

To address research question RQ4, a latent variable, Public Charging Perception, was measured using a 7-point Likert scale, where 1 means "totally disagree" and 7 means "totally agree." The participants indicated on the Likert scale to what extent they agreed with the statements about the public charging station that they mostly use. The median and SD for each statement about public charging perception are presented in Table 2. The reasons for asking about the public charging station that the participants mostly use were to facilitate the cognitive task of recalling their previous experiences and forming an overall evaluation of them, and to reduce the variability of the qualities of different stations that the users may have previously encountered. Figure 5 visualizes the responses for both groups.

Table 2. Mean and standard deviations for all items assessing the latent variable Public charging perception.

	M (SD)
It is reliable.	5 (1.9)
It has a good price.	2 (2.2)
It is in a convenient distance from my home.	2 (2.19)
I have the freedom to charge the car at any time.	4 (2.19)
It is convenient to leave the car parked there while charging.	6 (1.8)
I feel that this is the only viable option.	5 (1.8)
The chargers are always available.	5 (1.97)
The parking rules are easy to understand.	6 (2.06)
It's a safe place to park the car.	5 (1.66)
The parking spot's size is big enough to fit my car.	6 (1.77)

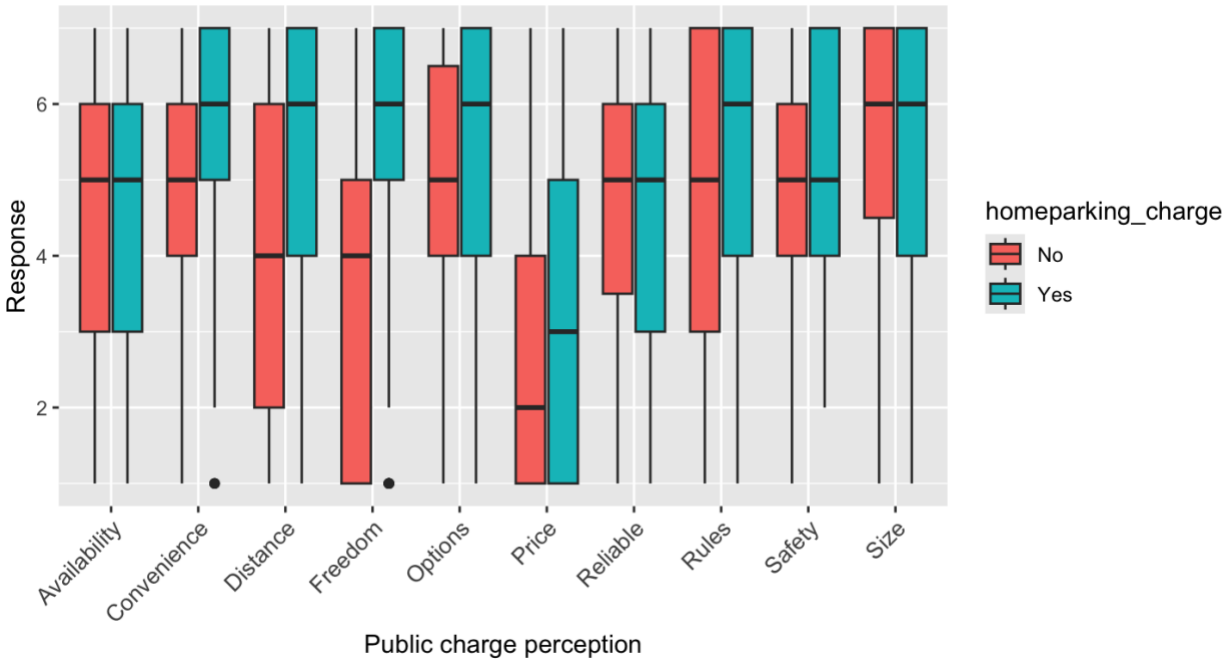

Figure 5: Public charging perception for EV users with and without home charging availability.

To test for differences between the two groups, linear regression models were performed, in which the variables Convenience, Distance and Freedom were set as outcomes and home charging availability as a predictor. For all three models, there is statistical evidence that the perceptions of users that do not have access to home charging were lower than of those of users who have home charging availability (see Table 3).

Table 3. Linear regression models of EV users' perception of Convenience, Distance and Freedom (for the groups with and without home charging availability).

	Convenience			Distance			Freedom		
	ß (SE)	*t*	*p*	ß (SE)	*t*	*p*	ß (SE)	*t*	*p*
Intercept	4.86(0.15)	30.84	0.000	4.27(0.19)	22.36	0.000	3.45(0.18)	18.96	0.000
Home charging available	0.83(0.22)	3.66	0.000	1.03(0.27)	3.74	0.000	1.86(0.26)	7.04	0.000
Model	R^2_{adju} = .05, F(1, 225) = 13.43, *p* = .000			R^2_{adju} = .05, F(1, 225) = 14, *p* = .000			R^2_{adju} = .17, F(1, 224) = 49.56, *p* = .000		

2 Discussion

This paper presents results that build knowledge of a previously overlooked group of existing and potential EV adopters – households lacking the possibility to install their own home charger. Previous research has mainly focused on early adopters of EVs, a group that predominantly consists of households with the possibility to install home charging. Conventional wisdom that most of the charging is done at home is based on studies with EV users who have home charging availability. This study and the research project from which it is based is one of the first research initiatives to target this specific group of users. More research is needed in this area for several reasons. First, vehicle owners residing in multi-dwelling houses has so far been laggards in EV adoption, more knowledge is needed to understand why. Second, improved understanding of charging needs and preferences of users without home charging is important for enabling efficient policy and commercial planning of placement and design of future public charging infrastructure. Actors with a commercial interest in public charging in urban environments ought to have significant financial incentives to explore this further, as this group will likely utilize public charging more than users with access to home charging. Initial evidence that commercial charging actors have an interest in understanding this group have been seen in the significant interest of these actors to participate in this research project.

In summary, the results of this study show that the group of users who do not have home charging availability perceive public charging as less convenient, further from their homes, and they have a lower perception of freedom to charge, compared to the group of users with access to home charging. This group also reported having less access to charging at work, and among those who have the possibility to charge at work, the frequency was relatively low. Lower charging access at work for this user group is an interesting finding. If true for the large population of potential EV adopters consisting of households without the possibility to install chargers at home it could be of large importance. Without access to either home or work charging these user or potential users will be completely reliant on public charging.

In terms of similarities, both groups have approximately the same distances to access charging infrastructure, their charging frequencies are similar (twice per week), and they report similar preferences for minimum SoC. Although the average charging frequency is similar, the results identified a behavioral pattern of frequent charging (five times per week) among a certain share of EV users who have home charging availability. This pattern may indicate a tendency to start charging as soon as the car is parked at home, regardless of the SoC.

Another similarity was the triggers for charging; for both groups, minimum SoC was the main charging trigger. Additionally, for both groups, the more spontaneous triggers "*When I have free time*" and "*When I pass by a charging station*" were the least selected options, indicating that charging is rather a goal-oriented behavior than spontaneous. This result suggests that charging behavior is triggered by economic factors, convenience, and routine, rather than spontaneous contextual factors. Therefore, we reason that the mere availability of charging locations may not be sufficient to fulfill the needs of these users. Their needs are rather connected to a routine, planned around the SoC and the minimum SoC that they feel comfortable with. This is an interesting finding that should be explored further in future studies.

The sample size and geographical spread of this study are small and narrow, respectively, which limits the generalization of the results. An expansion of this study geographically and with more users would be highly relevant to better understand the behavioral patterns of EV users who do not own a home charger and rely on public charging. Better understanding of this group of EV users is important for the design of government policy as well as for industry in how to better cater to the needs and preferences of potential EV adopters who will need to rely on public charging and other charging infrastructure not located at their point of residence.

Acknowledgments

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Presenter Biography

Érika has a Ph.D. in Psychology from the University of Gothenburg. Her research is focused on transport behavior, mobility and sustainable innovation. Érika is employed as a senior researcher at RISE Research Institutes of Sweden and her current work is focused on charging behavior, use of electric micromobility, and carsharing use.