ANALISYS OF USER PREFERENCES ON ELECTRIC MOBILITY IN FOUR EUROPEAN COUNTRIES

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ABSTRACT
Electric vehicles are seen as one of the most promising sustainable alternative in the current fight against increasing pollution worldwide. However, they are still seeing a limited spread among drivers. Behind buying an electric vehicle, or deciding when and where to charge it, there are evaluations strongly influenced by costs, technology characteristics, user experience and several other aspects. One of the challenges is to deepen the knowledge about the users' perceptions of these aspects. The paper presents the relevant results obtained from two Stated Choice (SC) experiments on users' preferences on electric mobility. Participants are asked to select, among a limited set of alternatives (each characterized by a list of attributes), the one they prefer. The first part of the survey investigates aspects related to car ownership. Different powertrain technologies are included in the study, electric and not, to represent a scenario as realistic as possible. To complete the set of alternatives' attributes, the availability of incentives on purchase and utilization are also included. The second part focuses on the features of the charging infrastructure. Charging points may be selected, for example, for their location, maximum charging power, which impacts on the duration of charging, or the cost of electricity, to mention the most important. Knowing the different behavior of EV drivers in typical situations, such as on a long journey on a highway or in an urban context, two experiments are carried out, tailoring the available charging points typology for the two choice situations.
Responses to 16 734 choice situations have been collected among four European countries (Italy, Spain, Netherlands and Estonia).

The analysis of the results may be used to give a big picture on the sample and their preference to identify the main factors considered by users in adopting ad recharging electric vehicles, also in future conditions, as may be of interest for city planners and decision makers.

1 INTRODUCTION
European Union has set clear targets for emissions reduction to progressively achieve carbon neutrality by 2050. The strong decision to stop sales of ICE cars from 2035

poses new challenges in European mobility scenario. On one hand it will be necessary to reduce the share of private transportation, on the other it will be necessary to update current car propulsions systems. Battery electric vehicles (BEV) are the preferred technology for achieving this goal, as also hybrid vehicles will be prohibited from 2035. However, a large transition scenario is expected between 2035 and 2050 in which traditional ICE cars will co-exist with BEV and hybrid vehicles. In this timeframe, huge investments and changes are needed both in the car industry and in national and local policies to guide the transition. The energy industry will also be involved, considering that electricity demand due to EV has already grown of almost ten times in the last five years, from 1 800 GWh in 2018 to the 19 000 GWh of 2022 (IEA 2022).
The present research work has been carried out in synergy with EU-founded INCIT-EV project (www.incit-ev.eu), which focuses on these topics and is aimed at building tools for local administrators to better plan electric mobility and charging infrastructure investments. The work has focused on developing and collecting trustable data to understand the scenario of e-mobility in four European countries (Italy, Spain, Netherlands and Estonia) that could be used to build discrete choice models in terms of EV adoption, charging infrastructure demand and power withdrawal demand.

2 LITERATURE REVIEW

Many authors have worked to understand drivers to EV adoption and develop forecasting models, but obtaining trustable data for model training is still the hardest task. Dedicated surveys are a popular method for collecting data, with equal preference for Stated Preferences (SP) and Revealed Preference surveys (RP). The first usually expose the travelers to various hypothetical scenarios and record their choices under different circumstances, while RP questionnaires retrieve actual travel information from the respondents (Lavasani et al. 2017).
RP data are more suitable for making correlations between socioeconomic characteristics and user behaviors, to have a clearer overview of the factors promoting and preventing EV spread. However, being an area that is constantly and rapidly changing, an SP approach can provide more data. As explained by (Gamba et al. 2022), SP survey can be used for understanding and predicting consumer choices in expected and future scenarios (stated choice, SC techniques)
Concerning basic socioeconomic information, such as gender, age, income and education, correlation with EV ownership change quite a lot across different countries and contexts. As an example, a recent analysis carried out in Norway, which is the country with the highest BEV adoption in Europe, concluded that owning a BEV is more probable for younger, higher educated and wealthier households (Fevang et al. 2021). On the contrary, a more geographically extensive research conducted in ten European countries (Verbist e et al 2023) (Austria, Belgium, Denmark, France, Germany, Hungary, Italy, Netherlands, Slovenia and Spain and Brussel Capital region) and a further research in Sweden (Westin, Jansson, e Nordlund 2018), concluded that the typical BEV driver is male, aged between 35 and 55 years old with higher education. Also, household type and urban context are perceived influential on the

decision of buying and EV, mainly due to availability of recovery space and recharge facilities. In general, families living in detached houses in suburban or rural context, are more likely to opt for an EV (Verbist e et al 2023; Westin, Jansson, e Nordlund 2018).
Another aspect that affects quite a lot the potential market share of EV is the degree of knowledge of this technology, as both the driving experience and daily operations differ a lot from combustion engines. However, it is hard to assess this information, also considering that EV technologies have evolved quickly in the last years. A previous experience in driving EV is positively correlated with the willingness to buy it (Chen et al. 2020). It is interesting that EV-based car-sharing is currently the most popular way to gain experience in electric vehicle (Schlüter e Weyer 2019). On the other hand, a bad experience with EV or past experience, especially in the early stages of electric mobility development, can generate further skepticism towards EV and raise the so called range anxiety (Bühler et al. 2014).
Finally, although this aspect is not deepened in this research, barriers to EV adoption can be raised by cultural aspects, considering that, at least in the western society, cars are a symbol of social status (Sovacool e Griffiths 2020), (Plananska, Wüstenhagen, e de Bellis 2023).

3 METHODS

This research makes uses of SC survey originally designed by (Gamba et al. 2022), and successively upgraded with some minor changes. The design of the choice situations was performed using Ngene, a software that helps the definition of discrete choice experiments with several possible approaches. In our case, a fractional factorial D-efficient Bayesian design was chosen. In the version distributed for the final data collection, participants had to start form a preliminary section (PS) containing general socio-economic questions (e.g. age, gender, average income, education) and some questions about the previous experience in driving an electric vehicle and using charging infrastructure. The full list of questions is reported in table 3.1. Then, every participant had to go through three different stated preferences surveys:

- Car ownership section (CO) about preferences when buying a new vehicle
- The first charging infrastructure survey (CI1), about preferences of EV charging while parked
- The second charging infrastructure survey (CI2), about EV charging on-the-go.

Each participant had to respond to 6 choice scenarios for each section, unlike the original version by La Gamba *et al*, limited to 5.

Table 3.1: List of questions in preliminary survey

Question	Answer option
How many cars are available in your household (whether owned or not)?	▪ 1 ▪ 2 ▪ 3 ▪ >4
Do you have a driving license?	▪ Yes ▪ No
Do you have experience with electric vehicles (whether HEV, PHEV and BEV)?	▪ None ▪ Yes, I know the technology but I have never driven an EV ▪ Yes, I have driven an EV before, but I don't know the technology ▪ Yes, I have driven an EV ▪ Yes, I rarely rent EV ▪ Yes, I occasionally rent EV ▪ Yes, I often rent EV ▪ Yes, I own an EV
Do you have experience with charging operations of electric vehicles?	▪ I own a private charging spot at home ▪ I use a private charging spot at my place of work/study ▪ I use public charging infrastructure ▪ I know there are some public charging stations near home ▪ I know there are some public charging stations near my place of work/study ▪ I know there are some public places (parkings, malls, restaurants, gyms, ...) equipped with charging points ▪ None at all
Do you know how the most common propulsion technology works?	▪ Yes, I don't need any further explanation ▪ Yes, but I would like more details ▪ No, I need an explanation
Date of birth	[entered as DD/MM/YYYY]
Gender	▪ Male ▪ Female ▪ I prefer not to answer
What is the average monthly net income in your household?	▪ 1: <1k€/month ▪ 2: 1-2k€/month ▪ 3: 2-3k€/month ▪ 4: 3-4k€/month ▪ 5: 4-5k€/month ▪ 6: 5-7k€/month ▪ 7: 7-10k€/month ▪ 8: >10k€/month
What is your highest degree of education?	▪ primary school ▪ secondary school

Question	Answer option
	▪ high school/professional ▪ university ▪ doctorate ▪ other
You live in…	▪ Urban context ▪ Suburban context ▪ Rural context

3.1 Car ownership survey

In the car ownership survey, participants had to imagine themselves in the situation of purchasing a new vehicle. In order to give the participants a choice situation as probable as possible, three sub-experiments were created based on car segment. Three typologies of cars with corresponding model examples were proposed:

- Car segment B: subcompacts, e.g. Ford Fiesta, Renault Clio, Volkswagen Polo
- Car segment C: compacts, e.g. Volkswagen Golf, Ford Focus, Skoda Octavia
- Car segment D/E: mid-size and large, e.g. Volkswagen Passat, Mercedec C-series, BMW 5-series

Based on the selection, participants were redirected to the corresponding set of choice scenarios, in which the level of variation of specific attributes as *price* and *range* were adjusted for the car segment. Then, each of the six choice scenario presented the comparison between two powertrain options (A and B), taken among the following: *Battery electric vehicles* (BEV), *Plug-in hybrid vehicle* (PHEV), *Hybrid electric vehicles* (non plug in NOME), *Bio-Fuel powered ICE vehicles*, *LPG/NGV powered ICE vehicle*, and *traditional ICE*. Respondents had to choose the best one according to their preferences based on the values of attributes such as purchase price and operating costs (gasoline, energy) but also different levels of incentives for both purchase and use (e.g., access to limited traffic zones). In addition, aspects more related to electric mobility are included in the choices such as range and charging times.
The fully list of attributes and relative levels are reported in table a.1 (Annex). The option *do not choose*, was however available and has been registered as *opt-out*.

3.2 Charging infrastructure surveys

After car ownership survey, two surveys about charging infrastructure were proposed. In the first case (CI1), respondents had to imagine the situation of driving a full electric vehicle and to charge it while not using. They had five options available:

- a public parking area equipped with charging point
- at home, at their private charging point
- near home, at a public charging point

- at work, at their private charging point
- near work, at a public charging point

Choice had to be made based on the attributes related to the cost and time of charging but also to the boundary conditions of the charging point more related to comfort with the presence of ancillary services, but also the possibility of reservation, renewable energy production, and the type of connection (e.g., wireless). . In this case the option *do not choose* was not available.
In the second survey about charging infrastructure (CI2), instead, the choice was about two generic charging options, considering that the decision had to be made while driving, e.g. during a long trip on a highway. Attributes and their level of variation, are reported in table a.2 (Annex).

3.3 Data collection and cleaning

Initially the survey was distributed first in Turin and Zaragoza for pilot testing, while a definitive version was spread in five European cities in the five Countries of the research, namely Turin for Italy, Zaragoza for Spain, Amsterdam for the Netherlands and Tallinn for Estonia. For the purposes of this work, the survey was adjusted to include some more socioeconomic questions and a specialized company in surveys was hired for data collection. The survey was spread between January and February 2023 in the five countries involved, at national level. During data cleaning procedure, only answers completed in all the four parts (preliminary survey and three SP surveys) have been considered. In total, surveys from 2832 people were collected, 43 have been discarded and 2789 were considered valid and processed.

4 QUALITY OF DATA AND SAMPLE FEATURES

At each participant six choice situations were proposed in each part, resulting in 16734 choice scenarios for each of the three parts (CO, CI1 and CI2). To check the reliability of the data, section 4.1 analyses the choice scenarios that were actually distributed, while section 4.2 focuses on revealed socioeconomic characteristics of the interviewed sample and compares them with the latest data available. Lastly, section 4.3 and 4.4 draw a picture of the attitude of respondents to cars, analysing car segment data and the declared experience of respondents with EV driving and charging operations.

4.1 Frequency of alternatives

The survey platform was programmed for distributing choice blocks as randomly as possible, subject to conditions for attributes and their levels, managed by Ngene. However, a check on the observed frequency of alternatives has been carried out to be aware of possible biases during the data collection process. Concerning CO survey, alternatives are proposed with even frequency, except for BEV, which is about three times more frequent (table 4.1). If looking at the frequency of coupling of the alternatives (table 4.2), not only BEV has been proposed more often, but it also has been proposed paired with PHEV, HEV and BEV itself, to better investigate which are the most relevant attributes in EV adoption.

Table 4.1: percentage of choice situation in which the corresponding engine type is proposed at least once. Opt-out option was always available.

n.	Engine type	Frequency
1	ICE	12.59%
2	BIOFUEL	12.80%
3	LPG/CNG	12.67%
4	HEV	12.67%
5	PHEV	12.90%
6	BEV	36.37%
	Total	**100.00%**

Table 4.2: percentage frequency of each couple of engine types.

	ICE	BIOFUEL	LPG/CNG	HEV	PHEV	BEV
ICE	0.60%					
BIOFUEL	8.74%	0.00%				
LPG/CNG	5.94%	5.69%	0.00%			
HEV	4.62%	4.01%	3.94%	0.00%		
PHEV	0.41%	1.67%	1.01%	1.11%	0.00%	
BEV	4.25%	5.50%	8.76%	11.67%	21.60%	10.48%

The same computation has been carried out for CI1 experiment, showing that options number 3 and 4 are slightly more frequent and more often proposed together. It is reasonably to suppose it will not generate biases in the result interpretation.

Table 4.3: percentage of choice situation in which the corresponding charging point type is proposed at least once.

n.	Charging point typology	Frequency
1	Public CP in public parking	17.57%
2	Private CP at home	17.61%

n.	Charging point typology	Frequency
3	Public CP near home	23.11%
4	Private CP at work	24.22%
5	Public CP near work	17.50%
	Total	**100.00%**

Table 4.4: percentage frequency of each couple of engine types.

	Parking	Home private	Home public	Work private	Work public
Parking	3.30%				
Home private	7.15%	0.00%			
Home public	6.45%	8.25%	3.22%		
Home public	9.90%	11.55%	13.36%	5.09%	
Home public	5.03%	8.28%	11.71%	3.45%	3.26%

4.2 Revealed socioeconomic characteristics of the sample

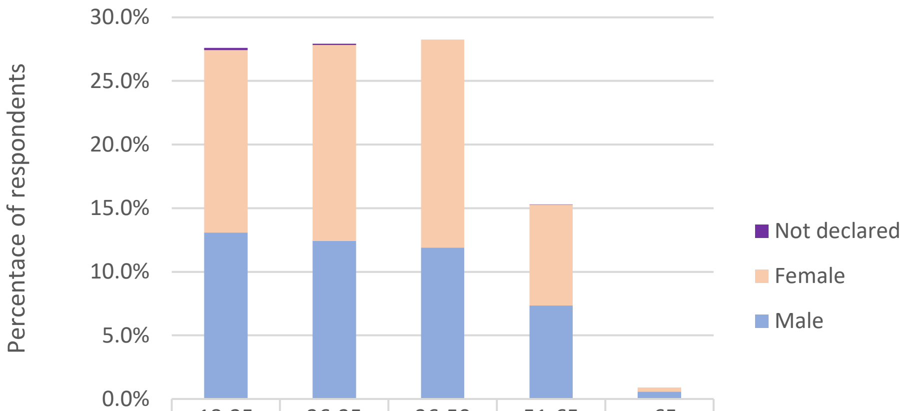
The survey was accessible to everyone above 18 residing in one of the for countries involved, without further targeting specific user groups. It has been chosen to collect data equally among the four countries and not proportionally to their number of residents (table 4.5).

Table 4.5: distribution of answers per country.

Country	Number of answers	Percentage
Italy	704	25.24%
Spain	693	24.85%
Netherlands	689	24.70%
Estonia	703	25.21%
Total	**2789**	**100.00%**

Respondents have been divided into five age groups based on their age on the day they completed the survey. From the graph in figure 4.1 it can be noticed that the first three age groups are equally represented, while people in the range 51-65 and >65 are in a lower percentage. The fact that the survey was distributed only by the internet, might have excluded those segments of population usually less familiar with surfing the web.

Gender, instead, is fairly distributed, with female slightly over numbering males. Not-declared option always has a frequency <1%.



	18-25	26-35	36-50	51-65	>65
Not declared	0.2%	0.1%	0.0%	0.0%	0.0%
Female	14.3%	15.4%	16.3%	7.9%	0.3%
Male	13.1%	12.4%	11.9%	7.4%	0.6%

Figure 4.1: gender characteristics by age group of the sample.

Income is expected to be an influential factor, especially for EV adoption. The distribution of income levels per country is shown in figure 4.2. Range €1.000-2.000 is the most frequent answer for Italy, Spain and Estonia, followed by the range €2.000-3.000. The distribution is completely different for the Dutch sample, due to the higher cost of life and higher average net wage in the country, coherently with Eurostat data (Eurostat 2022a).

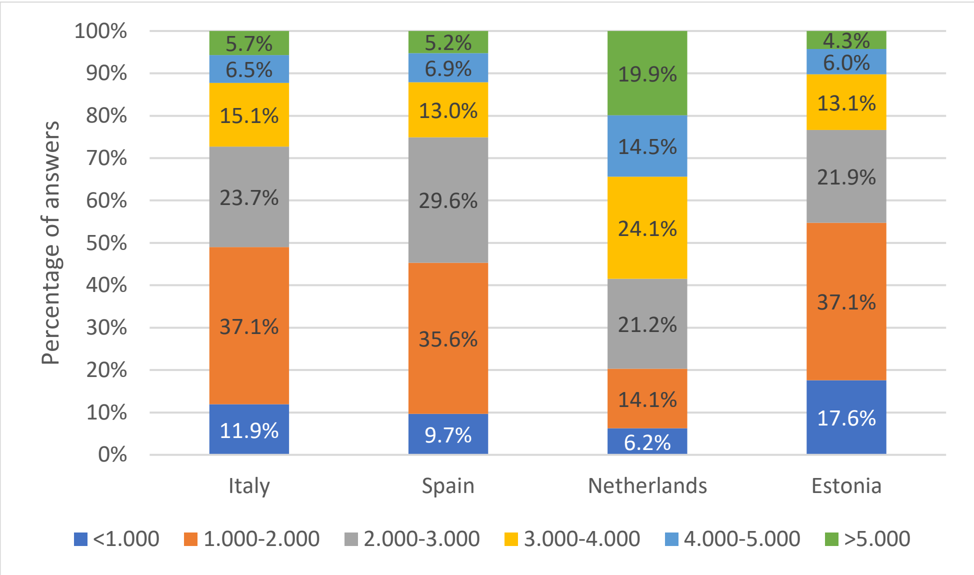


Figure 4.2: distribution of declared net incomes per country

Concerning education level, instead, most of respondents have a technical-professional education or a bachelor’s degree. This could potentially influence the answer to the questionnaire, as a higher education can help understanding the technical differences of the propulsion proposed in the choice scenarios, as well as their environmental impact.

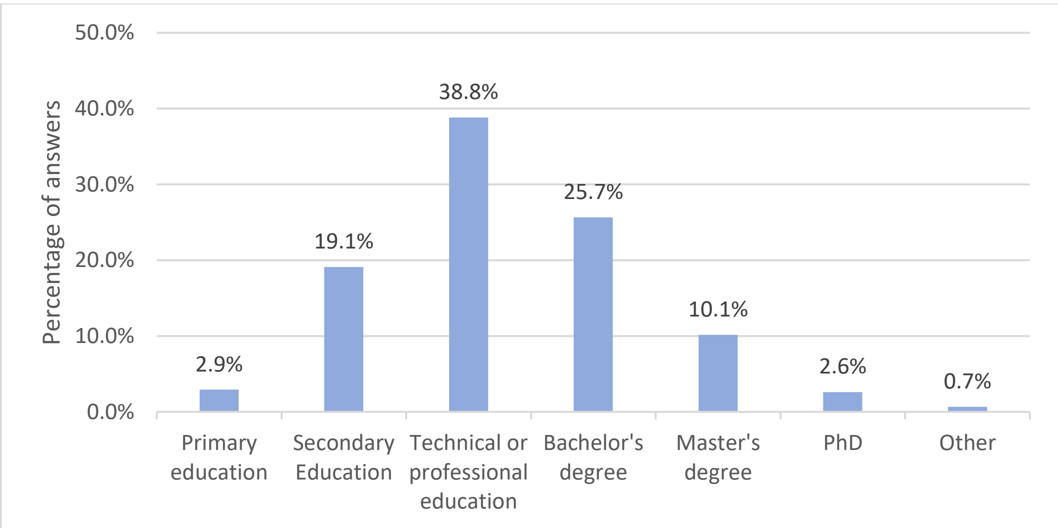


Figure 4.3: distribution of declared education level.

Finally, considering the place of living, urban area is another factor that can influence the choice of powertrain or the way of charging a BEV/PHEV (Westin, Jansson, e Nordlund 2018). figure 4.4 shows the distribution of declared living context (to be chosen among *urban, suburban* and *rural*), compared to those officially reported by (Eurostat 2022b). Percentages between the two data sources are quite different, meaning that the sample is not representative of the average situation. However, this can be explained considering the difference both in the definition and in the perception for respondents of the adjectives *rural, periuban* and *urban*.

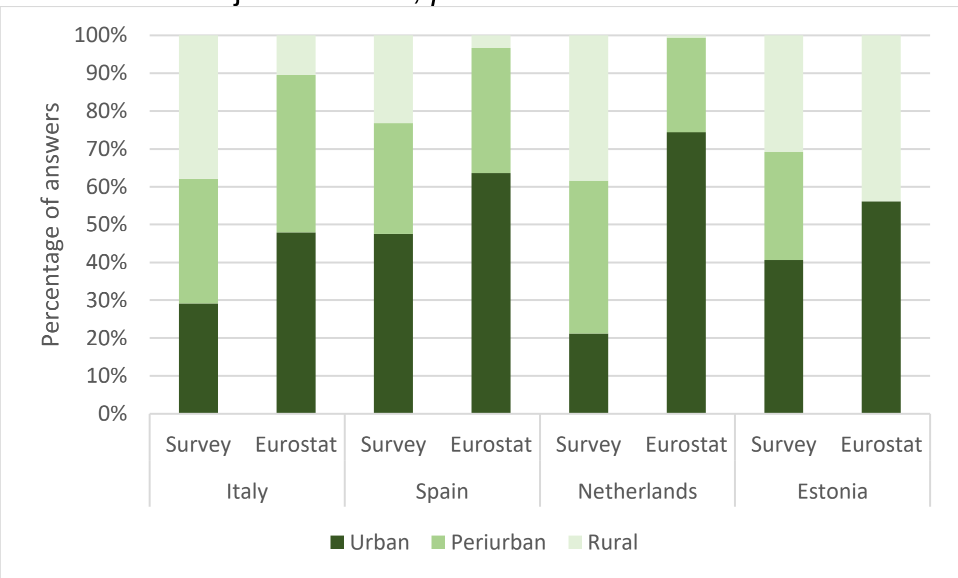


Figure 4.4: distribution of living context declared in the survey, compared to distribution from Eurostat (data about suburban Estonia is not available).

Of those claiming to live in an urban context, small and medium cities are always predominant with respect to large cities, coherently with the average size of urban settlement of the countries involved. However, note that answers have been aggregated for those choosing any value above 200.000 inhabitants. In fact, in the original dataset, some people answering form the Netherlands and Estonia, claimed to live in a city greater than 1,5 million, even though there are not cities as big in those countries. Once again, this might be due to a bias in people’s perceptions of the actual environment they live in.

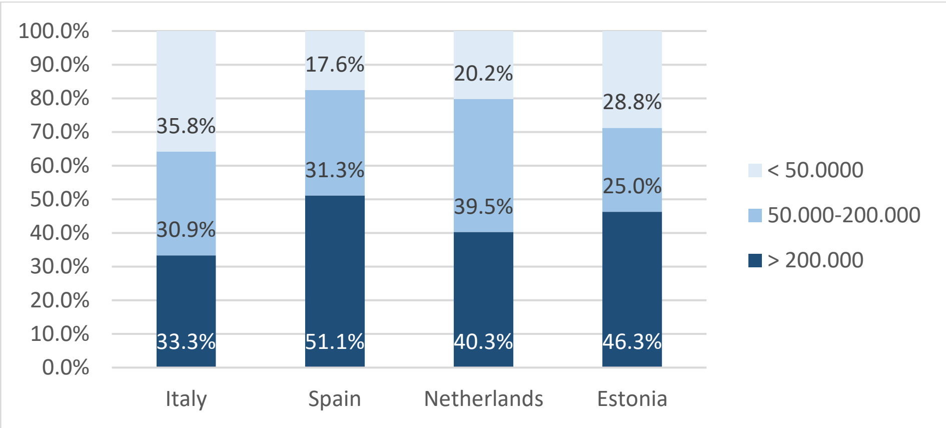
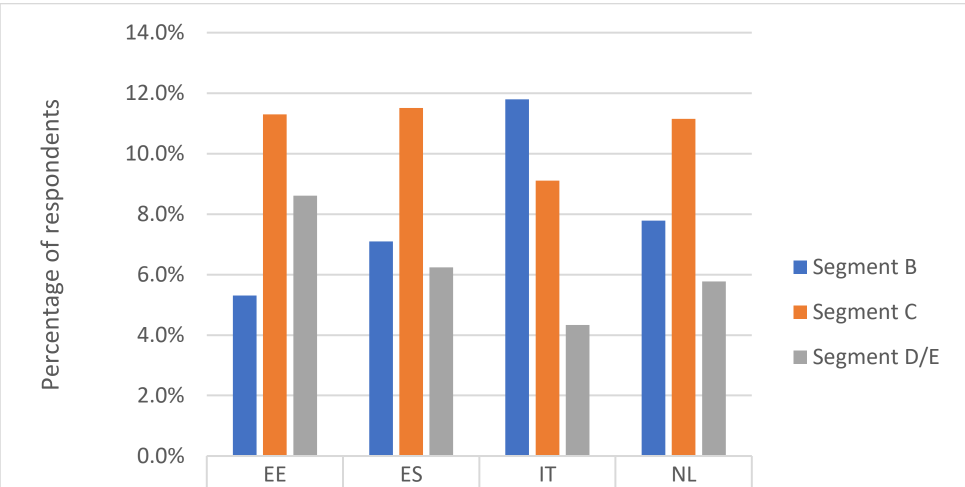


Figure 4.5: Distribution of city size declared in the survey.

4.3 Revealed car segment data

Before CO survey, respondents were asked to select the car segment they are most likely interested into. Results reported in figure 4.6 show that car segment C is the most preferred, followed by car segment B, following the average European distribution (ACEA 2022). The trend is the opposite for the specific case of Italy, where smaller cars of segment B are preferred, as also confirmed by available data (UNRAE 2023).



	EE	ES	IT	NL
Segment B	5.3%	7.1%	11.8%	7.8%
Segment C	11.3%	11.5%	9.1%	11.2%
Segment D/E	8.6%	6.2%	4.3%	5.8%

Figure 4.6: Car segments chosen at the beginning of CO survey by respondents.

4.4 Revealed previous experience with EV driving and charging

A focus of this work has been understanding the average degree of knowledge of EV and how this experience can drive purchase choice or recharging behaviour. In general, data show that the interviewed sample is poorly informed about the many types of powertrains available on the market and has a poor experience both with EV and the charging infrastructure operations. This confirms the value of proceeding with a stated choice approach instead of detecting revealed choices in electric mobility.
More in detail, the first question has been whether the participant was fully aware of the differences among the propulsion types proposed in the CO survey. Only 23% of respondents was fully aware of the technical difference of the alternatives, while 36% was partially aware. 41% of respondents declared not to have any technical knowledge.
Concerning direct experience with driving an EV, a dedicated question was asked, and answers have been grouped as reported in Table 4.6:

Table 4.6: Grouping of answers about EV experience.

Answer	Group
None	No experience
Yes, I know the technology but I have never driven an EV	
Yes, I have driven an EV before, but I don't know the technology	Tried at least once
Yes, I have driven an EV	
Yes, I rarely rent EV	Occasional user
Yes, I occasionally rent EV	
Yes, I often rent EV	Frequent user
Yes, I own an EV	

Final results show that majority of respondents are not familiar with EV, followed by those that have tried EV only once (Figure 4.7).

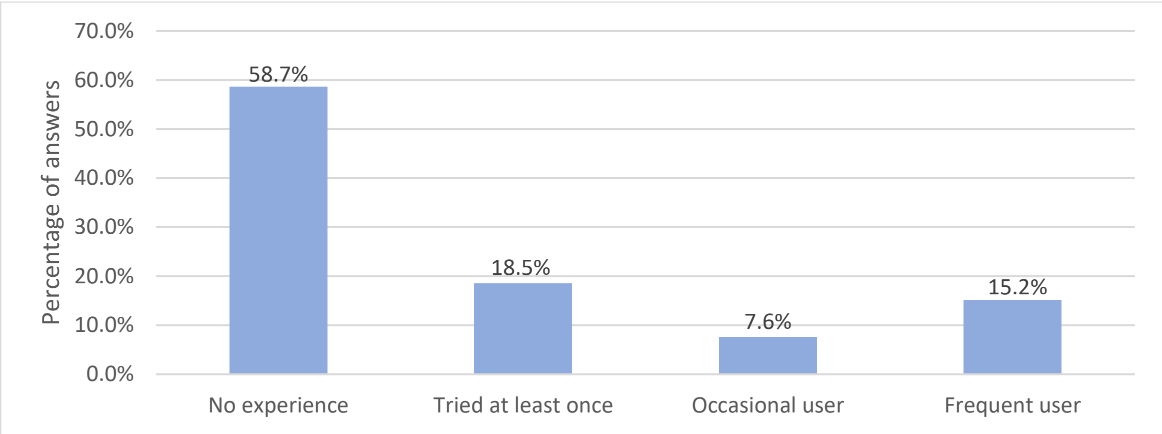


Figure 4.7: EV experience declared in survey.

Finally, experience with charging infrastructure was asked as multiple-choice questions with multiple answers possible. Once again, most of respondents do not have any previous experience with charging infrastructure, but a significant part is aware of charging points spread in the city, especially next to public spaces and amenities (Figure 4.8).

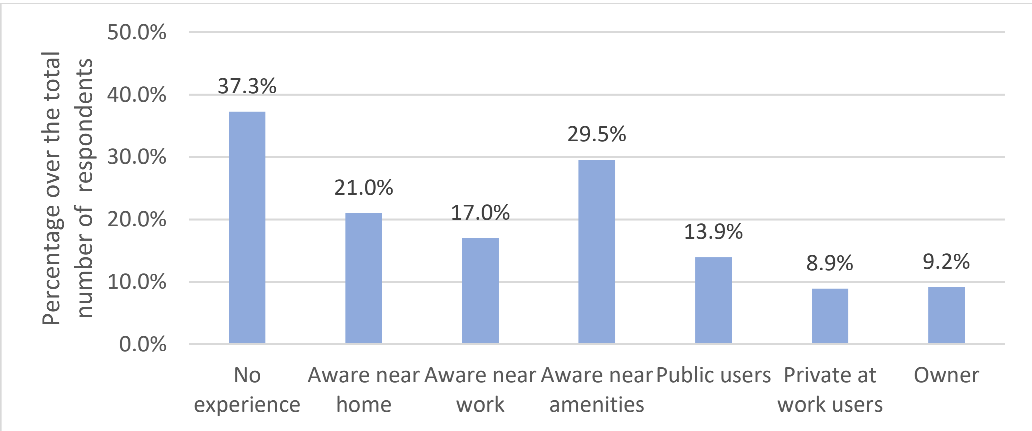


Figure 4.8: experience with EV charging points. Percentages for every column is over the total number of respondents.

5 RESULTS

5.1 Car ownership survey results

Final answers to each choice scenario were analyzed considering that alternatives were not proposed with the same frequency. Table 5.1 has been obtained by removing choice scenario proposing the same engine type (BEV-BEV: 1754, ICE-ICE: 101, rif. table 4.2) and counting how often each option has been chosen against how often it was proposed to normalize the result. BEV and PHEV were chosen less frequently with respect to other options. This distribution draws a preference for all those engine types that need to be recharged (BEV and PHEV) and all other option that just need a fuel refill. Users are generally skeptic also about biofuels probably due to the lack of information about them.

Table 5.1: Number of times each option was chosen (column: chosen) compared to the number of times the option was proposed at least once (proposed).

	Engine	Num. of choice scenarios in which the option was chosen	Num. of choice scenarios in which the option was proposed	% chosen over proposed
1	ICE	4011	1771	44.15%
2	BIOFUEL	4285	1448	33.79%
3	LPG/CNG	4240	2133	50.31%
4	HEV	4241	1962	46.26%
5	PHEV	4316	1848	42.82%
6	BEV	8665	2902	33.49%
0	*opt-out*	16734	2815	16.82%

Considering gender, the graph in figure 5.1 shows that there is not any significant trend in the final choice, except that woman seems to be more likely to opt-out than men.

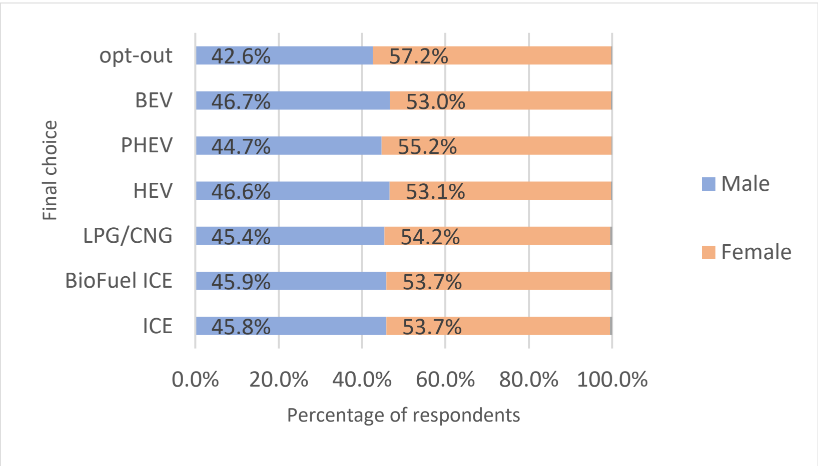


Figure 5.1: share of genders for every final choice of engine type.

Looking at age group, instead, it seems that people in the range 51-65 and <65 years old have more difficulties in the choice, and more likely to opt out (Figure 5.2). Other engine types, have an equal distribution.

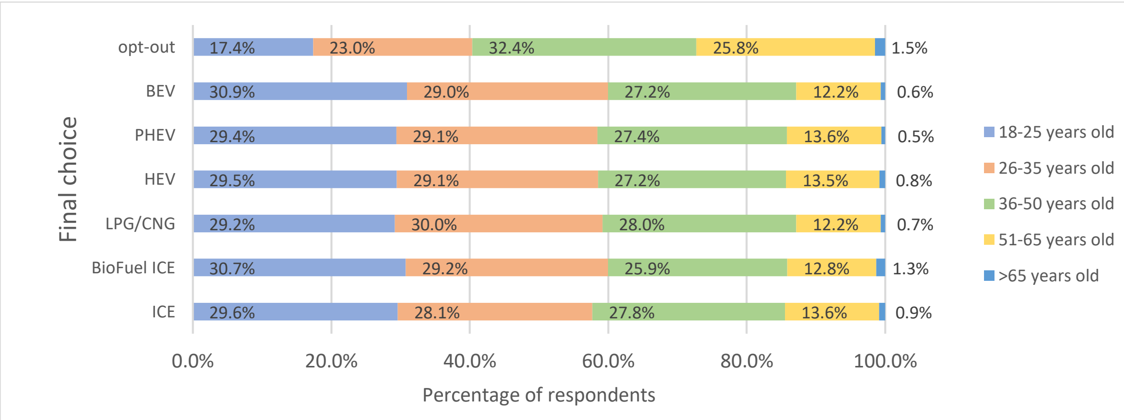


Figure 5.2: share of age groups for every final choice of engine type.

The same graph proposed for the income distribution shows that people with lower budget are more likely not to choose (Figure 5.3). However, neither income has a significant influence on the choice, although it is expected to be the most influential parameter. Once again, this confirms that choices were made based on attributes presented in the choice scenarios and were not influenced by the personal characteristics of respondents.

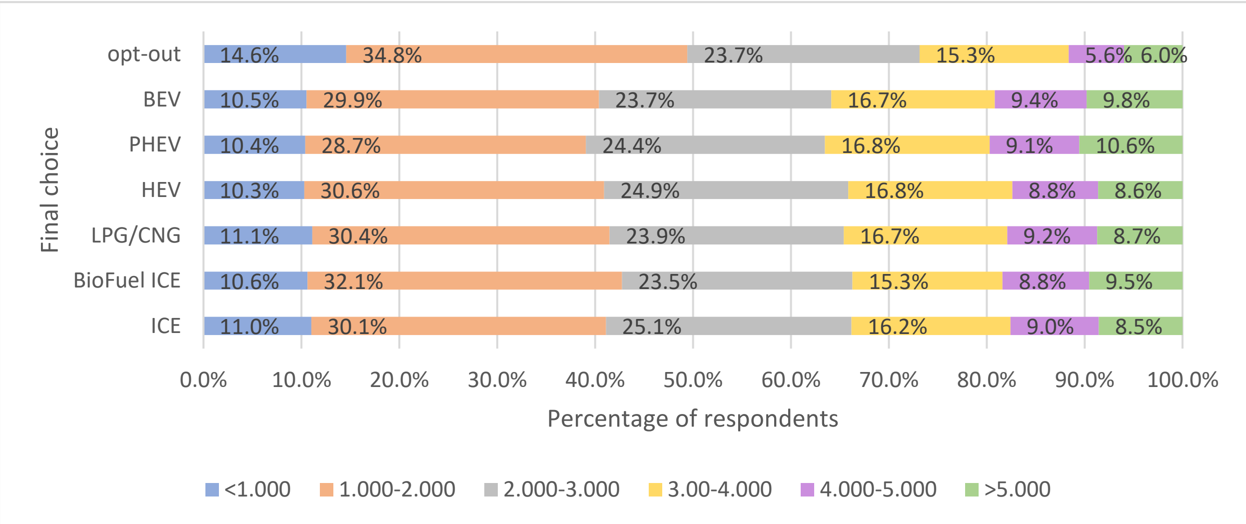


Figure 5.3: share of income ranges for every final choice of engine type. Income is expressed in EUR/month.

Finally, also people with lower education are more likely to opt out (Figure 5.4).

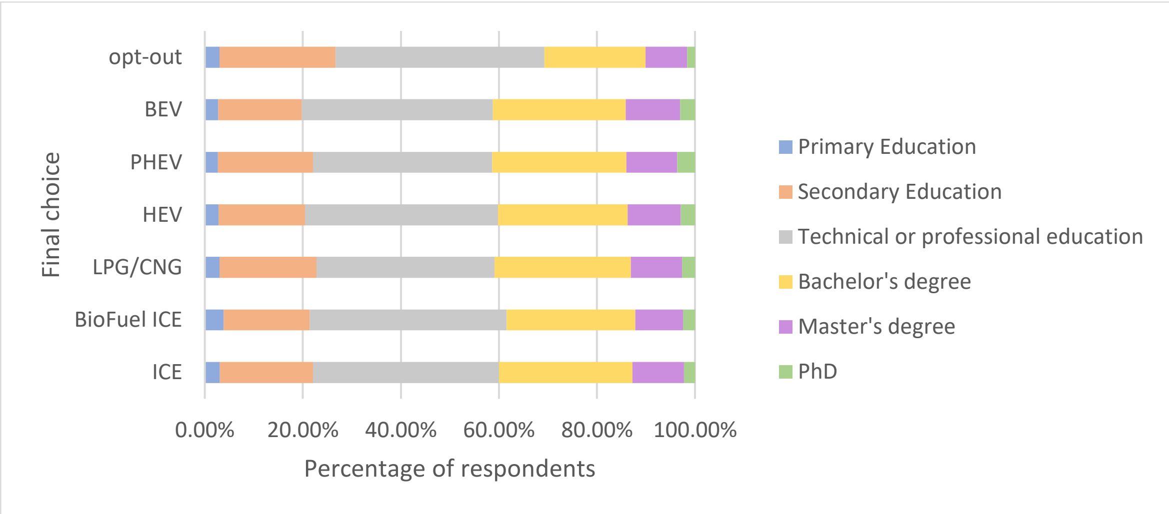


Figure 5.4: share of education level for every final choice of engine type.

More significant insights are from the correlation between previous experience and final choice. Although there is not strong polarization, people used to drive an EV (owners or frequent renters) are 25% more willing to consider BEV or PHEV (Figure 5.5). Coherently, people with no previous experience in driving EV tend to choose combustion engines or, even more often to opt-out.

Similar considerations can be made looking at answers to the question about knowledge of the different propulsion technologies (Figure 5.6). As reasonably expectable, people with no clear idea on the practical operations required to use EVs tend not to choose or to choose combustion engines, while people with a clear knowledge of EVs are more willing to adopt EV.

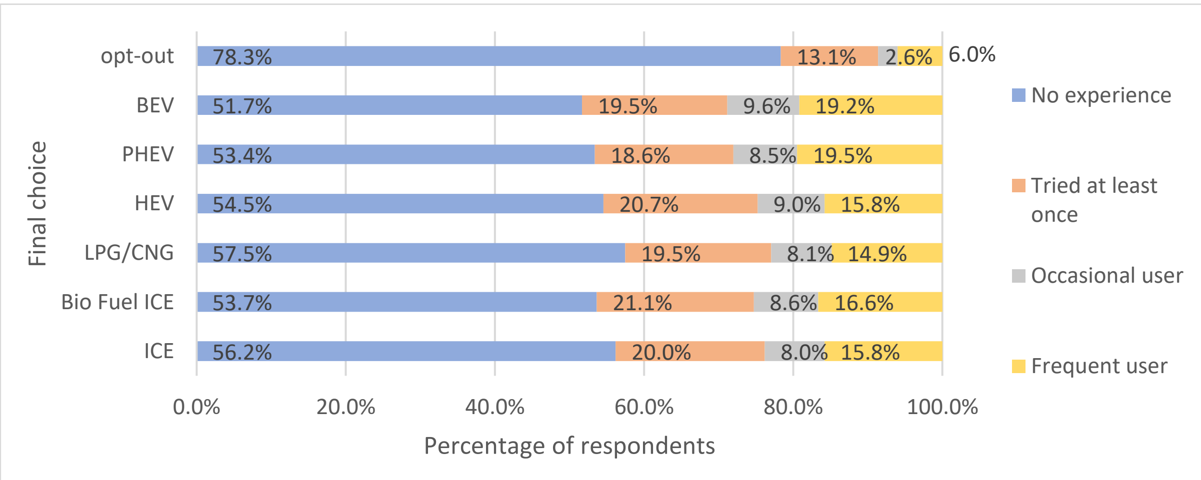


Figure 5.5: previous experience level related to final choice of engine type.

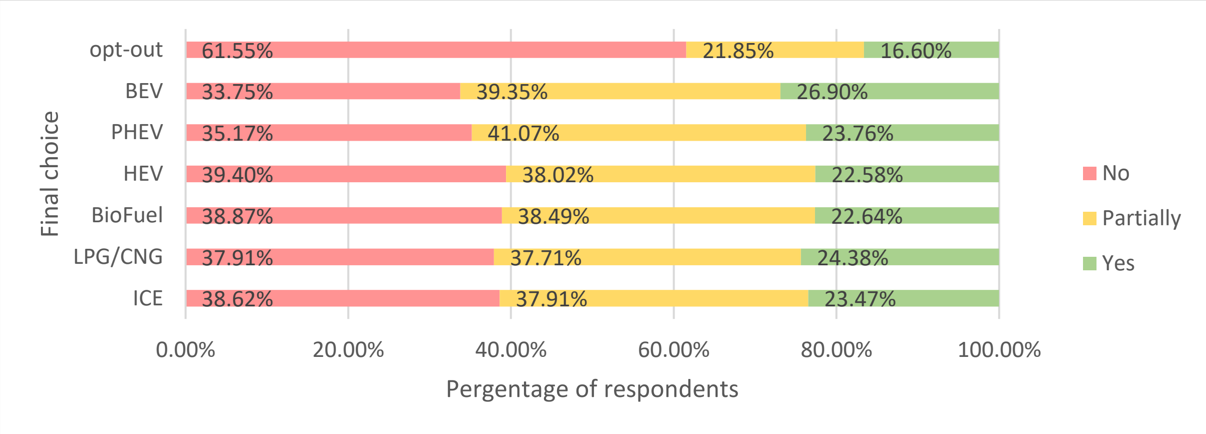


Figure 5.6: declared level of knowledge of propulsion technologies related to final choice of engine type.

5.2 Charging infrastructure survey results

Concerning recharge preferences, only data from survey CI2 were analyzed, as CI1 does not present alternatives based on charging point location. A first overview of the answer shows that, although alternatives are not proposed evenly, a private charging point at home is the most preferred option, followed by a public charging point near home (Figure 5.2).

Table 5.2: Number of times each option was chosen (column: chosen) compared to the number of times the option was proposed at least once (proposed).

	Option	**Num. times proposed**	**Num. times chosen**	**%**
1	Public parking	5327	2282	42.8%
2	Home private	5895	3382	57.4%
3	Home public	7195	3407	47.3%
4	Work private	7254	3098	42.7%
5	Work public	5311	2079	39.1%

Correlation analysis with basic socioeconomic characteristics, i.e. gender, age group, income and education has also been carried out, but no significant trend has been found, meaning that respondents have answered based solely on the attribute level, and not on their personal characteristics. This is confirmed when comparing the declared experience with charging infrastructure with the final choice and no correlation is evident by previous behavior and stated preference (figure 5.7).

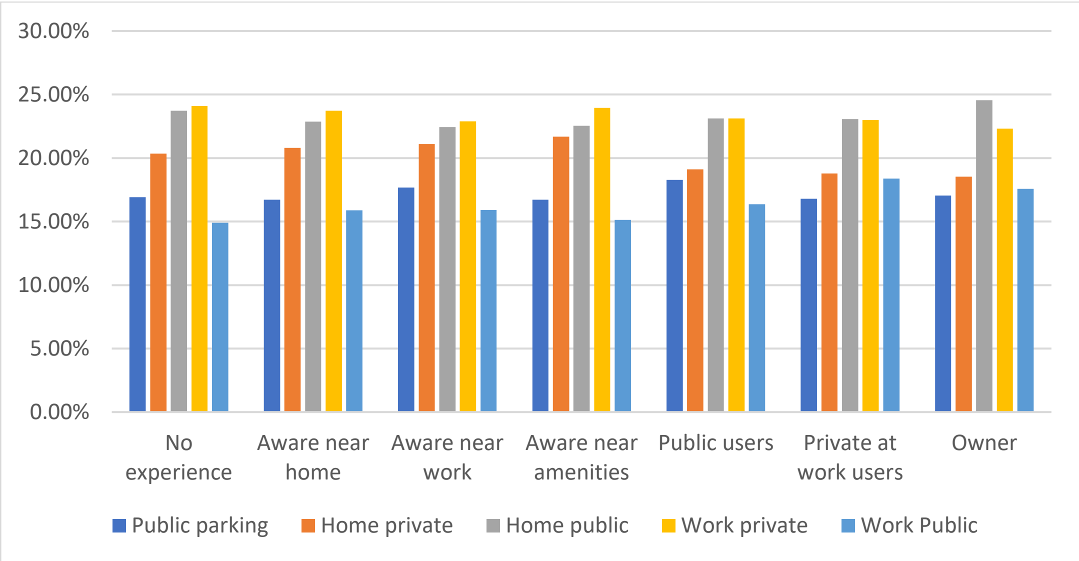


Figure 5.7: final choice of charging option related to previous experience with EV charging points.

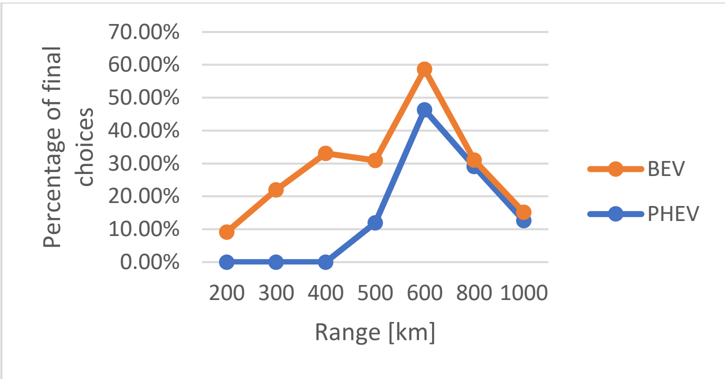
5.3 Factors related to range anxiety

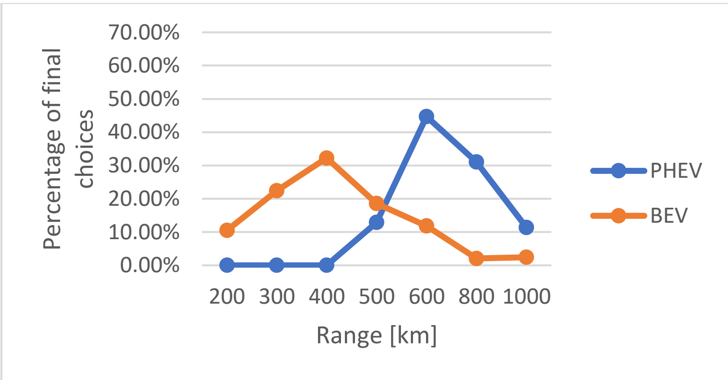
Driving range anxiety is defined as the *"concern that an EV might not have enough driving range to reach the desired destination due to its limited battery size"* (Pevec et al. 2020). If declining this into technical aspects, range anxiety is generated by the capacity of the battery and the time required to recharge it, but also by the diffusion level of recharging facilities. Data about these characteristics are analyzed, filtered by living context of respondents. In fact, perception can change between an urban and rural neighborhoods (Pevec et al. 2020).

Starting from expected range of the vehicle,

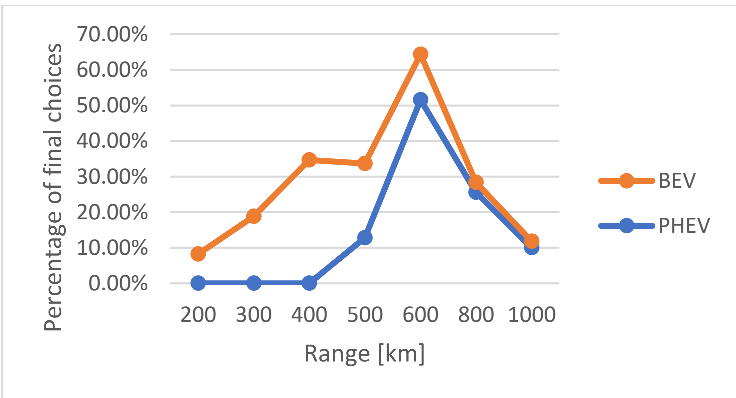
figure 5.8 plots the percentage of final choices with the corresponding range proposed in the choice scenarios. If looking at BEV, 600 km is the most desired range, both in an urban and a rural context, while suburban residents are satisfied with a lower range of 400 km. For PHEV, instead, most appreciated driving range is 600 km (to be considered as total range in EV and ICE mode) in all three contexts. This is reasonable if supposing that PHEV adopters might be skeptic about EV and are convinced to need a more extended range than BEV. Also, 600 km can be a good compromise between range and price. In fact, choices for cars with range greater than 600 km decrease rapidly both for BEV and PHEV, being that they were proposed with prices higher than €50 000.

(a)





(b)

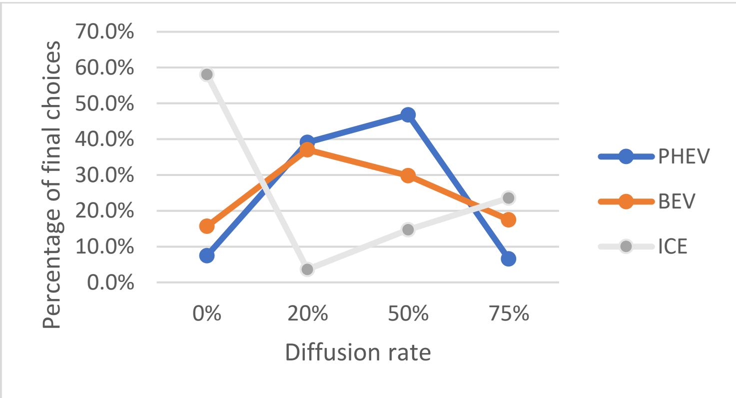


(c)

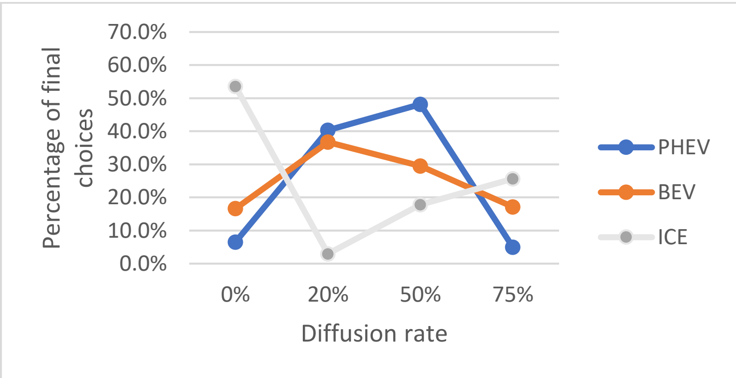
Figure 5.8: Percentage of BEV and PHEV choices as a function of proposed range for (a) urban, (b) peri-urban and (c) rural residential contexts.

Reproducing the same plots with diffusion (
figure 5.9), it is clear that a diffusion rate of 20% (1 out 5 parking slots or charging stations equipped with EV charger) satisfies most of BEV adopters, while PHEV adopters wish a diffusion of 50% (1 out of 2 parking slots equipped with EV charger).

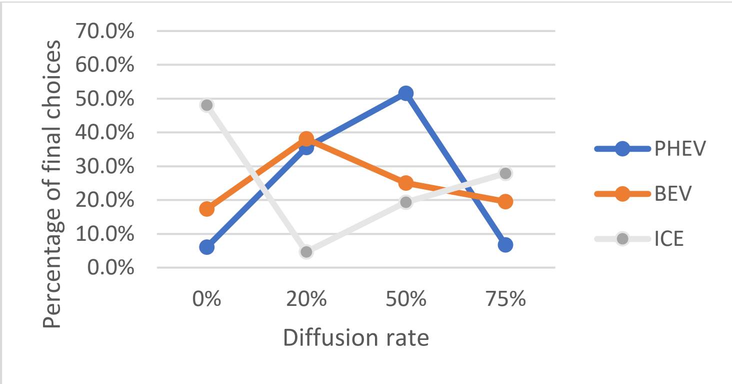
At 0% diffusion rate, almost no one is willing to buy a powertrain that requires plug-in, and ICE choices have a peak, instead. Values are the same for urban, suburban and rural context. This confirms the hypothesis that PHEV adopters suffer from range anxiety and PHEV is seen as a safer alternative to BEV due to the presence of a backup powertrain. However, results show that it is not expectable that the percentage of choices decreases for higher diffusion ranges. This result would require a further analysis to better understand whether higher level for the attribute *diffusion* were proposed combined with higher values for EV *price or other penalizing attributes for EV. However,* no correlation was observed between the price of the vehicle and the diffusion level of the scenario.



(a)



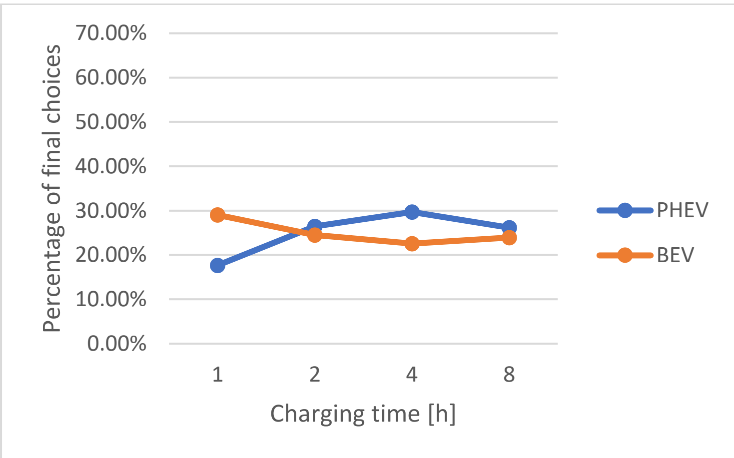
(b)



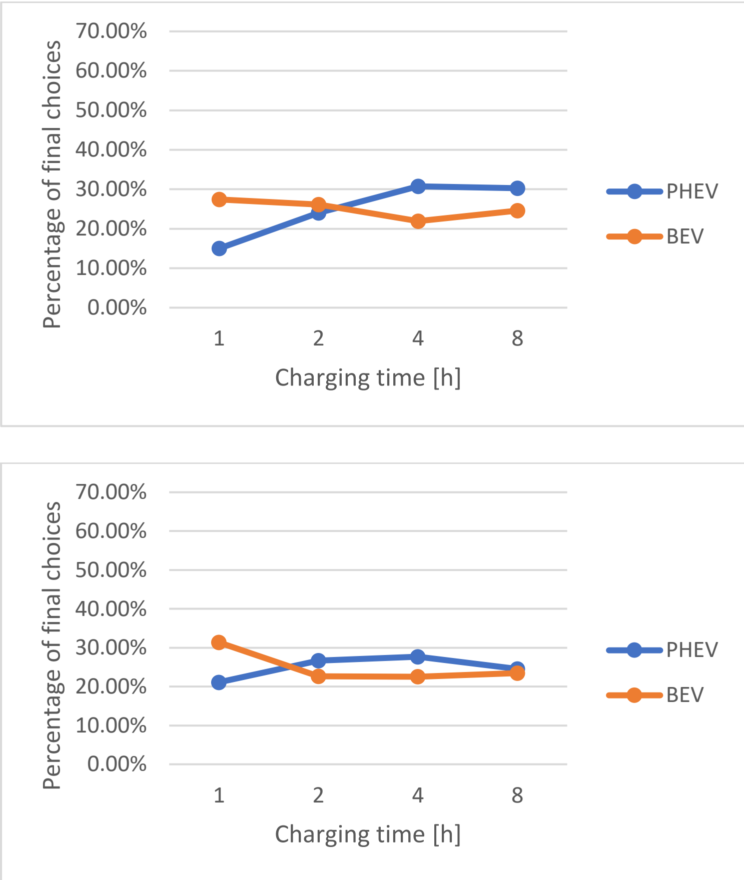
(c)

Figure 5.9: Percentage of BEV and PHEV choices as a function of proposed diffusion rate of charging infrastructure for (a) urban, (b) peri-urban and (c) rural residential contexts.

Contrary to expectations, charging time does not have an influence on choices, showing a rather plane behavior. Of course, shorter charging time values are attractive for BEV users, but not for PHEV. This might also be explicable considering that PHEV adopters do not need to charge their batteries quickly, because in case of need they can run in ICE mode. No significant differences are observable among the three graphs.



(a)



(b)

(c)

Figure 5.10: Percentage of BEV and PHEV choices as a function of proposed charging time infrastructure for (a) urban, (b) peri-urban and (c) rural residential contexts.

Lastly, no correlation has been found between the number of cars declared and the final choice, contrarily to what is often found in the literature. Most probably this aspect is noticeable from RP method only.

6 CONCLUSIONS

Three SP surveys (Gamba et al. 2022) have been caried out for a detailed data collection: one about preferences of user when buying a car and two about preferences when recharging an electric vehicle. At the same time, socioeconomic characteristics and data about past or present experience of user with e-mobility have been collected and correlations have been investigated. In general, few dependencies were observed between revealed characteristics and stated choices, meaning that respondents made their choices based on the attributes presented and were not biased by their personal condition. This can be considered a positive outcome of the experiment, as the dataset is therefore reliable for calibrating discrete choice models in a future research development.More in detail, concerning gender, age, education

and urban context, no correlation have been notices, unlike other past works, which were however based on RP data (Verbist e Barrera, s.d.; Westin, Jansson, e Nordlund 2018; Chen et al. 2020). Not even income has impacted answer to purchase choice scenario. However it was observed that when the opt-out option was proposed (i.e. in Car Ownership experiment), female individuals, aged between 51 and 65 years old, with lower education level and without previous experience at driving and EV have more probability of not choosing. It
Then, a deepening about barriers to EV adoption, led to the quantification of parameters affecting the so-called range anxiety. BEV drivers are satisfied with an autonomy range of 400km and a diffusion of charging infrastructure of 1 out of 5 parking slots or charging stations equipped with charging point. PHEV drivers, instead whish a range of 600 km and a charging infrastructure penetration of 1 out of 2. This concludes that PHEV is preferred by those drivers more affected by range anxiety, as a double powertrain is perceived as safe backup. Recharge infrastructure diffusion is the main aspect preventing BEV adoption, based on the observation that when a 0% charging was proposed, choices of BEV or PHEV dropped to their minimum, while ICE was the most popular option. In addition, poor experience and knowledge about differences of EV from conventional cars affects EV penetration, but also other more sustainable alternatives like biofuels. This might be a great insight for policymakers, to address more resources in promoting e-mobility experiences a technical training.

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A. ANNEX

Table A.1: Attributes and level of variation of the car ownership survey (Gamba et al. 2022)

Car's feature	Levels description		
	B segment	***C segment***	***D/E segment***
Engine	1. ICEV 2. BIO-FUEL ICEV 3. LPG/NGV ICEV 4. HEV 5. PHEV 6. BEV		
Price	1. 15 k€ 2. 20 k€ 3. 25 k€ 4. 30 k€	1. 35 k€ 2. 40 k€ 3. 45 k€	1. 50 k€ 2. 60 k€ 3. 70 k€
Operating cost per 100km	1. Baseline -25% 2. Baseline 3. Baseline + 25%		
Incentive on purchase	1. Disincentive (extra taxes based on CO2 emission and engine power) 2. None 3. 3k€ with scrapping (to be deducted from purchase price) 4. 6k€ with scrapping (to be deducted from purchase price) 5. 10k€ with scrapping (to be deducted from purchase price)		
Incentive on utilization	1. None 2. Free access and free parking in LTZ 3. Free access, free parking in LTZ and access to bus lane		
Range	1. 200 km 2. 300 km 3. 400 km 4. 500 km 5. 600 km 6. 800 km	1. 300 km 2. 400 km 3. 500 km 4. 600 km 5. 800 km	1. 400 km 2. 500 km 3. 600 km 4. 800 km 5. 100 km
Charging time	1. Not applicable 2. 2 h 3. 1 h 4. 30 minutes 5. 15 minutes		
Diffusion of charging infrastructures	1. Only private charging 2. 1 out of 5 (20%) 3. 1 out of 2 (50%) 4. 3 out of 4 (75%) 5. All (100%)		

Table A.2: Attributes and level of variation of the car ownership survey (Gamba et al. 2022)

<table>
<tr><th rowspan="2">Charging infrastructure feature</th><th colspan="2">Levels description</th></tr>
<tr><th>Case 1: charging while on the road</th><th>Case 2: charging while doing other activities</th></tr>
<tr><td>Charging point typology</td><td></td><td>1. Public parking area equipped with charging point
2. Home (private)
3. Near home (public)
4. Work (private)
5. Near work (public)</td></tr>
<tr><td>Charging price per 100 km</td><td colspan="2">1. < 2 € (with periodic subscription)
2. 2 € (-50% than average EU price at home)
3. 4 € (average EU price at home)
4. 12 € (x3 than average EU price at home)</td></tr>
<tr><td>Charging time</td><td>1. 2 h
2. 1 h
3. 30 minutes
4. 15 minutes</td><td>1. 4 h
2. 2 h
3. 1 minute
4. 30 minutes</td></tr>
<tr><td>Possibility of booking</td><td colspan="2">1. No
2. Yes (optional)</td></tr>
<tr><td>Waiting time</td><td colspan="2">1. < 5 minutes
2. 5 – 15 minutes
3. > 15 minutes</td></tr>
<tr><td>Comfort and ancillary services</td><td colspan="2">1. None, only the charging point
2. Covered areas
3. Food and shops</td></tr>
<tr><td>Energy from renewable sources</td><td colspan="2">1. No
2. Yes</td></tr>
<tr><td>Connection technology</td><td colspan="2">1. Wired
2. Wireless</td></tr>
</table>