D2.1: User characterization: patterns and habits

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Technical References

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[1] PU = Public

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0. EXECUTIVE SUMMARY

This document is the deliverable "D2.1 – Users characterization: patterns and habits" of the H2020 project INCIT-EV (project reference: 875683).

The deliverable D.2.1 is aimed at investigating the current framework and the potential of electric mobility in Europe along with the clustering of current and potential EV users. According to this goal, the deliverable D2.1 firstly identified the evolution of the EV market to point out the trend of the electromobility for passenger cars and light duty (commercial) vehicle in different EU countries. The analysis highlighted how the EV market evolution is still at an early stage in most of the EU countries with the exception of some Northern country.

Starting from this market situation, the analysis about the current user's driving behaviour (as daily distance travelled, number of daily trips and daily travel time) and parking habits has been performed to evaluate potential promotion of the EV diffusion. The result is promising for a diffusion of EV, since present driving ranges of EVs in the market are significantly higher than average mobility needs of user.

After a further analysis on the use of the existing charging infrastructure has been performed to reveal some potential common aspects with the user's driving behavior. The study highlight that driving behaviors match with ones about the use of the existing charging infrastructure by EV users. In particular, low energy demand for charging EV is compatible to the short daily distance travelled by person and by EV passenger cars. Additionally, EV charging is also influenced by the location of the charging station.

Finally, this deliverable also presents a literature analysis of the EV-users and EV early adopters characterization. In particular, profiling of EV users and early adopters and the description of main leading factors in the marketing of Electric Vehicles at EU and International level are presented. In particular, the analysis pointed out that in most of the analyzed cases EV users or EV early adopters are approximatively identified by an high yearly income with an high level of education, while EV ownership is spread in middle aged people with a wider range. The main leading factors influencing these users in purchasing an EV are basically related to the higher efficiency of EV with respect to conventional cars (corresponding to lower fuel costs), the reduced environmental impact, the reduced maintenance cost of the EV, and a better standard of quality in driving an EV. In contrast, potential factors opposing people in purchasing EVs are related to the higher costs of EV compared to conventional cars, the lack of charging infrastructures and the driving range of an EV.

The delivery of this deliverable is done in accordance to the description in the Grant Agreement Annex 1 Part A with no time deviation and no content deviation from the original planning.

0.1 Acronym Table

Acronym	Definition
BEV	Battery Electric Vehicle

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Acronym	Definition
CPO	Charging Point Operator
CS	Charging Station
DSO	Distribution System Operator
EMP	E-Mobility Provider
EV	Electric Vehicle
FCD	Floating Car Data
GDPR	General Data Protection Regulation
ICT	Information and Communication Technology
LDV	Light-Duty Vehicle
PHEV	Plug-in Hybrid Electric Vehicle
SOC	State Of Charge
V2G	Vehicle-to-Grid

0.2 Index of Table

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1. INTRODUCTION

The deliverable D.2.1 has been developed within the task T2.1 (user characterization including mobility patterns and parking habits) of the INCIT-EV project aiming at investigating the current framework and the potential of electric mobility in Europe along with the clustering of current and potential EV users.

The sources of information have been the analysis of national, regional and metropolitan surveys on EV penetration (purchase and use), mobility pattern and parking habits in the Partners' Countries; surveys on the use of existing charging infrastructures in EU; historical FCD (Floating Car Data) to estimate mobility and parking habits of users; analysis of surveys for users characterization and market segmentation including socio-economic and behavioural user features.

According to the goals of the task, the deliverable D2.1 firstly aims at identifying the evolution of the EV market to point out the trend of the electromobility for passenger cars and light duty (commercial) vehicle (LDV) in different EU countries. This overview is propaedeutic to understand the current framework of the diffusion of the electromobility in Europe and to present the picture of the EV penetration both in the market and in the circulating fleets.

Stating the situation presented here, the promotion and the increase of the EV market and its diffusion is strongly influenced by many factors. Among the others, the two main aspects to be considered are the user's driving behaviour (as daily distance travelled, number of daily trips and daily travel time) and its parking habits. The former influences the energy consumption of the EV and, consequently, it is the key to understand if EV is capable to capture and satisfy mobility needs of the users according to the driving range of the EV battery. On the other hand, both main aspects potentially influence the charging needs for the EV in terms of charging station location and its technical specifications. These user's characteristics were preliminarily pointed out through a review and a literature analysis thanks to the data search and the contribution of the project partners involved in Task 2.1. The data of driving and parking habits presented in this deliverable refers to national and local scale (i.e. some partners' cities) to highlight the potential differences of mobility needs and behaviour. All the data presented and analyzed in the literature are based on national survey and consequently affected by uncertainty due to many factors (e.g. different approach in calculating/defining some quantities in each country; data can be biased by personal evaluations of the interviewed persons which might underestimate or omit some information; etc.). As will be highlighted later, this condition generally makes difficult to compare data from different sources. Nevertheless, literature analysis gives an approximate general framework of the driver's habits in different EU countries, pointing out that mobility needs can be favourable captured by EV, especially at the metropolitan and city level where driving ranges are shorter.

To overcome the limitations of the analysis of the literature analysis we resorted to a different analysis and approach based on the use of Floating Car Data (FCD). FCD are geo-localized data directly collected by moving vehicles through onboard GPS receiver or cellular phone. The use of this data allows to assess how current mobility patterns can accommodate electric mobility, either in case of passenger cars or light-duty vehicles. Due to the limited availability of this kind of data, only a specific focus on the metropolitan and city area of Turin (one of the partner's city where a use case will be developed) is presented in this deliverable. The FCD was processed to obtain for passenger cars and Light-Duty Vehicles (LDVs) the daily distances travelled, the duration and the location of the stops in the city of Turin. The data used in this approach focuses better the driver behaviour since origin/destination relations, speeds and distances are precisely evaluated for each vehicle monitored by onboard GPS receiver. In particular, GPS data can be used to precisely understand how

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passenger cars and LDVs are moving within a geographical area by statistical and spatial analysis. Results will be useful for the Decision Support Systems (DSS) developed within the project in WP 6.

After, a further literature analysis is presented describing the behaviour of the EV users when charging, since the analysis and the promotion of the diffusion of EVs cannot ignore the use of the charging infrastructure. Main results, such as the average charging time or the average energy demand during charging session, are pointed out from a previous European project called Green eMotion where data of charging events were registered and analysis were focused on the diffusion of user-friendly electromobility in EU. Results of the past EU project describe how users interact with the charging infrastructure considering more than 2,500 charging points installed across EU (i.e. France, Germany , Spain, etc.) to supply electricity for roughly 2,000 EVs (at the end of 2011). The results discussed here highlight also the difference in using the infrastructure according to the location of the charging stations (e.g. on street, at home, in public parking, etc.). In addition, where available, a focus on data regarding the use of the charging infrastructure and its main technical characteristics are presented for some partners' cities to present the diffusion and availability of current charging points.

Finally, this deliverable also presents a literature analysis of the EV-users and EV early adopter characterization. In particular, profiling of EV users and early adopters is presented for different EU and international context pointing out the main social, cultural and economic characteristics. The description of main leading factors in the marketing of Electric Vehicles at EU and International level are also presented.

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2. EV MARKET

In the years 2016 – 2019 the passenger EVs market share recorded growth in all the countries participating in the project, except Turkey (with 0% market share over the whole period, Figure 1). However, both the growth rate and the actual market share vary substantially among different states. The clear leader is Norway, with 60,5% EV market share in 2019, which is roughly double the value of 2016 thanks to the strong national incentives applied to the purchase and use of zero-emission vehicles. The other country with considerable share of EVs on the market is the Netherlands, with an increase from 6% to 16,5% in the same period. In other states the growth of EVs share is much slower, and in the year 2015 only one of them reached 5% (Portugal). Moreover, Battery Electric Vehicles (BEVs) seem to be overall more popular than Plug-in Hybrid Electric Vehicles (PHEVs), contributing to the majority of EVs market share in all the countries.

Norway is also the leader of transition to EVs when it comes to light duty vehicles. However, for Light-Duty Vehicles (LDVs) the market share is much lower than for private cars, reaching maximum value of 5,5% in Norway in the year 2019. Other countries are behind, with France, the Netherlands and Germany standing out from the rest, however not exceeding market share of 2%. For LDVs, practically no PHEVs are purchased and almost 100% of this market belongs to BEVs (Figure 2).

Even though the market share of EVs is growing everywhere, they still constitute a relatively small part of the whole circulating fleet. The dynamics of this indicator are similar to the development in EVs market share. For private vehicles, the fleet is most saturated with EVs in Norway where in 2019 they constituted 11,66% of all the passenger vehicles (Figure 3). However, for other countries this value is still very low in 2019 and does not exceed 1%, with exception of the Netherlands (2,4%). Norway has also the highest penetration of EVs in the LDV fleet (Figure 4), however the share barely reaches 1%. In other countries this value is even lower, most of the time not exceeding 0,5%.

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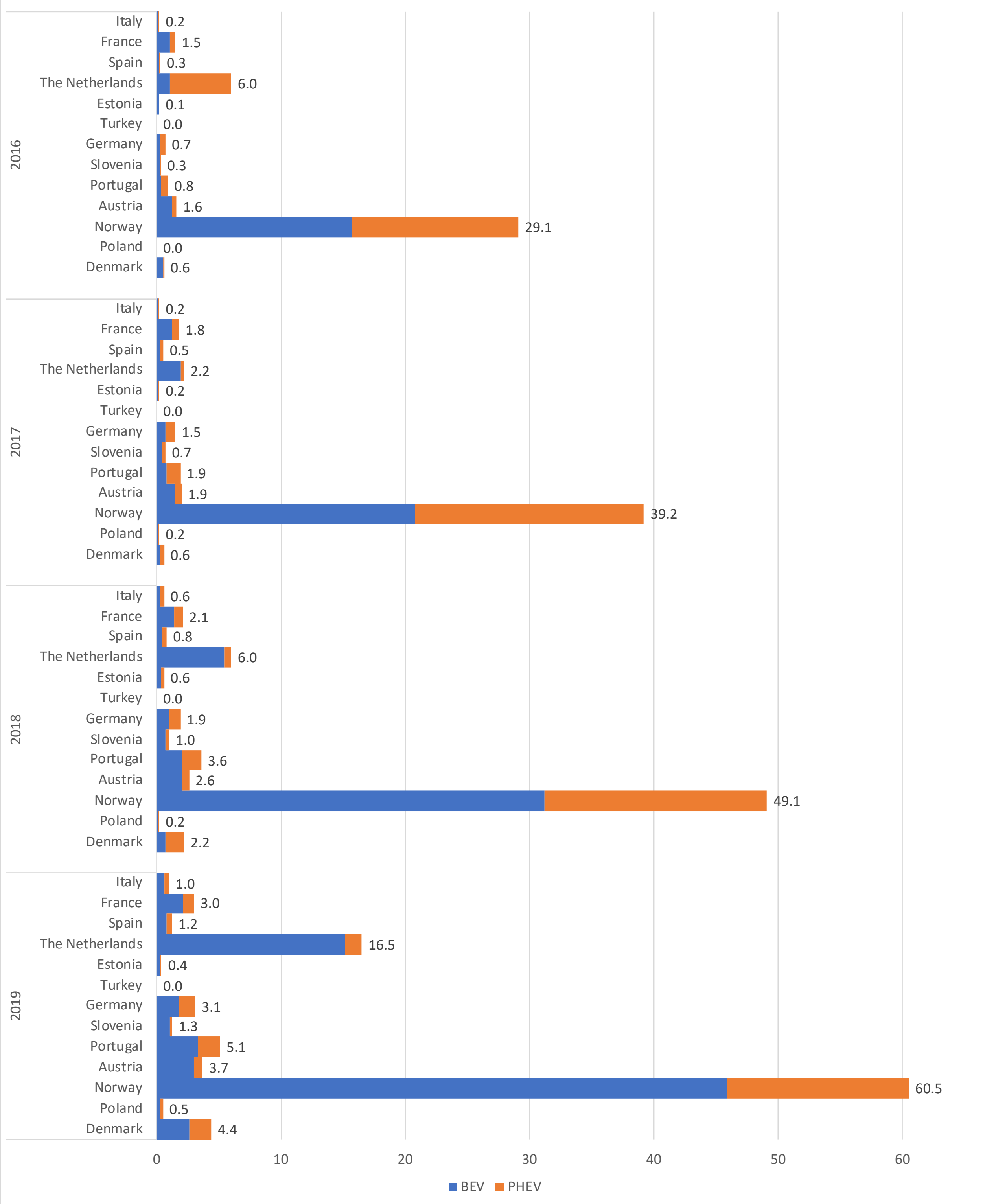

Figure 1. Electric passenger cars market share by years in different EU countries (%) (LINKS elaborations based on EAFO data)

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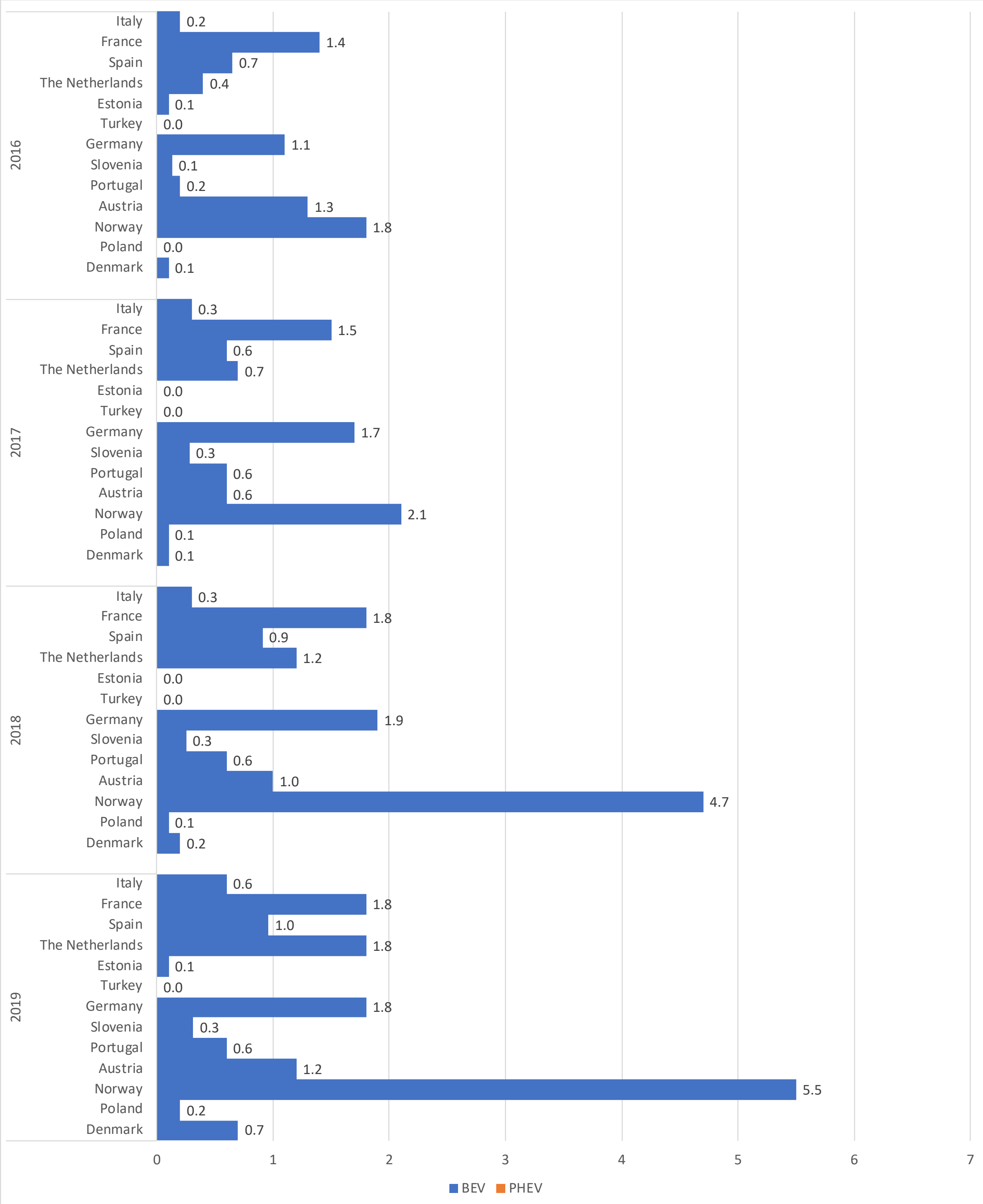

Figure 2. Light duty electric vehicle market share by years in different EU countries (%) (LINKS elaborations based on EAFO data)

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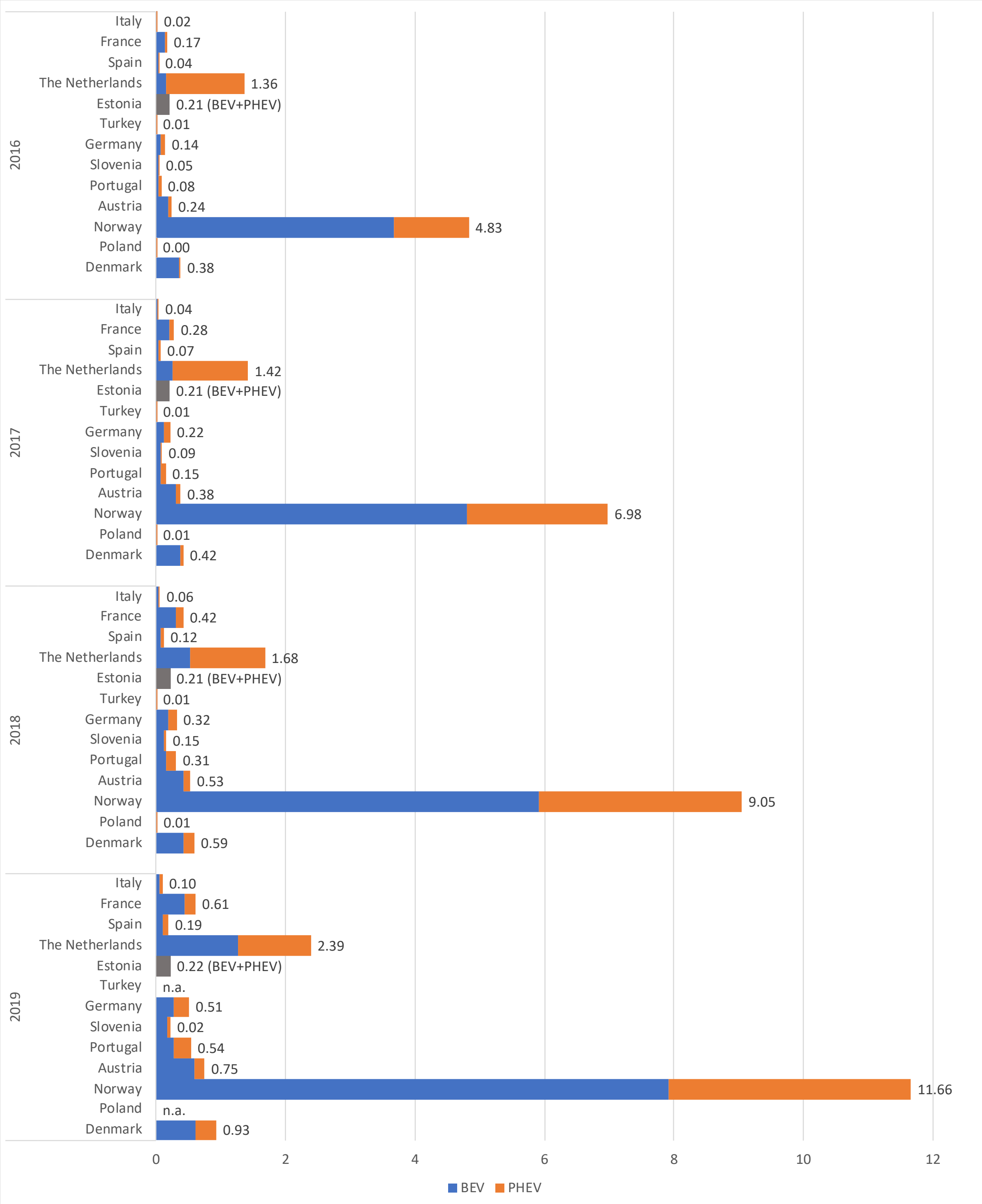

Figure 3. Electric passenger cars share in the circulating fleet by years in different EU countries (%) (LINKS elaborations based on EAFO data)

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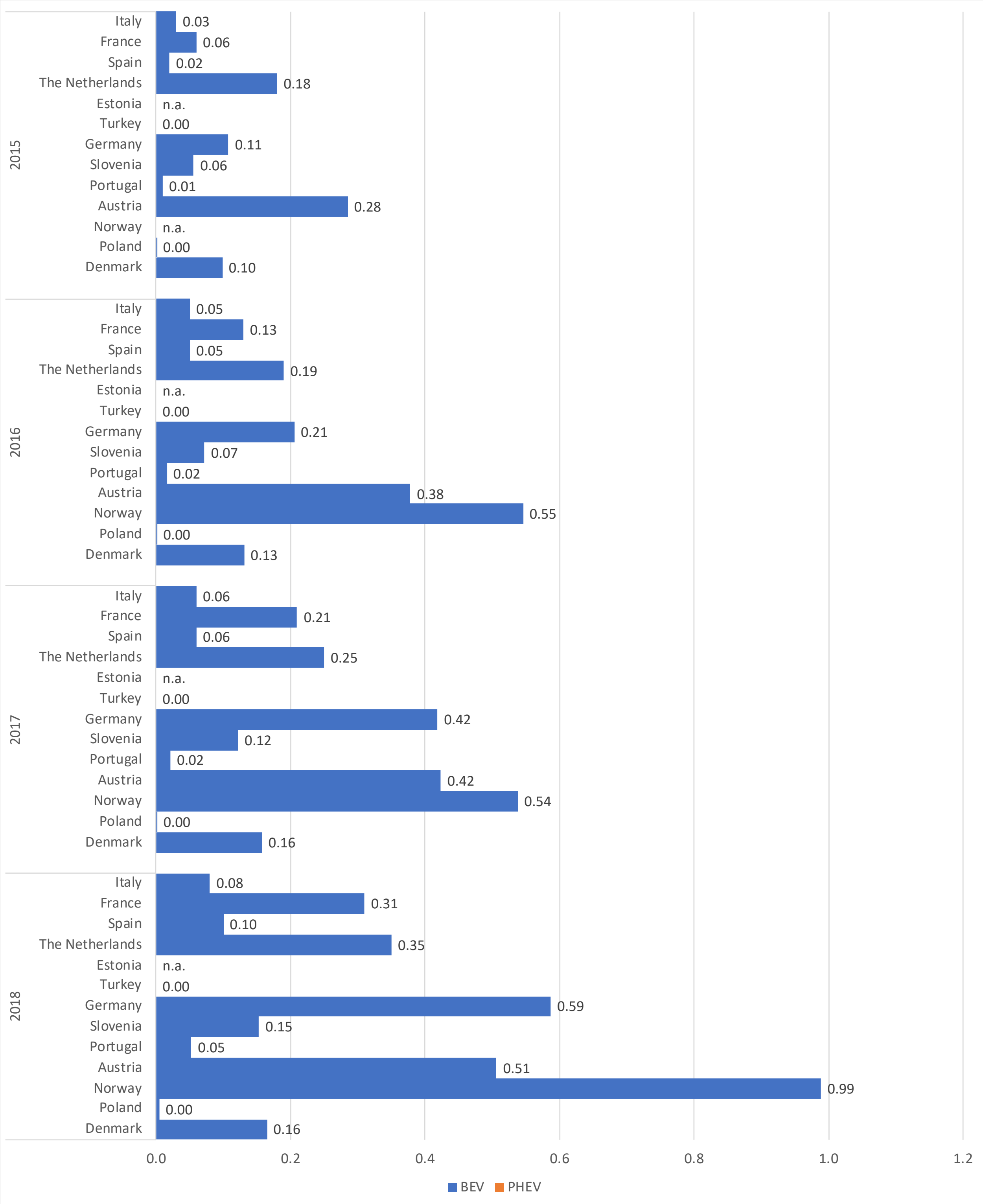

Figure 4. Light duty electric vehicle share in the circulating fleet by years in different EU countries (LINKS elaborations based on EAFO data)

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The national trends described above can be apparently also observed in some partners' cities as shown in Figure 5 and Figure 6. In fact, Turin, Zaragoza, Tallinn and Bursa still have a market penetration of electric passenger cars not exceeding 1%, with the exception of Paris that presents a market share for BEV close to 4.5%and for PHEV close to 3% in 2019 (Figure 5). More relevant appears instead the market share of hybrid electric vehicle in Turin and Bursa.

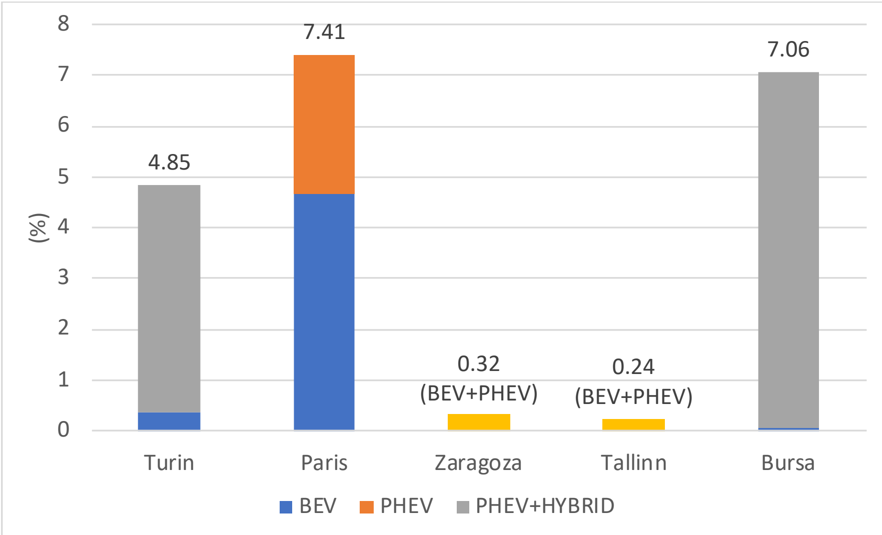

Figure 5. Electric passenger cars market share by partner's cities in 2019 (LINKS elaborations based on partners data)

Similarly to the corresponding national trends, market penetration of electric Light Duty Vehicle does not exceed 1% in some partner cities like Zaragoza and Bursa (Figure 6), with exception of Paris that surprisingly have a relevant local market share for BEV and PHEV close to 4.3% and 1%, respectively.

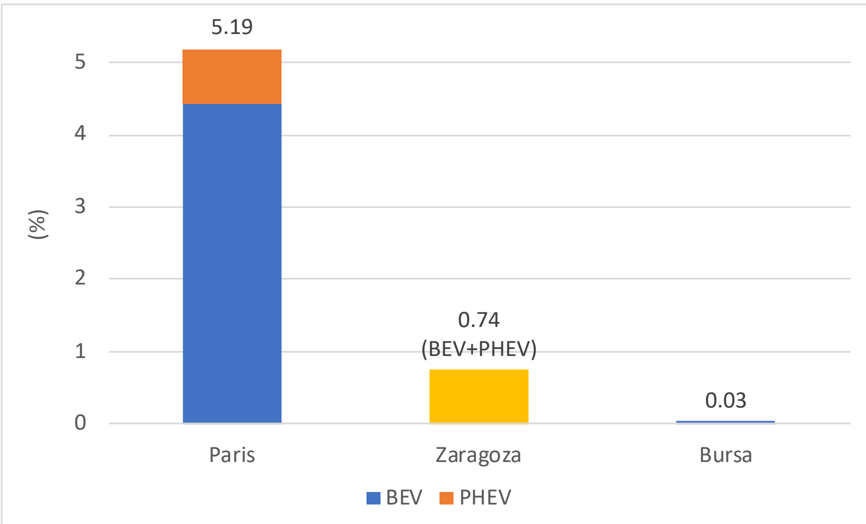

Figure 6. Light duty electric vehicle market share by partner's cities in 2019 (LINKS elaborations based on partners data)

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3. MOBILITY PATTERN AND PARKING HABITS

This chapter discusses a number of mobility indicators which are significant for EVs deployment. Namely, following subsections address daily distance travelled, daily travel time and daily trips. Additionally, also parking habits are discussed due to their great importance for the location and use of charging stations.

Initial intention was to gather and compare those data for all the countries participating in the project. However, it turned out to be extremely difficult due to poor availability and lack of homogeneity of data. This problem was also noticed by the European Commission, which resulted in guidelines for standardization of collecting mobility data, based on comparative analysis of a number of national mobility surveys (Ahern et al., 2013). In that document a number of problems with comparability of data from various countries are mentioned, such as “application of distinct methodological approaches based on varying concepts (e.g. the definition of what is regarded as trip), differing data collection times (e.g. workday coverage vs. seven day week), specific national conditions (e.g. availability of sampling frames etc.) or the prevailing law (e. g. data protection regulations, privacy policy).” For that reason, although data from national mobility studies are also presented in this chapter, they should be treated cautiously, and their comparability may differ in each single case.

However, apart from records coming directly from countries, also two large studies discussing mobility behavior on European level were conducted in the past at the initiative of the European Commission. Despite having their own limitations (e.g. addressing a limited number of countries), thanks to applying the same methodology to multiple countries they provide a good overview and possibility of comparison of mobility patterns in various EU member states. One of the studies addresses driving and parking habits of European car drivers (Pasaoglu et al., 2012), whereas the other includes all modes and examines travel behavior regarding daily and long trips, as well as opinions on innovation and transport policy (Fiorello & Zani, 2015).

3.1 Daily distance travelled

The values that can be found in the table below were obtained from various national sources on mobility behaviour of the citizens.

Location	Year	Daily distance travelled [km/person/day]	Source
Italy	2018	25,8	15 ° Rapporto sulla mobilità degli italiani
Torino	2019	14,0	Politecnico Torino (based on FCD)
France	2008	25,2	La mobilité des Français (2008)
Paris	2008	13,0	La mobilité des Français (2008)
Spain	2012	26,4	Cuentas ecologicas del transporte (2016)

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the Netherlands	2018	36,1	Centraal Bureau Statistiek
Estonia	2020	34,6	Republic of Estonia Road Administration
Turkey	2018	37,7	Turkish Statistical Institute
Germany	2017	39,0	Mobility in Germany – short report (2019)
Slovenia	2017	34,5	Slovenia Statistical Office
Portugal	2017	28,7	Mobilidade e funcionalidade do território nas Áreas Metropolitanas do Porto e de Lisboa (2017)
Austria	2014	35,7	Österreich unterwegs (2016)
Vienna	2014	28,1	Österreich unterwegs (2016)
Norway	2014	47,2	2013/14 Norwegian Travel Survey – key results
Poland	2015	19,7	Badanie pilotażowe zachowań komunikacyjnych ludności w Polsce (2015)
Denmark	2019	40,0	Danish National Travel Survey

Table 1. Daily distance travelled (various sources)

The data span from 13 to 47,2 km/person/day. It is worth mentioning that the highest value was registered in Norway, which is also the country with the highest share of EVs. As already discussed, comparability of those numbers is limited, therefore for comparative purposes below we present the same metric coming from a study applying single methodology to six different EU countries (the most populous ones, Figure 7).

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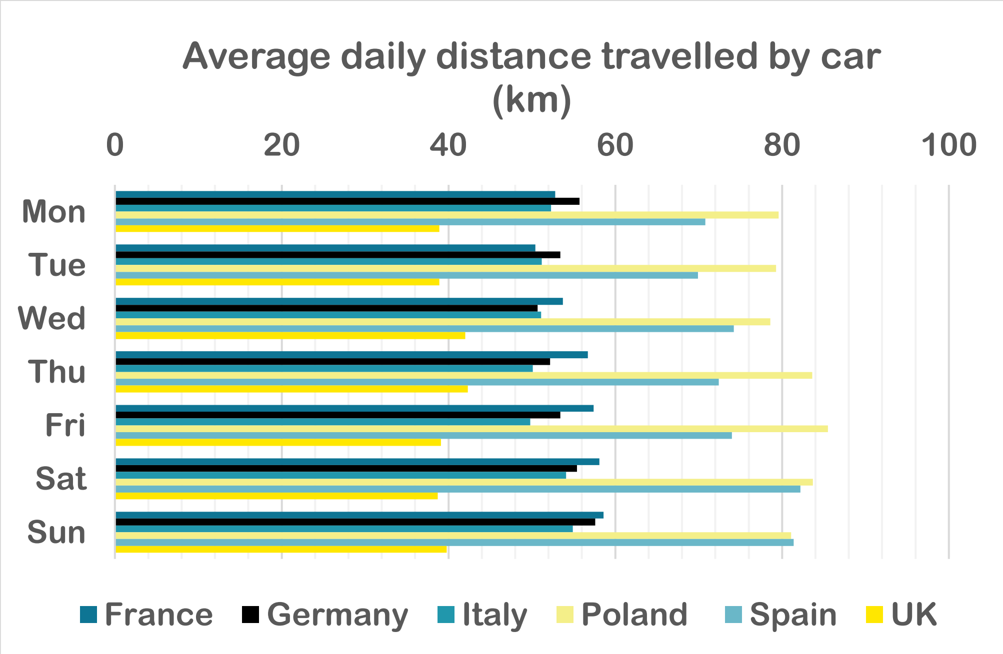

Figure 7. Average daily distance travelled by car (Pasaoglu et al., 2012)

Countries can be assigned into three different groups. Poland and Spain have clearly the highest travel distances by car. On weekdays Polish drivers travel the further distances daily of all the countries (around 80 km), and on weekends the distances of Spanish car users also increase, making the values for Poland and Spain almost equal. On the opposite side, there is the UK with the average daily distance of roughly 40 km a day. The remaining three countries can be classified to the third group with the average daily distance between 50 and 60 km per day.

In the context of EVs the important conclusion is that distances by car in this range can be easily covered by the batteries that are currently available on the market. Moreover, the average distance covered on weekends is not significantly different from weekdays. This might seem contrary to intuitive expectation of more long distance leisure trips on Saturday and Sunday. Thus, EVs seem to be also able to cover the average travel demand on these days.

In addition to the above data for car, below also average daily distances of most frequent trips for all modes together can be found. In this case the metric is available for all EU countries (Figure 8).

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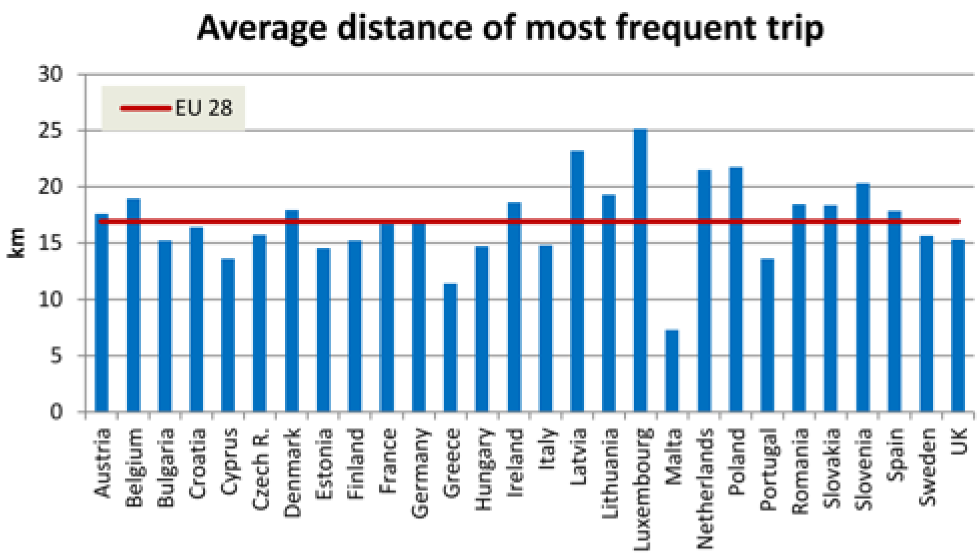

Figure 8. Average distance of most frequent trip (all modes) (Fiorello & Zani, 2015)

The average distance equals 17 km/trip. Only in five countries the number falls outside the interval of 14 -20 km with Luxembourg and Malta showing extreme values. These values are averaged distances taking into account all transport modes, but the distance also differ substantially between modes, as it is shown in chart of Figure 9.

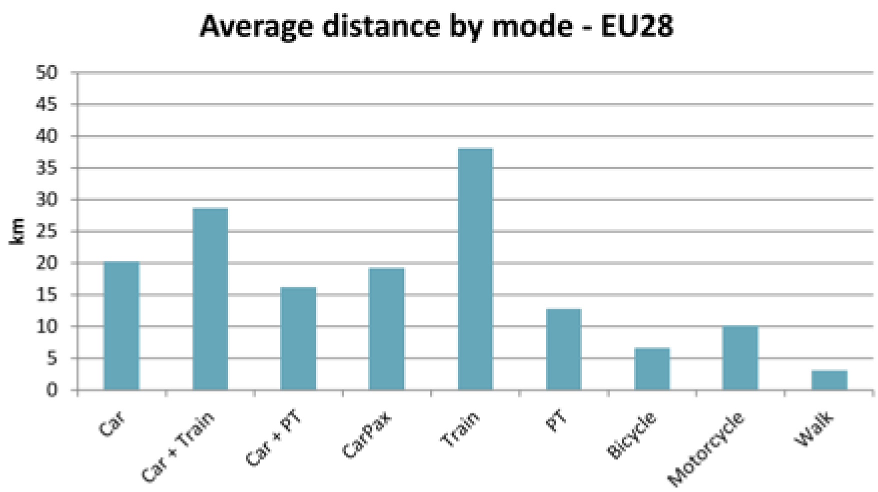

Figure 9. Average distance travelled by mode (Fiorello & Zani, 2015)

The longest are trips by train (on average 38 km), followed by car trips (20 km). Trips by public transport are usually 13 km long, and walking and cycling rarely is longer than 5 km (Fiorello & Zani, 2015). It can be concluded, that both the average distance travelled by car and train could be comfortably covered by the available EV batteries.

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3.2 Daily travel time

Data on travel time gathered from a variety of national sources is presented in the table below (Table 2Table 13). In general, the values are in line with the hypothesis of daily travel time budget, which is reported to be 1-1,3 hours/per day depending on the study (Ahmed & Stopher, 2014). The only outlier here is Poland. The reason might be an unexpectedly low number of daily trips reported in the national study (on average 1,39 trip/day), which was used to obtain daily travel time.

Location	Year	Daily travel time [hours]	Source
Italy	2018	0,8	15 ° Rapporto sulla mobilità degli italiani
Torino	2019	1,22	Politecnico Torino (based on FCD)
France	2008	0,93	La mobilité des Français (2008)
Paris	2008	1,18	La mobilité des Français (2008)
Spain	2007	0,98	Movilia (2007)
the Netherlands	2018	1,24	Centraal Bureau Statistiek
Estonia		no data	
Turkey		no data	
Germany	2017	1,41	Mobility in Germany – short report (2019)
Slovenia	2017	0,89	Slovenia Statistical Office
Portugal	2017	1,16	Mobilidade e funcionalidade do território nas Áreas Metropolitanas do Porto e de Lisboa (2017)
Austria	2014	1,16	Österreich unterwegs (2016)
Vienna	2014	1,33	Österreich unterwegs (2016)
Norway	2014	1,30	2013/14 Norwegian Travel Survey – key results
Poland	2015	0,56	Badanie pilotażowe zachowań komunikacyjnych ludności w Polsce (2015)
Denmark	2019	0,93	Danish National Travel Survey

Table 2. Daily travel time (various sources)

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Figure 10 contains data from the European Commission study applying a single methodology to six different countries.

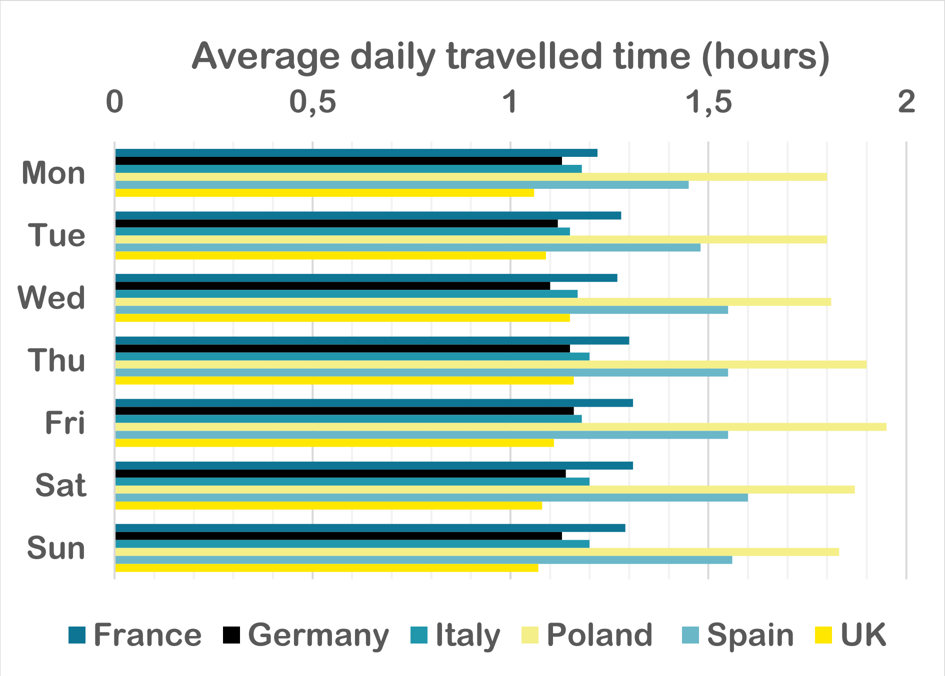

Figure 10. Average daily travelled time by car (Pasaoglu et al., 2012)

Here on the other hand, Poland has the longest travel duration by car (1.8 hours and more), followed by Spain (roughly 1.5 hours a day). The other four countries can be qualified into the same category with daily travel time of more or less 1.2 hours per day, which is similar to majority of results coming from national mobility surveys. In addition to data for car drivers presented in Figure 10, the figure below represents average time of the most frequent trip for all EU countries, including all modes.

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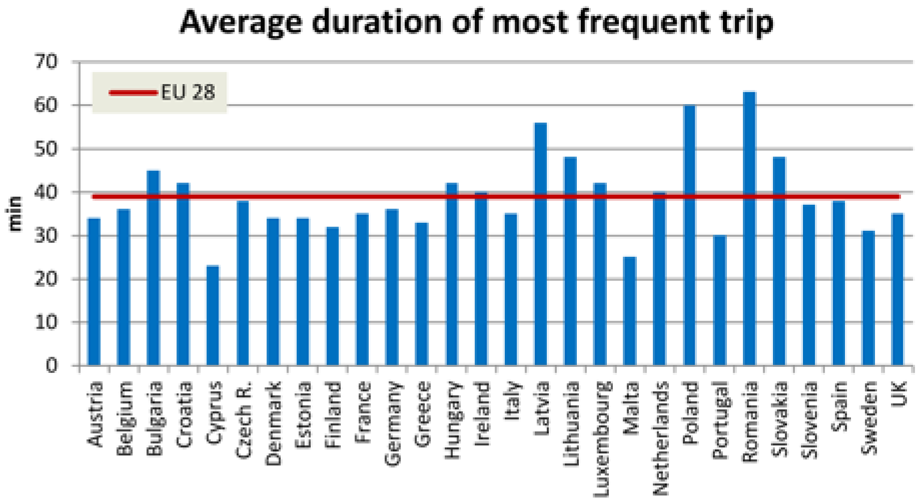

Figure 11. Average duration of the most frequent trip (all modes) (Fiorello & Zani, 2015)

The average trip duration for all EU 28 countries is 39 minutes. Apart from the two small island countries (Malta and Cyprus) the results are rather homogenous, with exception of Eastern European countries. The authors of the report explain this by either large share of multimodal trips in these countries, or higher number of irregular long trips during the week which increases the daily average (Fiorello & Zani, 2015).

3.3 Daily parking time

In the context of EVs the periods when the car is parked are especially important, as they are the opportunity for charging the battery. Moreover, it is evident from the data discussed above that the time when a car is on the move constitutes only a very minor part of the day and most of the time the vehicle is parked.

Unfortunately, parking behaviour is typically not included in any national level mobility studies. For the purpose of this deliverable the results of Pasaoglu et al. (2012) are discussed. The data is divided into three charts, representing parking habits on weekdays, Saturdays and Sundays.

Parking time was categorized by the authors into active and inactive parking. Active parking means the parking time between consecutive trips during the day, whereas inactive parking is the parking time before the first trip of the day or after the last trip of the day. On weekdays the active parking amounts to roughly 6 hours per day, and inactive parking to more than 16 hours per day. On Saturdays and Sundays the inactive parking duration is even longer, which can be explained by lack of commuting during the weekend (thus no prolonged parking during working hours).

Although there exist some small differences between the countries, in practical terms they do not have major significance. Regarding EVs, the most important conclusion is that the duration of active and inactive parking is homogenous for all the six countries, and its duration can serve as a positive indicator for possible charging availability both at home and at workplace.

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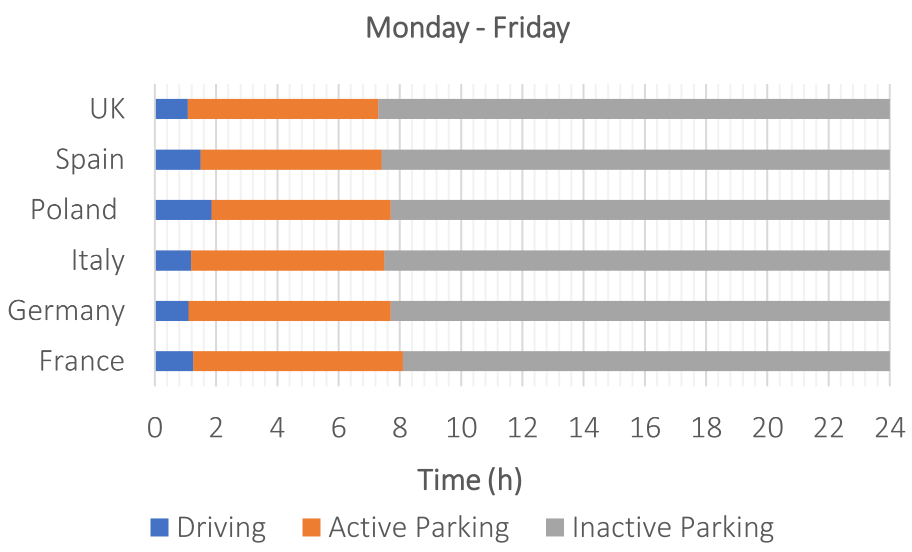

Figure 12. Average daily distribution of driving and parking time (weekdays) (Pasaoglu et al., 2012)

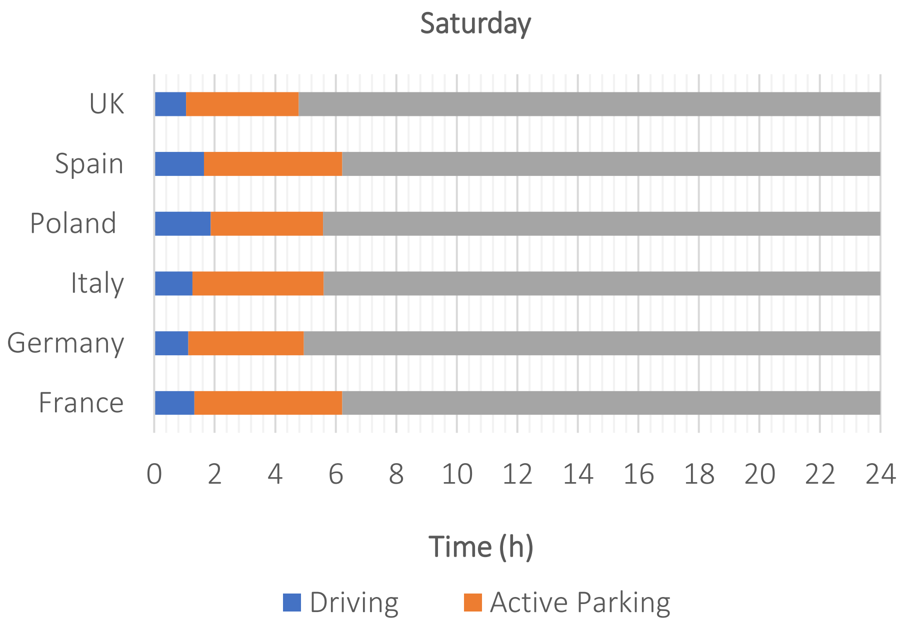

Figure 13. Average daily distribution of driving and parking time (Saturday) (Pasaoglu et al., 2012)

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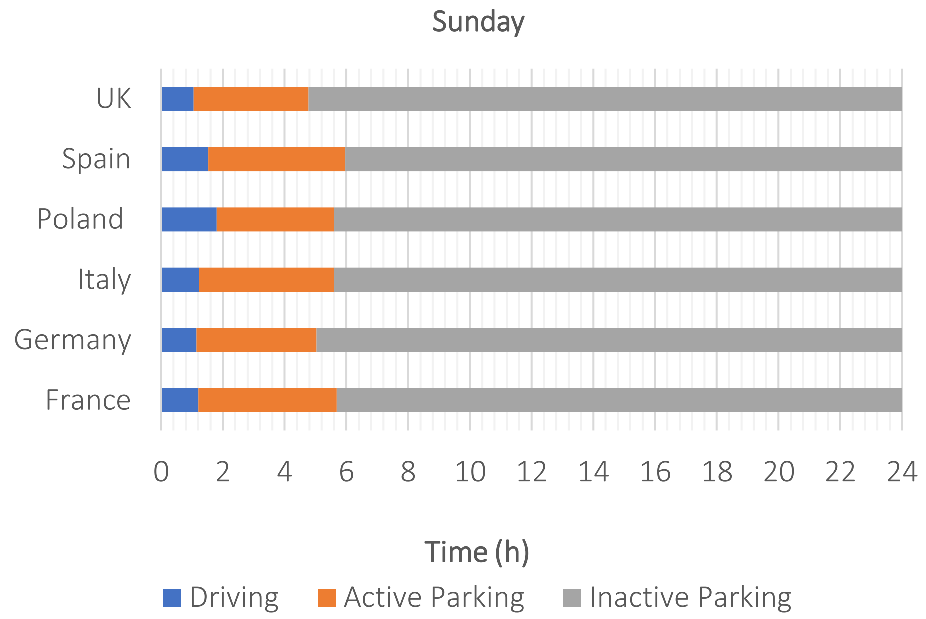

Figure 14. Average daily distribution of driving and parking time (Sunday) (Pasaoglu et al., 2012)

Due to the mentioned difficulty in collecting parking data, only for a very limited number of countries participating in the INCIT-EV project such information could be found. The data that were retrieved are presented in the Table 3.

Location	Year	Daily parking duration [hours]	Source
Spain	2012	23,28	Cuentas ecologicas del transporte (2014)
Germany	2017	23,23	Mobilität in Deutschland (2019)

Table 3. Daily parking time by car on national level(data from project partners)

The parking duration for both Spain and Germany is almost the same, however it is in both cases more than 30 minutes longer than the average daily parking duration for all the countries examined by Pasaoglu et al. (2012). It is difficult to speculate about the source of this difference. Possible source might be the fact that averaging parking time on national level is very sensitive to the sample used, as parking times might differ a lot depending on the area (urban/suburban), parking fees or day of the week.

Some indication of this can be found in the example of three project partner cities, for which it was possible to obtain parking data (Table 4).

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Partner		Private cars		LDV		Source
		Weekday	Weekend	Weekday	Weekend	
Torino	Total	3,22	2,76	2,37	2,6	Politecnico Torino (based on FCD)
	Paid time slot	2,63	2,23	2	2,09	
Bursa		1,43	4,05	1,22	3,685	Bursa Public Transportation Management
Tallin		2,63	2,23	-	-	AS Ühisteenused

Table 4. Daily parking for passenger car time on local level (data from project partners)

Of course, the above data represents parking time measured within cities and ignores the “inactive” parking time (I.e. the time when the car is parked before the first trip of the day or after the last trip of the day), therefore the numbers are much lower than in case of data for national level, which consider total parking time in 24 hours.

3.4 Daily trips

According to national mobility data from various sources, in the majority of countries people make on average between 2,5 to 3 trips per day (Table 5).

Location	Year	Daily trips [#]	Source
Italy	2017	2,3	15 ° Rapporto sulla mobilità degli italiani (2018)
Torino	2019	2,61	Politecnico Torino (based on FCD)
France	2008	3,15	La mobilité des Français (2008)
Spain	2007	2,8	Movilia (2007)
the Netherlands	2018	2,68	Centraal Bureau Statistiek
Estonia		no data	
Turkey		no data	

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Location	Year	Daily trips [#]	Source
Germany	2017	3,1	Mobility in Germany – short report (2019)
Slovenia	2017	2,82	Slovenia Statistical Office
Portugal	2017	2,66	Mobilidade e funcionalidade do território nas Áreas Metropolitanas do Porto e de Lisboa (2017)
Austria	2014	2,8	Österreich unterwegs (2016)
Vienna	2014	2,9	Österreich unterwegs (2016)
Norway	2014	3,26	2013/14 Norwegian Travel Survey – key results
Poland	2015	1,39	Badanie pilotażowe zachowań komunikacyjnych ludności w Polsce (2015)
Denmark	2019	3	Danish National Travel Survey

Table 5. Daily trips (various sources)

This number is similar to observations from the study of Pasaoglu et al. (2012), in which the averaged value for the whole week for all the six examined countries is equal to 2,6 trips/day (Figure 15). For most of the countries the results are quite homogenous, with exception of France for which the average is 2,9 trips/day.

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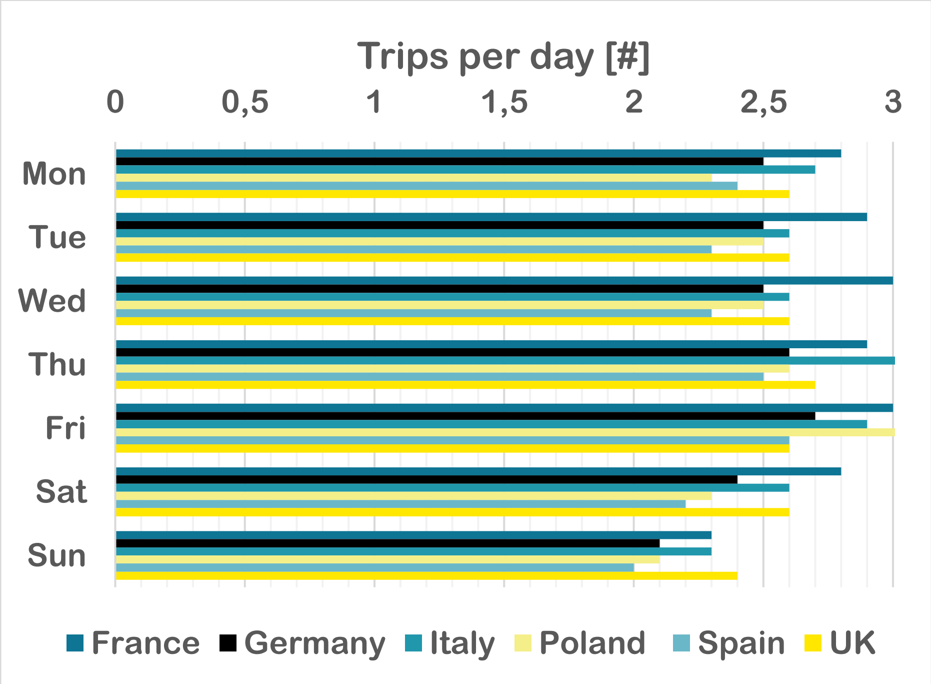

Figure 15. Trips per day by car (Pasaoglu et al., 2012)

The above chart also indicates generally higher trip frequency on Fridays , as well as a lower number of trips on weekends. However, considering relatively small sample within the study only the reduced number of trips on Sundays can be taken as a robust result, since lower trips are expected due to a reduced use of vehicles by drivers, while other values should be treated with care.

In addition to the frequency of trips, also their destination is particularly relevant for potential location of EVs charging stations. The chart below represents the distribution of various trip chains within all the daily trips (Figure 16).

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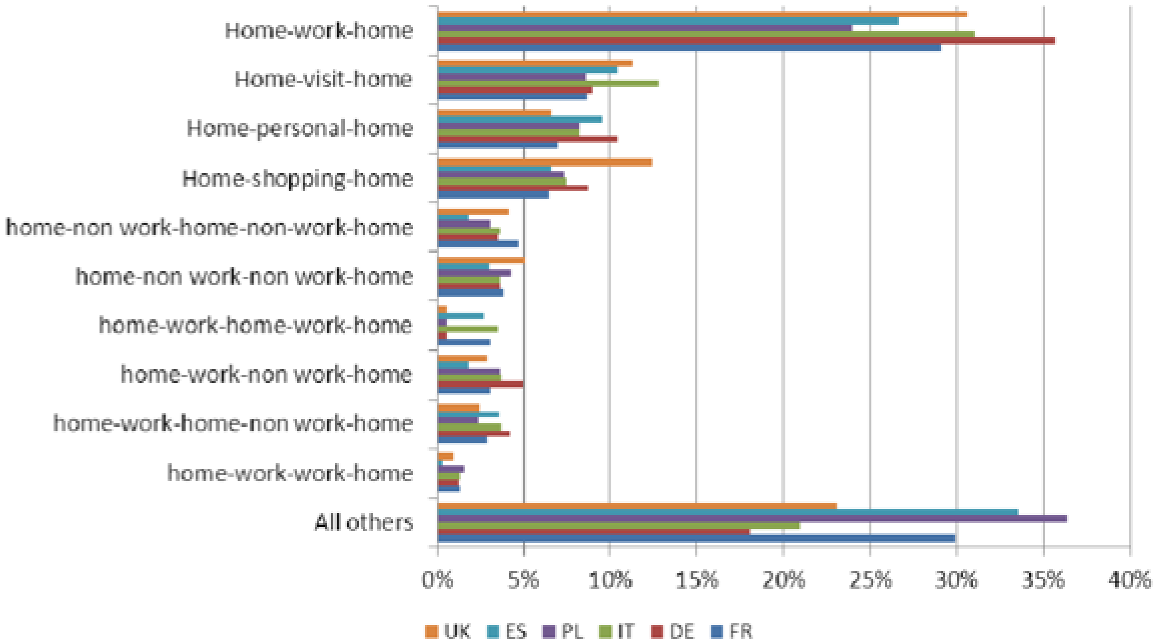

Figure 16. Frequency of trip chains by purpose for passenger cars (Pasaoglu et al., 2012)

An important observation is that the majority of trips are single-purpose trips. In most countries trip to work amounts to one third of daily trip chains, and the other three single-purpose trips (visit/personal/shopping) make up another quarter of daily trips. It is relevant information for EV charging, as it allows for longer uninterrupted parking time at the destination.

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4. FLOATING CAR DATA ANALYSIS

As already stated in the previous chapter, the usefulness of conventional mobility surveys for comparative studies between countries is limited. Reliability of such results is also limited due to possible mistakes and misunderstandings from the respondents. In recent years dynamic development of big data technologies led to broader exploitation of GPS data in the field of transport and mobility. One of the examples is work of De Gennaro et al. (2014), examining driving patterns in Italian provinces of Florence and Modena for assessing the potential of EV adoption. The authors reflect that “The GPS data are more accurate than surveys data, since they are based on precise and sequential sampling of the driving patterns, not affected by personal interpretation as it can occur with survey interviews.”

That study was followed few years later by Paffumi et al. (2018), who extended the dataset with GPS data from a number of European cities to prepare a broad comparative study on mobility patterns in multiple countries in Europe. The major metrics presented in their work are included in Table 6.

Vehicle type	Location	Average trip distance [km]	Average trip duration [m]	Average parking duration [h]	Number of trips per day [#]
Private vehicles	Province of Modena	7,69	11,63	4,07	7,8
	Province of Florence	7,85	13,0	4,33	8,0
	Province of Amsterdam	19,68	14,32	1,14	19,7
	Province of Brussels	7,75	9,13	1,45	7,7
	Province of Paris	16,97	20,05	1,18	17,0
	Province of Luxembourg	11,88	13,99	1,703	11,9
Commercial vehicles	Province of Lisbon	14,96	22,44	1,07	15,0
	Province of Krefeld	90,51	90,84	0,80	88,8
	Province of Warsaw	51,84	55,90	0,94	51,8
	Province of Bratislava	22,93	22,89	0,40	22,9
	Province of Vienna	37,43	35,96	0,48	37,9
	Province of Ljubljana	50,69	75,79	0,87	45,3

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Vehicle type	Location	Average trip distance [km]	Average trip duration [m]	Average parking duration [h]	Number of trips per day [#]
	Province of Zagreb	29,31	45,63	0,99	24,3
	Province of Budapest	44,14	43,25	0,91	44,1
	Province of Sofia	16,37	23,40	0,94	16,4
	Province of Athens	11,0	26,15	0,69	11,0

Table 6. Key mobility statistics for various European cities based on GPS data (Paffumi et al., 2018)

Again, the authors highlight the benefits of GPS data. They also notice certain discrepancies between their results and the numbers found by literature review of mobility surveys. The number of trips they registered was usually higher than those from the surveys, whereas the average trip distance was either higher or lower. The authors suggest that the survey results might be biased either by the type of the survey or personal evaluations of the respondents (e.g. ignoring short trips as irrelevant).

Taking into account the above observations and most recent trends in mobility research, for the purpose of the current study an in-depth analysis of floating car data for the city of Turin was carried out, which is presented next in this chapter.

4.1 The city of Turin

The main goal of this analysis was to assess how current mobility patterns can accommodate electric mobility, either in case of passenger cars or light-duty vehicles. Trips were analyzed for evaluating their compatibility with typical battery ranges.

On the other hand, idle times between consecutive trips can provide useful information for the ECS infrastructure development.

The available floating car data (FCD) datasets at POLITO – DIATI originate from black boxes installed on vehicles (very low number of actual EV). All trips were recorded within Turin Metropolitan City, including the main city and more than 300 towns in the area, either as origin or destination or as crossing trips between external zones.

4.1.1 Data import

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4.1.1.1 Features of interest

Datasets contain a lot of various information, not all useful for the analysis. Selected features are:

- Trip ID
- Device ID
- Departure Datetime
- Arrival Datetime
- Departure Latitude and Longitude
- Arrival Latitude and Longitude
- Departure ISTAT (Italian Institute of Statistics) city code
- Arrival ISTAT (Italian Institute of Statistics) city code
- Distance travelled [km]
- Speed [km/h]
- Vehicle Manufacturer
- Vehicle model
- Temperature at departure
- Temperature at arrival

4.1.1.2 Full dataset formation

Observation period lasted from 15/01/2019 to 14/01/2020. A dataset for each day is available in .csv.gz format. Daily datasets are merged into one single dataset.

4.1.2 Preliminary operations

4.1.2.1 Travel times computation

Each trip travel time (TT) was computed as the difference between trip arrival and departure. Alternatively, but more inaccurately, TT can be computed as the traveled distance divided by the speed.

4.1.2.2 Vehicles models and segments

Vehicles of the same model are sorted together, despite their versions may be different. Subsequently, the models are further divided into specific groups, for both passenger and light-duty vehicles.

Passenger cars

A model classification based on market segmentation and vehicle types is introduced:

- A-segment / City car / Minicompact
- B-segment / Supermini / Subcompact
- C-segment / Small family / Compact
- D-segment / Large family / Mid-size
- E-segment / Executive / Full-size

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- F-segment / Luxury saloon / Full-size luxury

Light-duty vehicles

Two different criteria are considered for classifying LDVs: maximum authorized mass (MAM) and body/chassis shape (which often is linked to the volume available). In the first case, several groups are defined as in Table 7. For the second case, categories in Table 8 are adopted, including approximated capacity ranges. The two classifications are combined for defining the final segments to be considered in the analysis (Table 9). Compact vehicles with mass lower than 2.5 t are excluded from further analysis, because such vehicles may be used either for freight or people transportation.

Label	Lower Bound [t]	Upper Bound [t]
<2.5	-	2.5
<3.5	2.5	3.5
<5	3.5	5
<7.5	5	7.5

Table 7. MAM-based classification for LDVs

Category	Label	Lower Bound [m^3]	Upper Bound [m^3]
Compact	C	4	7
Mid	M	6	9
Large	L	8	13+

Table 8. Body-based classification for LDVs

Label Segment	Lower Bound [m^3]	Upper Bound [m^3]	Lower Bound [t]	Upper Bound [t]
C35	4	7	2.5	3.5
M35	6	9	2.5	3.5
M50	6	9	3.5	5
L50	8	13+	3.5	5
L75	8	13+	5	7.5

Table 9. Final segments of LDVs considered in the analysis.

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4.1.2.3 Data screening

Data are grouped by date and the following variables were plotted against time, for observing possible peculiar behaviours of data availability in time:

- Total distance travelled [km]
- Total travel time [h]
- Unique IDs [#]
- Unique models [#]

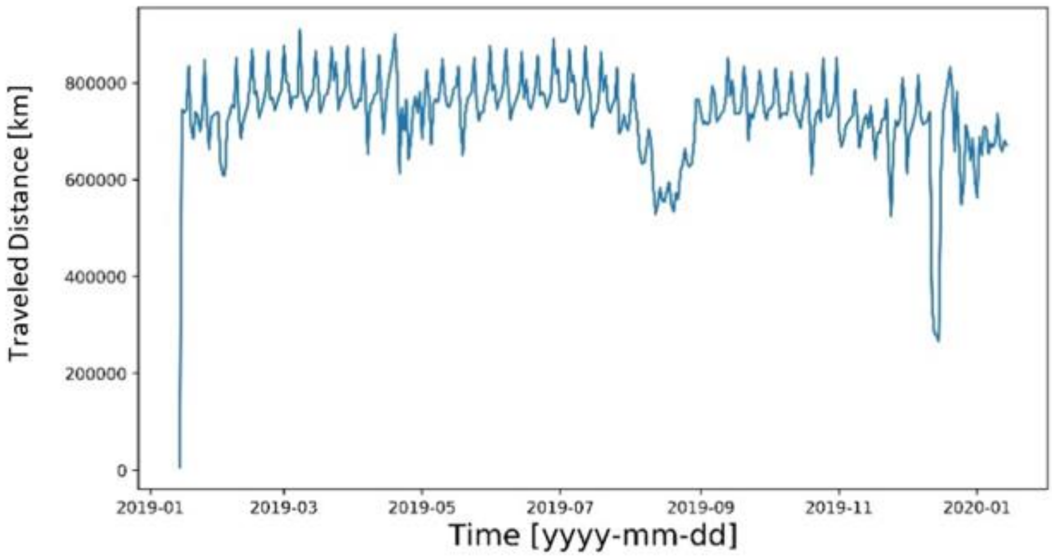

Figure 17. Example of quantities plotted against time: Total travelled distance for passenger cars

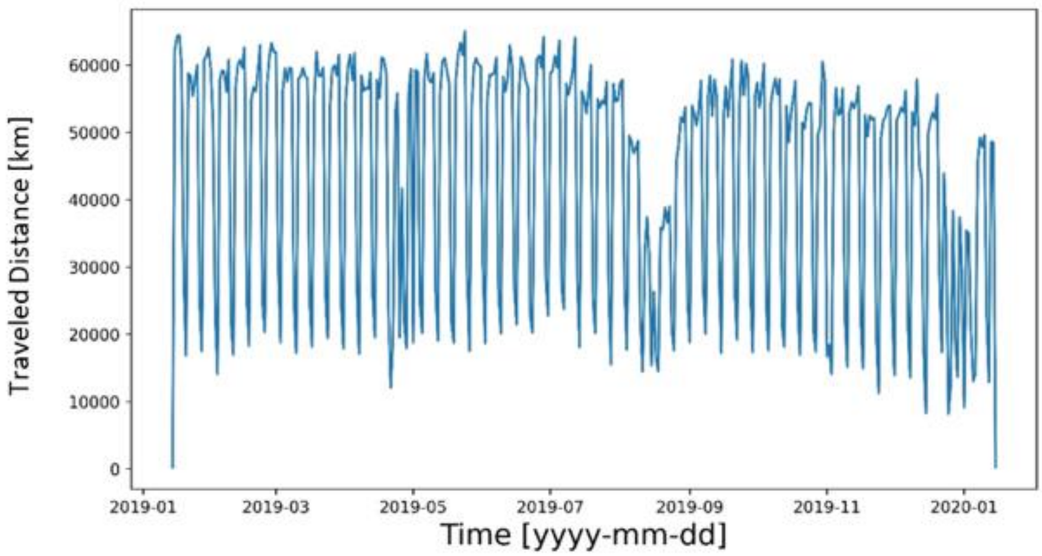

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Figure 18. Example of quantities plotted against time: Total travelled distance for passenger LDVs

4.1.2.4 Data quality control

A number of data checks were performed in order to detect possible significant discrepancies in the gathered data. For each trip, the recorded value of speed was compared to the ratio between distance and time. Moreover, the recorded distance and the computed time (as difference between arrival and departure) were compared to the product of speed and time, and to the ratio between speed and time, respectively. Absolute and relative errors were computed for these comparisons.

4.1.3 Daily travelled distances

4.1.3.1 Trips spanning over two days

Some of the recorded trips end the next day after the day they started. For the purpose of analysis, trips that cover two days were split in two: first sub-trip lasts from the departure time to 23:59:59 of the same day, whereas the second sub-trip starts at midnight of the next day, and ends at the original trip arrival time. Average speed is assumed to be the same for both sub-trips. Consequently, travelled distances are linearly proportional to the sub-trips travel times.

4.1.3.2 Daily individual statistics

Data were grouped by date and ID. Vehicle segment information was also included. The following daily individual statistics were computed:

- Distance travelled
- Travel time
- Number of trips
- Average spatial speed

4.1.3.3 Daily individual mobility patterns

Daily individual activity (I.e. each daily trip for a given ID) is categorized depending on the origin and destination locations, as follows:

- Internal (I): all trips inside the study area
- External (E): all trips outside the study area
- Other (O): some trips inside, some trips outside the study area

Three different study areas are taken into account:

- Turin municipality (1 city, Turin)
- Turin conurbation (Turin plus 31 surrounding cities)
- Turin Metropolitan City (Turin plus 311 other cities)

In this section (Daily traveled distances) all data are used for collecting statistics, while in the further one (Idle times) only trips which end in Turin are considered, since a focus on the Turin Municipality is made.

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4.1.3.4 Daily average statistics

Daily individual statistics were averaged over the entire observation period, separating weekdays from Sundays. More precisely, for limiting the effect of the trips performed by commuters, only Tuesdays, Wednesdays, and Thursdays were considered as weekdays.

4.1.3.5 Cumulative distribution function

The most suitable cumulative distribution function and its parameters were identified, in order to describe the experimental daily individual travelled distance cumulative curve. In this way, it can be easily observed how much of the daily individual demand (in percentage terms) is met by battery range values.

In our case, log-normal distributions provided interesting results in terms of conservativity and goodness of fit.

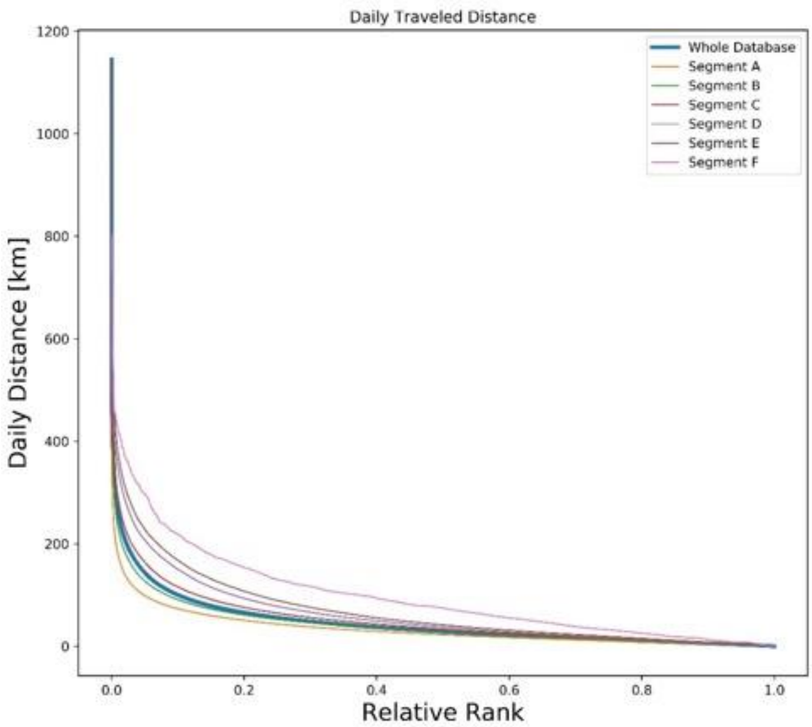

Figure 19. Experimental distribution of individual daily distances for each passenger car segment

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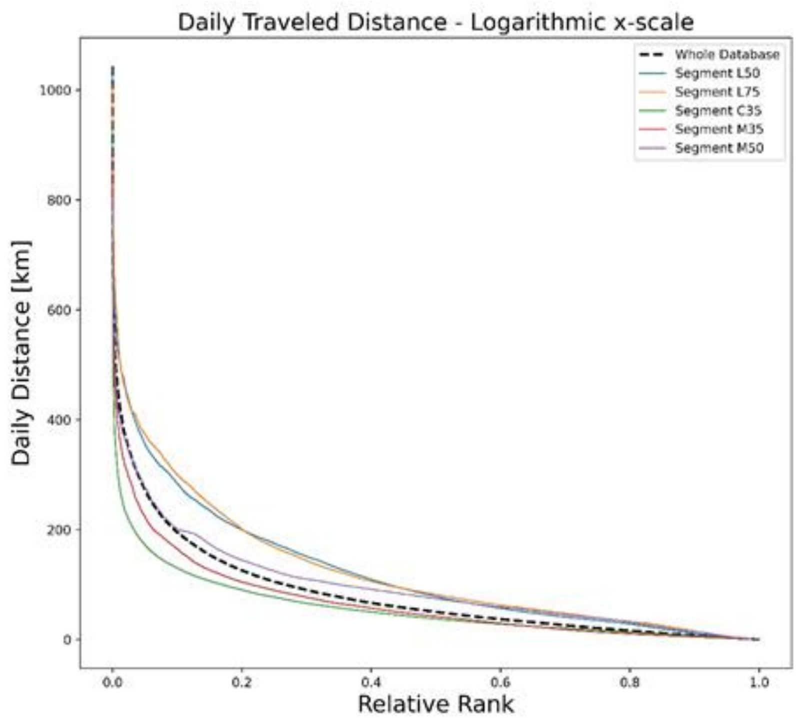

Figure 20. Experimental distribution of individual daily distances for each LDV segment

4.1.4 Idle times

4.1.4.1 Idle times definition

Idle times (ITs) are computed as the difference between departure time of a trip and arrival time of the previous trip performed by the same ID. In the case of the last trip recorded for a given ID, the difference between trip arrival time and 23:59:59 of the same day is computed, since no assumption can be made about the following day activity.

4.1.4.2 Idle time categorization

In order to properly analyse idle times, they are categorized according to their duration and specific time within the day. These aspects are tightly coupled with the design of charging infrastructure.

Kind of IT	Abbr.	Characteristics	Supposed location
Brief	B	< 5 min	Around town
Standard	S	> 5 min < 24 h	Workplaces Shopping centers Recreation centers

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			Parking facilities **Around town**
Nocturnal	**N**	**> 5 min** **< 24 h** **Nocturnal hours (2, 3, 4, or 5 AM) included**	**Home**
Long	**L**	**> 24 h**	**Home**

Table 10. Idle times classification

4.1.4.3 Activity before the idle time

Total distance travelled and travel time are computed considering all the trips performed by a given ID in the same day the IT occurs, before than the IT itself. In the i^{th} row, the cumulated distance and time include also traveled distance and time of the i^{th} trip . For instance, in the row representing the first trip of the day, cumulated traveled distance in the day is equal to the distance covered with the trip itself. On the other hand, considering last trip. Cumulated distance before the idle time coincides with the total traveled distance in the day.

4.1.4.4 Parked fleet

For each ID and date, daytime was divided into 30 minutes slots. It was checked if a trip occurs in each time slot. Comparing the number of IDs not performing any trips to the total number of IDs observed in same day, percentage of vehicles that were parked for the whole time slot duration is obtained. Eventually, these results were averaged over the entire observation period.

4.1.4.5 Spatial screening

The information already included in the dataset shows how ITs are distributed among the Turin Metropolitan City, in particular how each city is represented. Indeed, trip arrivals coincide with the position where IT takes place.

4.1.4.6 Spatial join

A zoning file (shapefile) of the study area (only Turin Municipality in this case) was imported. ITs are spatially joined with the aforementioned shapefile in order to assign each IT the city zone in which it ends. This can be achieved using latitude and longitude of the trip arrival.

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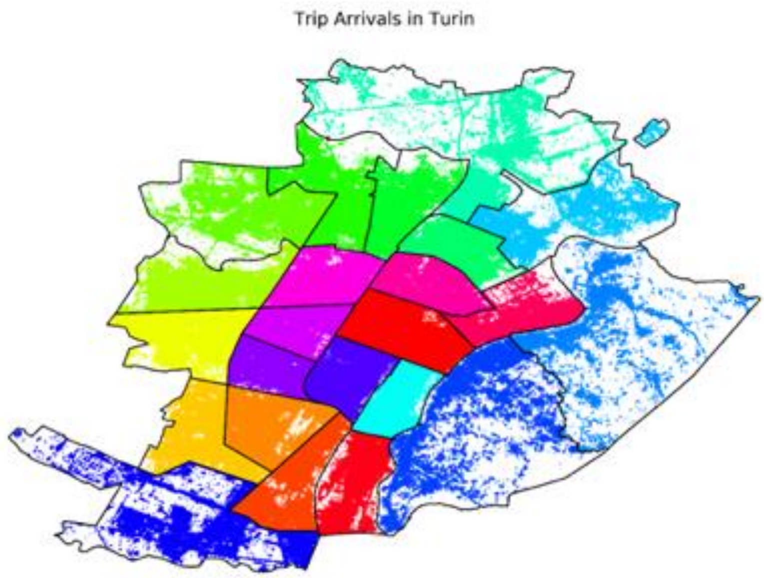

Figure 21. Trip arrivals in Turin different zones (passenger cars)

4.1.4.7 Aggregation by zone

ITs are grouped by the city zone and by the category in which they fall. For each zone and for each category of IT, average duration and number of ITs were computed and plotted on spatial maps. Kernel regression curves (KDEs) were built for validating these results.

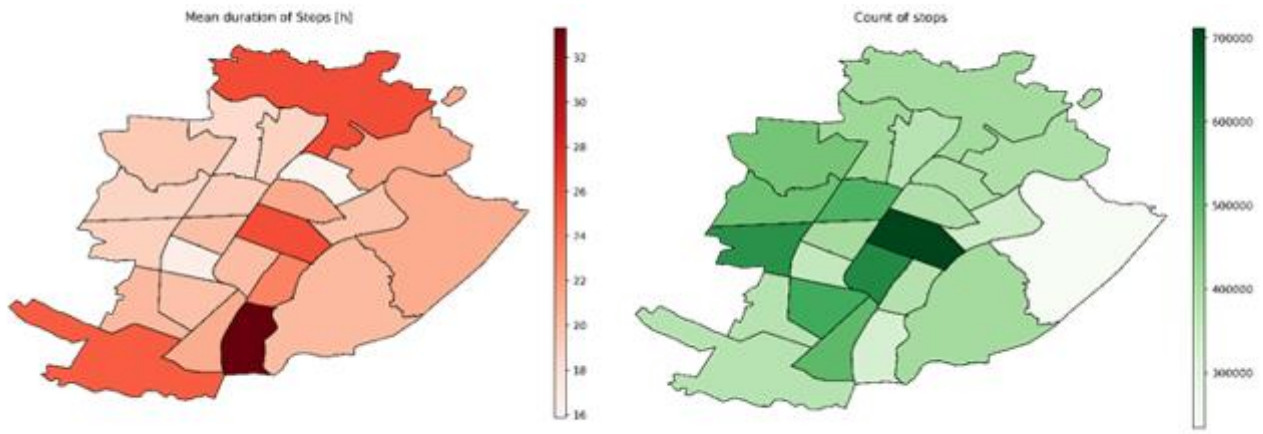

Figure 22. Aggregation at zonal level: mean duration (left) and count of ITs (right) for each zone (passenger cars)

4.1.4.8 Parking habits

To observe parking habits in relation to pricing policies a preliminary screening has been performed identifying the duration of parking activities where and when a fee is applied. Toll parking areas in Turin are in the city center and in nearest zones and a fee is applied (approximately) from 8:00 to 19:30. Therefore a map of toll parking zones included in the study area is imported as a shapefile and only idles times included in that time period are selected. Thanks to another spatial join operation, it can be stated if the IT at issue

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takes place in these areas or not. If so, given the schedules of toll parking areas, it is computed how much time is spent in these areas when a fee is provided. This approach, based on the cited approximate assumptions, cannot provide fully reliable results, because in the area different fees and timing are applied. However, this preliminary screening confirms that the parking duration when pricing is active is shorter. The figure on the left shows that most of the map is yellow meaning that ITs last less than 1 hour, consistently with the probability density chart on the right. A few and sparse points with higher values are plotted with darker colors: those however may represent private parking located within the area or specific points of interest such as multistorey car parks, hospitals, parks and monuments. The figure on the right details the distribution of the parking duration in this area: most of the idle times lasts less than half an hour, while a decreasing trend is observed for higher IT durations, except for the bin indicating 11 hours-long ITs, which may describe a not neglectable residential behavior in several neighborhoods located in the city center. In detail, 1st percentile is close to 0 (0.0017), while 50th and 99th percentiles are respectively about 50 min (0.8289 h) and 30 hours (29.9578).

Figure 23. Example of parking areas, ITs taking place, their spatial distribution and duration (passenger cars)

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5. USE OF EXISTING CHARGING INFRASTRUCTURES

To understand the optimal way for smooth deployment of EVs it is important to look at both demand and supply sides of personal mobility. Therefore, in addition to understand the current mobility behaviors and patterns it is also crucial to analyze how the already existing charging infrastructure is utilized. This chapter further discusses in detail the available data for the cities participating in the INCIT-EV use case demonstrations.

5.1 European Overview

Before discussing the charging situation in these particular locations, it is informative to look first at overall situation in Europe. Corchero et al. (2015) conducted the first and so far the only comprehensive analysis of charging infrastructure on European level. Their results are based on data collected over three years for 8 countries. Below, some of the results are discussed to give an overview of the use of charging infrastructure on continental level.

5.1.1 Battery state of charge

One of the discussed metrics is the level of battery when the charging is initiated. It provides information on how charging behavior is affected by range anxiety.

		Charge			Trip		
		N total	Average Initial % SOC	Initial % SOC<20	N total	Average Final % SOC	Final % SOC<20
Owner	Municipality	7,885	63,8	3,50	39,620	74,5	0,90
	Private company	10,350	61,5	4,10	5,187	75,2	1,10
Use	Business use	7,138	62,7	3,90	5,187	75,2	1,10
	Captive fleet	5,870	64,2	2,30	34,622	75,5	0,50
	Private use	3,212	58,6	4,80			
	Rental	2,015	62,5	7,10	4,998	67,2	3,40

Table 11. State of charge (Corchero et al., 2015)

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In Table 11 it can be observed that usually users do not wait until the battery is almost empty and tend to charge the battery when they have the opportunity to do so, most often at roughly 60% of battery level. The share of users plugging in their EVs when the battery is charged less than 20% is very low (a bit higher for rental cars). It suggests that range anxiety is overall a significant issue, probably caused by relative scarcity of charging points.

5.1.2 Utilization of plug-in time

A useful indicator to assess the effectiveness of charging infrastructure utilization is the share of time when the vehicle is charging in relation to the total time when it is plugged into the charging station.

On average, among all EV users and types of use the average plug-in time equals roughly 5 hours, of which only 2,3 hours are used for charging. It means that typically more than half of the time when a vehicle is plugged in it is not being charged (Figure 24). Thus, it is predicted that by incentivizing or penalizing the users a large gain in effectiveness of charging stations is possible. It can be also observed that the higher share of idle time occurs from midday on, whereas before noon charging infrastructure is used more effectively.

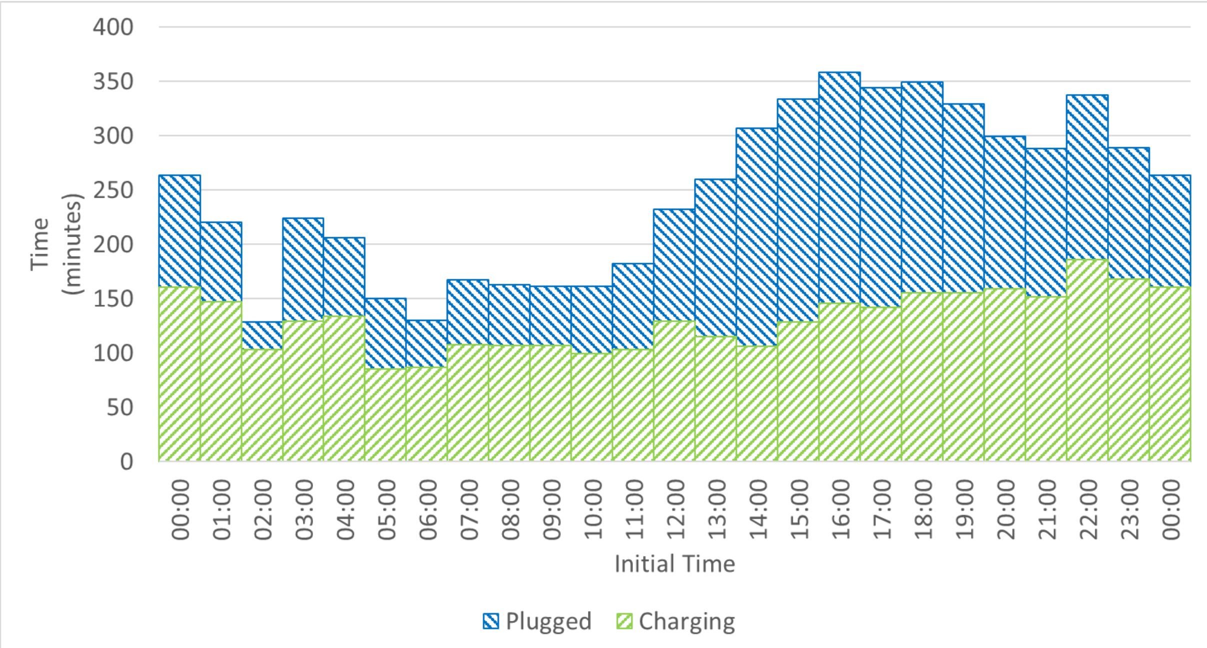

Figure 24. Utilization of plug-in time (Corchero et al., 2015)

According to the results presented in Figure 24, **Erreur ! Source du renvoi introuvable.** Table 12 shows the charge time lengths by the different location of the charging stations. The average charging time is within 3-4.5 hours It is noticeable that the distributions of charging times are similar among CS in different locations, while a higher frequency of shorter charges can be observed for CS located on street (close to 3 h). In contrast, office parking and public access parking facilities present longer charging times, with an average of just over 4 h.

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Charge Time Duration (min)				
Location	Average	Min	Median	Max
Household	201.8	5.0	168.0	1437.0
Office parking	258.4	5.0	168.0	1438.0
Public parking	259.0	8.8	165.0	1410.0
Street	169.2	5.0	119.0	1437.0

Table 12. Charge time by Charging Station location (Corchero et al., 2015)

5.1.3 Charging profile by owner type/use

The data shows that there is a relation between type of use and ownership of the vehicle and the charging profile, in particular the charge starting time.

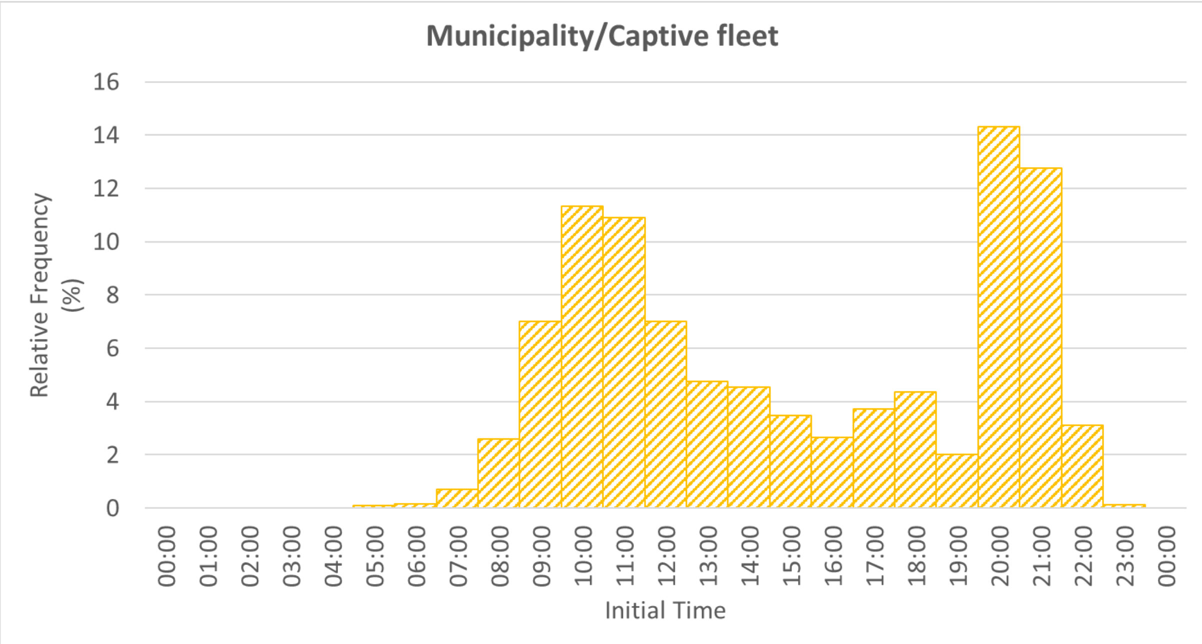

Figure 25. Charging profile for municipality/captive fleet

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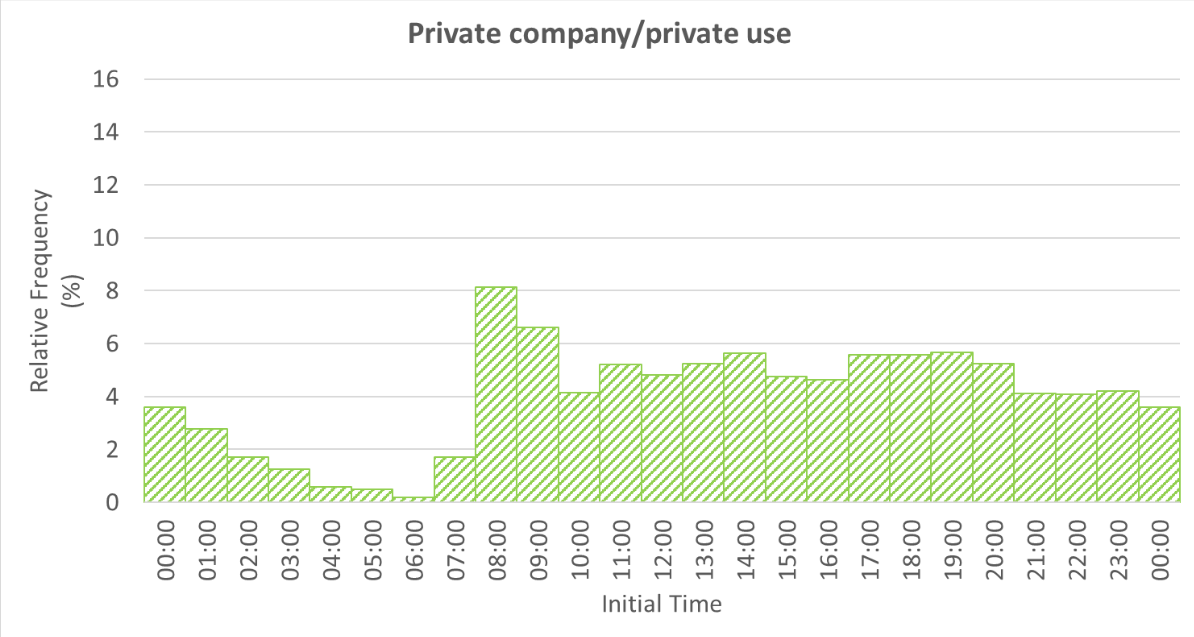

Figure 26. Charging profile for private company/private use (Corchero et al., 2015)

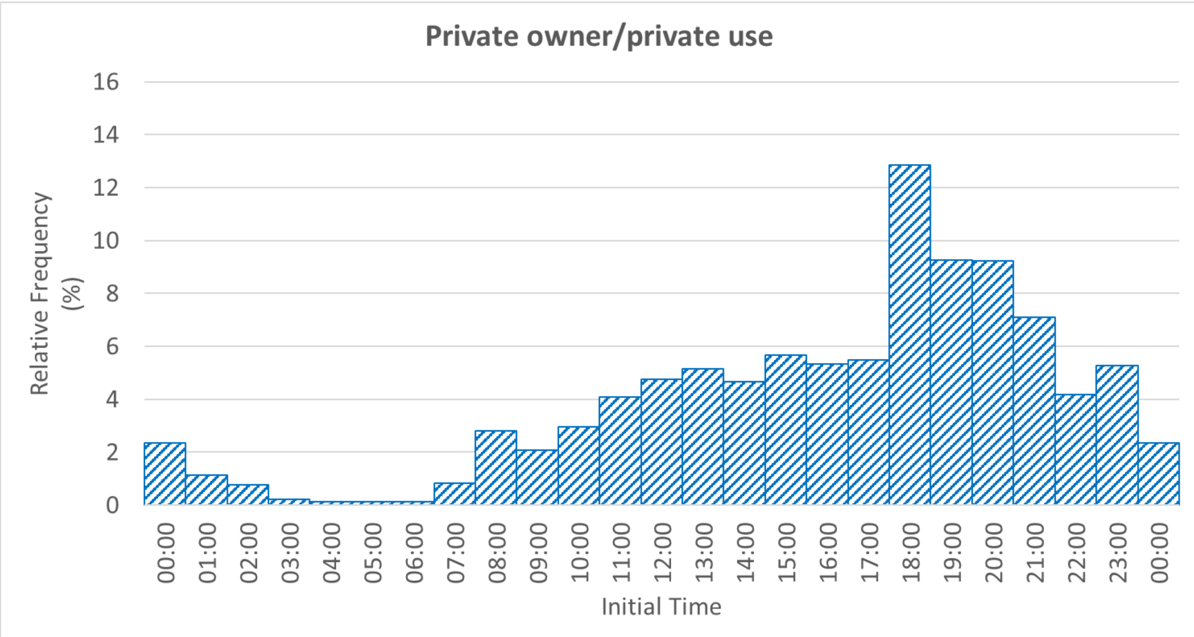

Figure 27. Charging profile for private owner/private use (Corchero et al., 2015)

Private owners tend to charge their vehicles mostly in late afternoon/evening. Captive fleets belonging to municipalities show clearly two peaks during the day – in the morning and in the evening. Private companies

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on the other hand show a much more flat and homogenous distribution than the other two ownership/use cases.

5.1.4 Charging profile by charge point location

Similar profiles were obtained with respect to the location where the charging takes place. The charts below represent starting times of charging in four locations: household, office, public parking and street. Household charging points show higher frequency for evening hours due to the fact that most of vehicles is used to leave home at early morning and to come back in the evening. Whereas for offices three peaks can be observed: in morning and afternoon rush hours, as well as in the evening around 21:00. The third peak can be correlated to the return of the company vehicle fleet. Similar peaks can be observed for stations located in the street, but with flatter distribution. For public parking spots the frequency of charging increases around noon and stays roughly homogenous throughout the rest of the day.

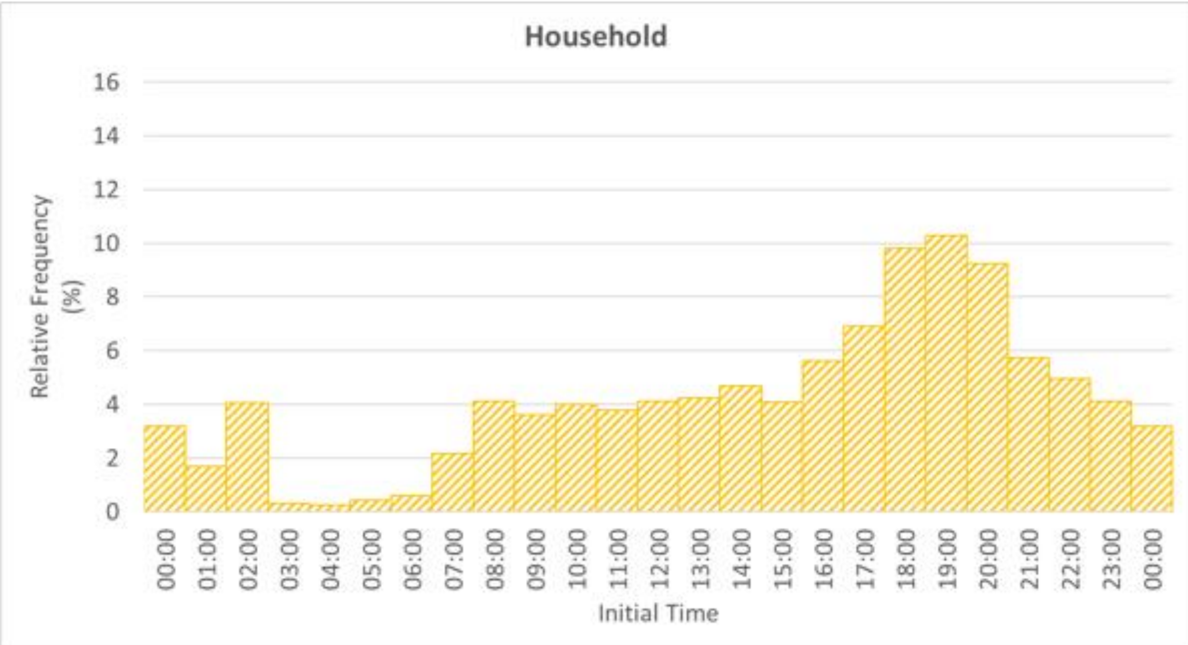

Figure 28. Charging profile for household (Corchero et al., 2015)

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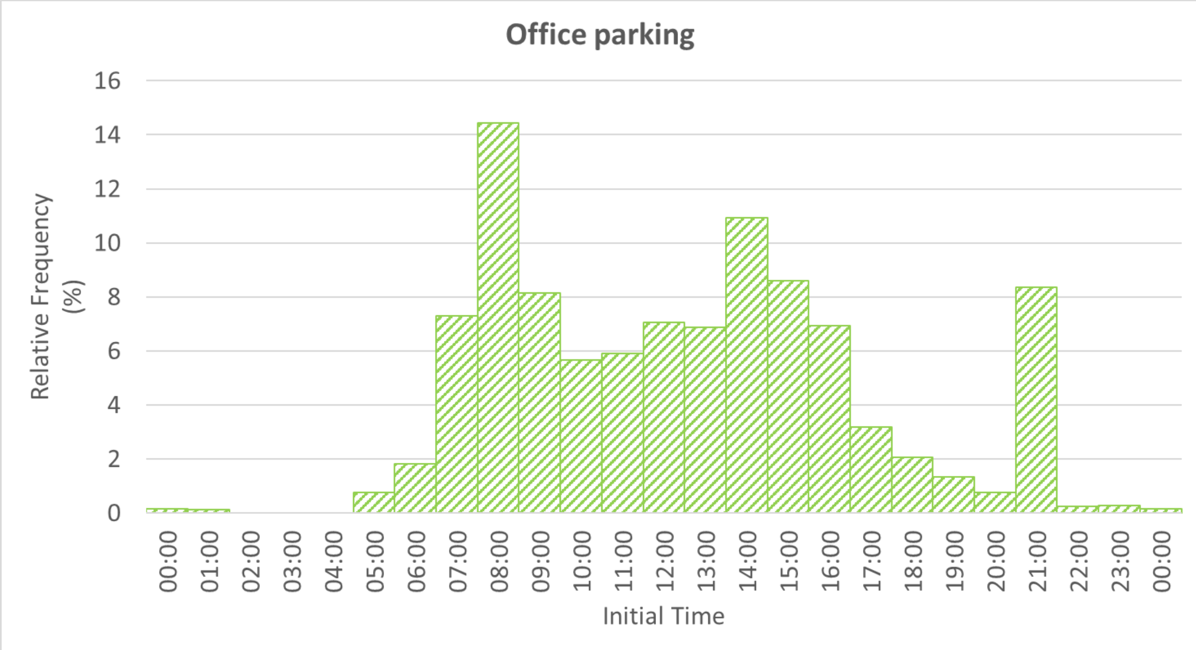

Figure 29. Charging profile for office parking (Corchero et al., 2015)

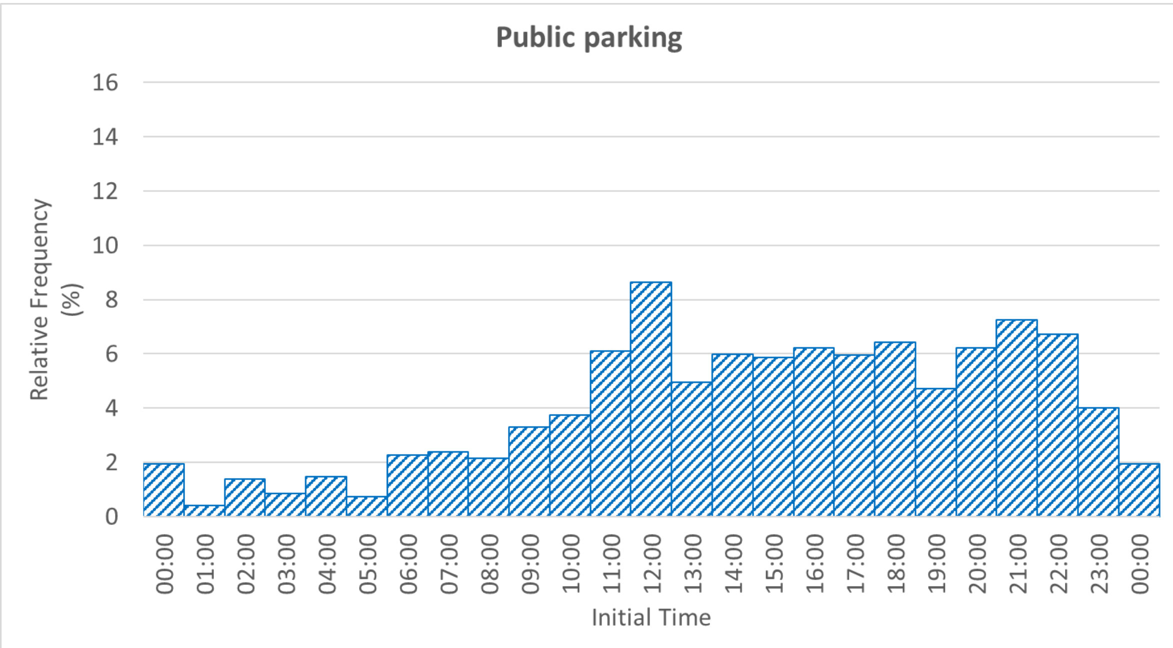

Figure 30. Charging profile for public parking (Corchero et al., 2015)

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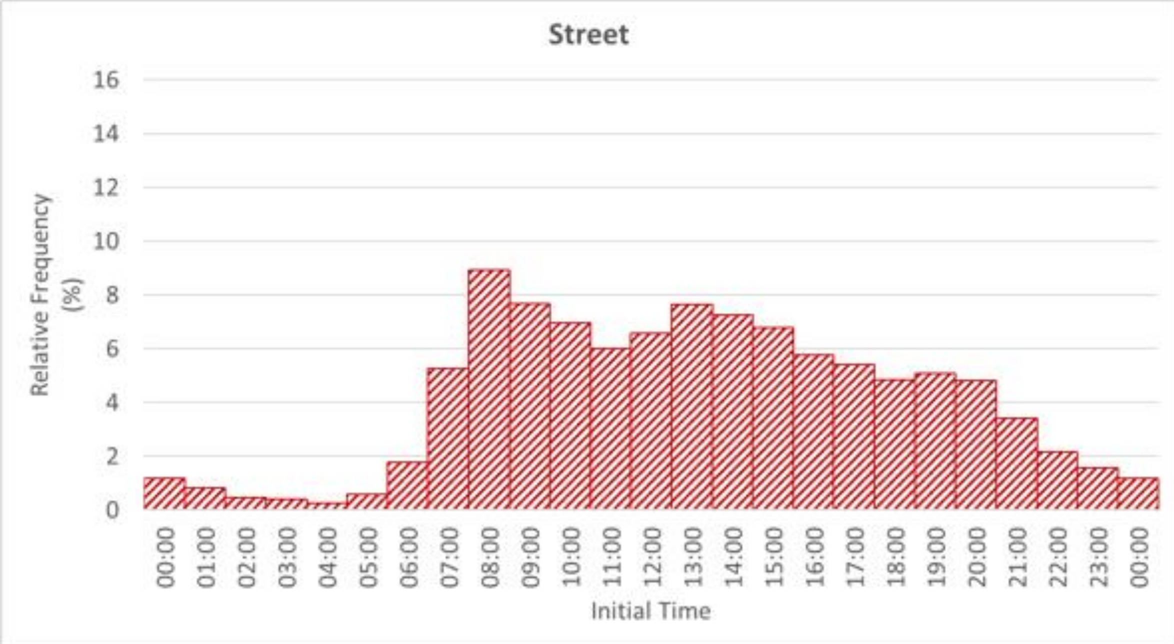

Figure 31. Charging profile for street (Corchero et al., 2015)

5.1.5 Energy consumption from the grid

As already observed for the charging profile in the previous section, the energy consumption distribution also changes according to the location of the charging points. It is noticeable how the charging processes in the street required less energy consumption but they are clearly more frequent. In fact, the average electricity demand from the grid for every charge event carried out in the street is about 4.91 kWh. In contrast, the average electricity demand for charging EV in other locations is significantly higher, between 7.57 kWh and 8.73 kWh.

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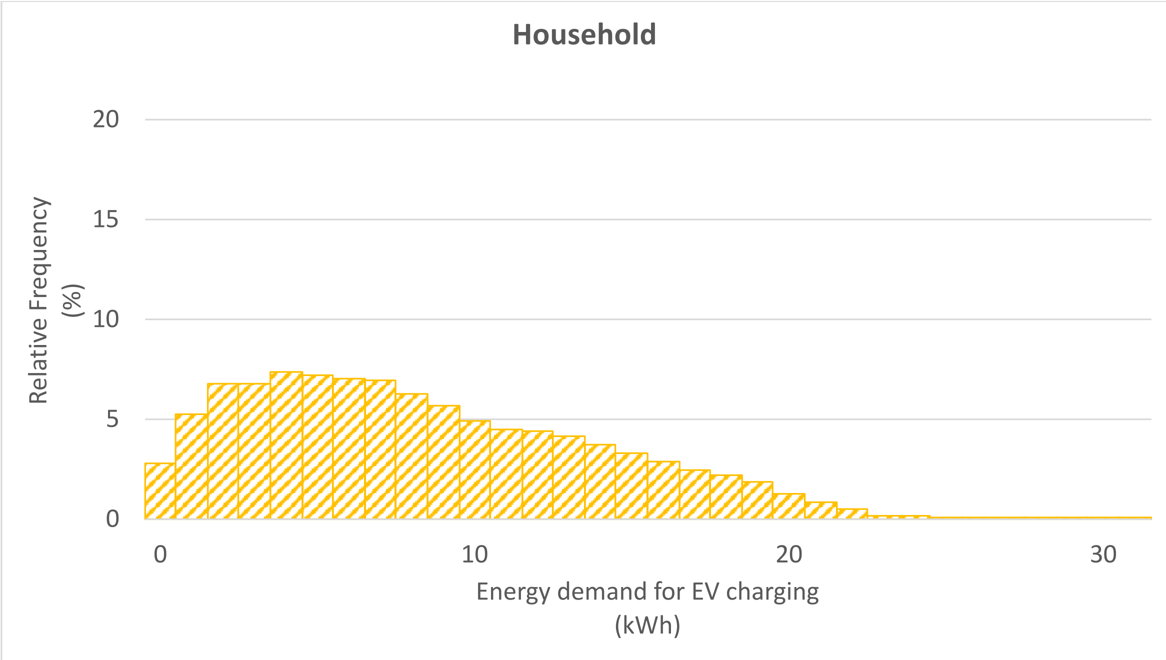

Figure 32. Energy demand for EV charging in household (Corchero et al., 2015)

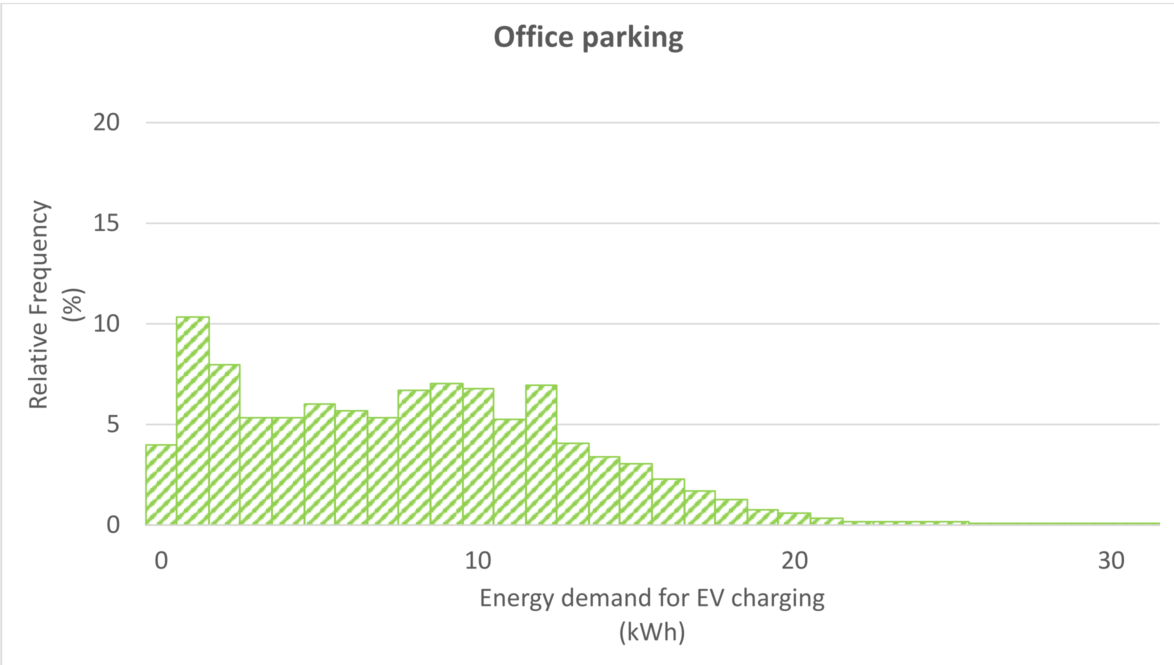

Figure 33. Energy demand for EV charging in office parking (Corchero et al., 2015)

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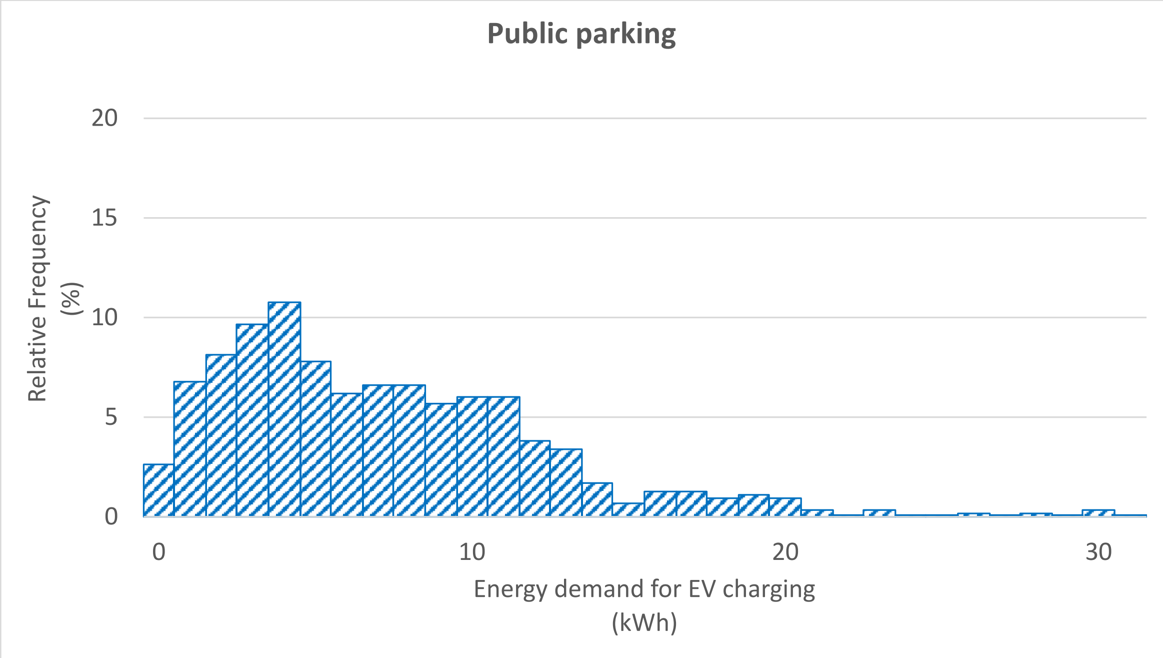

Figure 34. Energy demand for EV charging in public parking (Corchero et al., 2015)

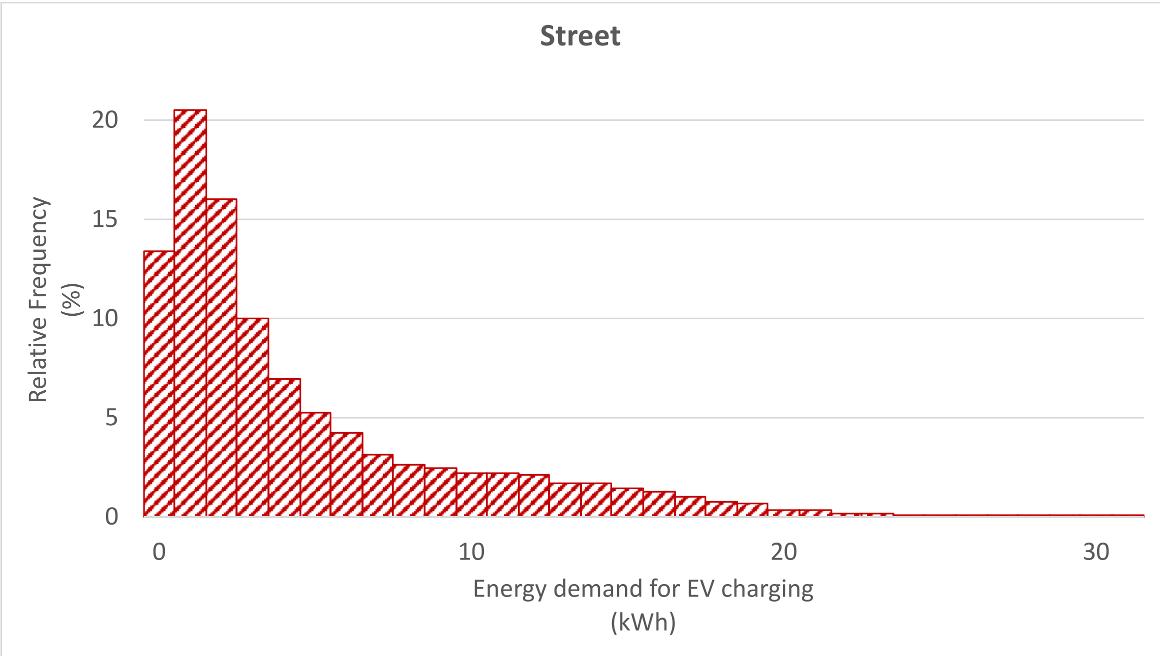

Figure 35. Energy demand for EV charging in street (Corchero et al., 2015)

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5.2 Partner cities

In this section a brief overview and description on the main characteristics of the charging infrastructure of the partner and follower cities are presented. Where currently available, data on the use of the charging infrastructure are also presented.

5.2.1 Haarlem

5.2.1.1 Nr of public charging stations and Nr of private for public use charging stations

Availability	Number of charging stations	Number of connectors
Public	240	480
Private for public use	150	n.a.

Table 13. Existing charging station in Haarlem

5.2.1.2 Location of public and private for public use charging stations (GIS map)

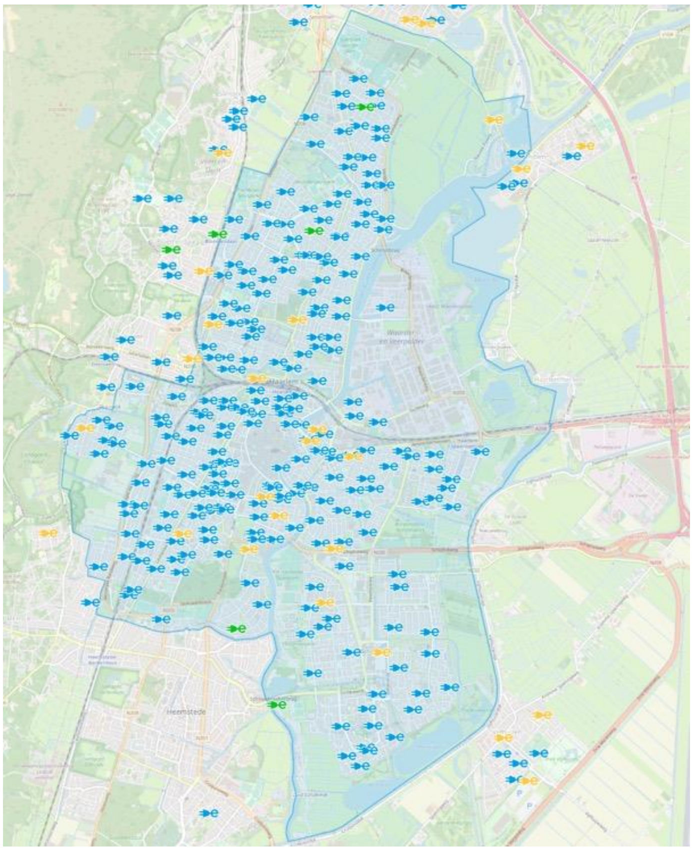

Figure 36. Currently existing charging stations in Haarlem (Source: laadkart.nl, year:2020)

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5.2.1.3 Percentage of distribution of charging poles by kind of connectors (AC or DC) and rated power

Current type	AC	DC	
Power	11kW	50kW	175kW
Public	100%	0%	0%
Private for public use	97,3%	1,92%	0,64%

Table 14. Distribution of charging station by type in Haarlem

5.2.1.4 Level of interoperability and V2G predisposition of charging stations

All charging stations are fully interoperable – any Mobility Service Provider can access the charging stations using an RFID card and all are equipped with ad hoc charging as well. None of the charging stations have a Vehicle to Grid (V2G) functionality.

5.2.1.5 Nr of charging service providers

Unlimited, non-restricted, more than 50 at present.

5.2.1.6 Distribution of energy charged per charging session

The average demand per each charging session measured in 2019 for public charging stations is 14,6 kWh

5.2.1.7 Distribution of duration of charging session

The average duration of charging session measured in 2019 is about 9,4 hours.

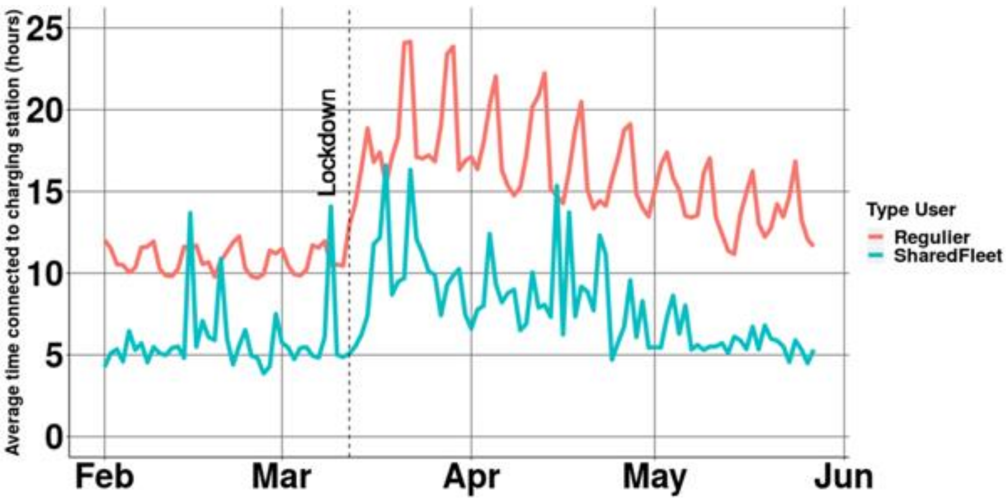

Figure 37. Average time connected to charging station, Haarlem 2019

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Interestingly, Figure 37 highlights the impact of mobility restrictions due to Covid-19. The duration of the charging session in fact growth after lockdown imposed by the Government in March. Longer charging sessions reflect the scarce use of electric vehicle that remain plugged to the charging stations.

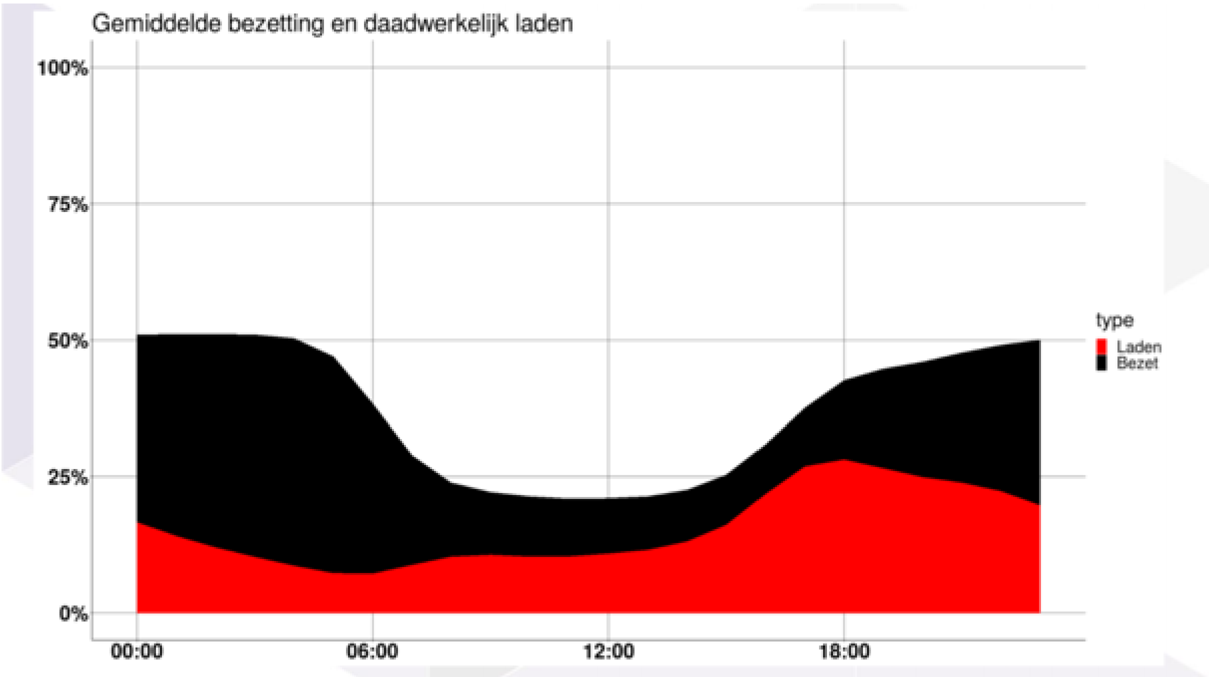

Figure 38. Utilization of plug-in time, Haarlem 2019 (laden=charging, bezet=occupied)

Figure 38 reflects instead the already mentioned effect presented in Figure 24 at European level where the plug-in time of the EV does not coincide in general with the effective charging time

5.2.2 Paris

5.2.2.1 Nr of public charging stations and Nr of private for public use charging stations

Availability	Number of charging stations	Number of connectors
Public	132	n.a.

Table 15. Existing charging stations in Paris

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5.2.2.2 Location of public and private for public use charging stations (GIS map)

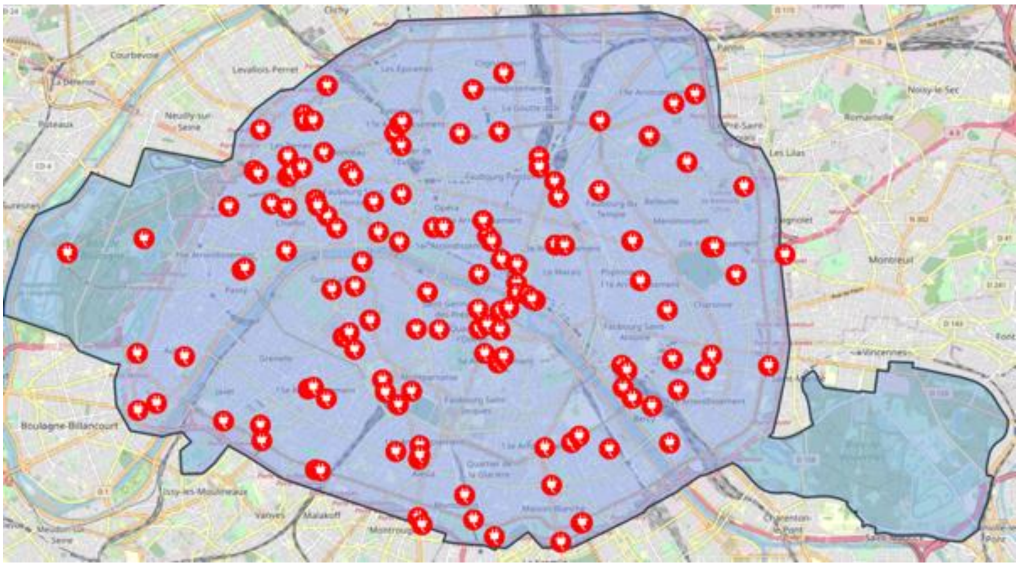

Figure 39. Currently existing charging stations in Paris (Source: Open Charge Map, June 2020)

5.2.3 Turin

5.2.3.1 Location of public and private for public use charging stations (GIS map)

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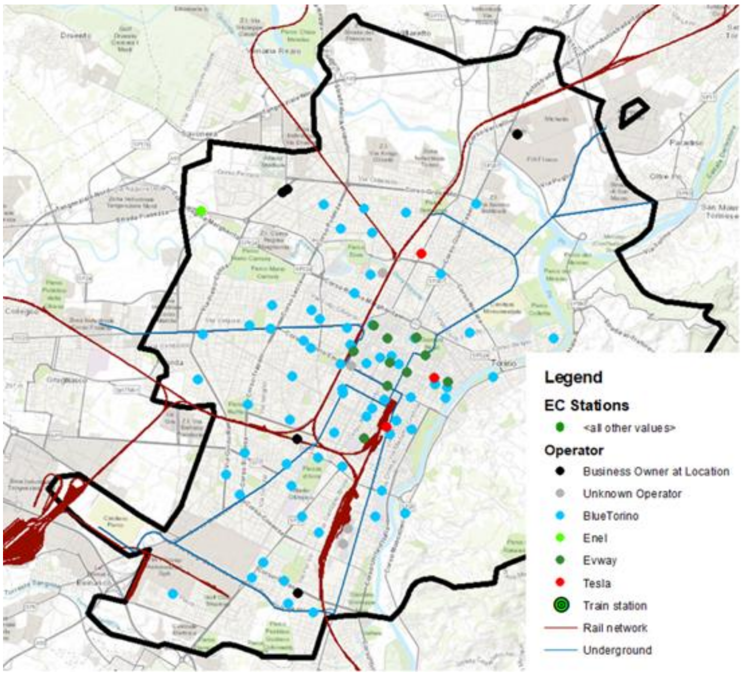

Figure 40. Currently existing charging stations in Turin (Source: Open Charge Map, June 2020)

The current network of charging stations will soon be completed with the construction of about 400 new stations widely distributed throughout the city. Each of the new station will include two DC points of 50 kW and one AC point of 22 kW.

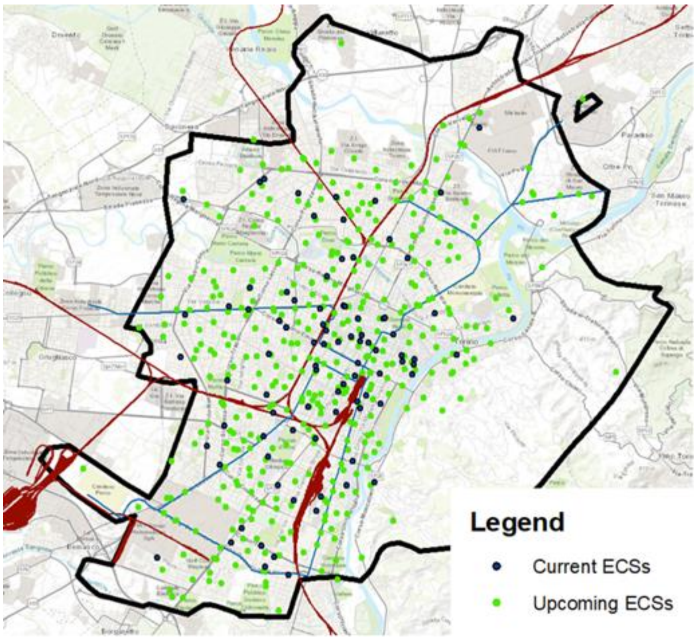

Figure 41. Currently existing and planned charging stations in Turin (Source: Open Charge Map, June 2020)

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5.2.3.2 Percentage of distribution of charging poles by kind of connectors (AC or DC) and rated power

Operator	Charging Stations	Recharge points			
		(AC)	(DC)	unknown	Total
Business Owner at Location	5	23	0	8	31
Unknown Operator	4	8	0	3	11
BlueTorino	65	237	0	0	237
Enel	1	0	0	0	0
Evway	10	20	0	0	20
Tesla Motors	3	3	0	0	3
TOTAL	**88**	**291**	**0**	**11**	**302**

Table 16. Charging stations in Turin (Source: Open Charge Map, June 2020)

Operator	kW
BlueTorino	7 (AC)
Enel	50 (DC)
Evway	11 (AC)
Tesla Motors	11 or 22 (AC)

Table 17. Power offered per Operator (Source: Open Charge Map, June 2020)

5.2.3.3 Distribution of energy charged per charging session

The data presented here for the city of Turin refers to charing session of private passenger cars in pubblic charging stations. Since, the present public charging infrastructure for private users is not still widely diffused (BlueTorino is a car sharing operator in Table 16), data availiability on the use of the charging infrastrucutre is limited. Nevertheless, Figure 42. Distribution of energy charged per charging session for Turin (LINKS elaboration on IREN data, 2019) shows the distribution of the electricity demand for a limited number of charging sessions (i.e. around 40) for charging station located on street. Even if the figure is not statistically sgnificative, the trend is quite similar to one observed in Figure 35 for charging station installed in Europe in a similar location (i.e. on street).

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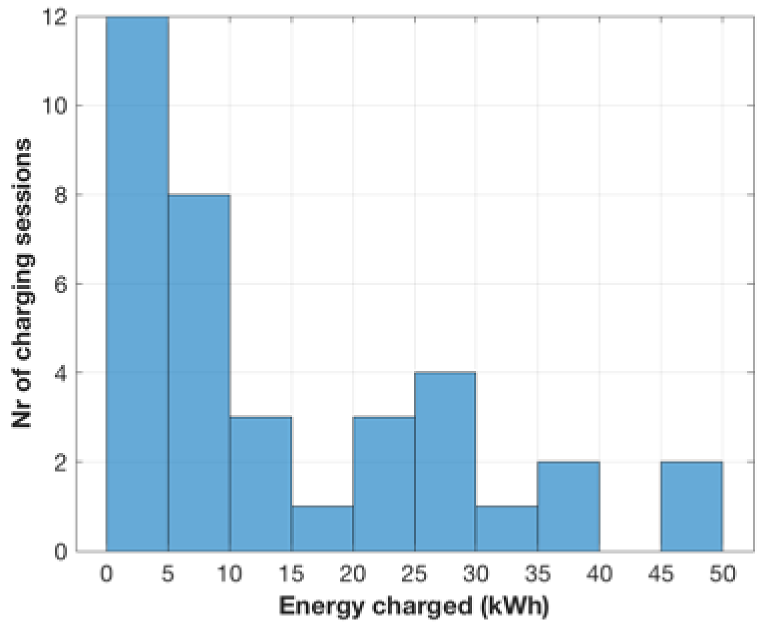

Figure 42. Distribution of energy charged per charging session for Turin (LINKS elaboration on IREN data, 2019)

5.2.3.4 Distribution of duration of charging session

Similarly, Figure 43. Distribution of duration of charging session for Turin (LINKS elaboration on IREN data, 2019) is still subjected to the scarcity of data availiability on the use of the charging infrastrucutre sue to the relatively scarce diffusion of public charging stations in Turin. Also in this case, even if the figure is not statistically sgnificative, most of the charging events have a duration still lower than 4-5 hours as already pointed out at European level in Table 12. **Erreur ! Source du renvoi introuvable.**

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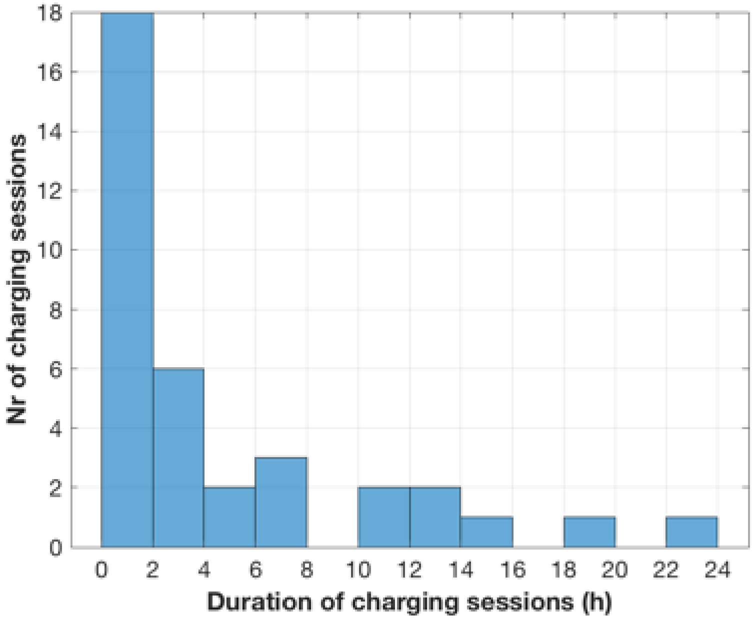

Figure 43. Distribution of duration of charging session for Turin (LINKS elaboration on IREN data, 2019)

5.2.4 Tallinn

5.2.4.1 Nr of public charging stations and Nr of private for public use charging stations

Availability	Number of charging stations	Number of connectors
Public	35	96

Table 18. Existing charging stations in Tallinn

5.2.4.2 Location of public and private for public use charging stations (GIS map)

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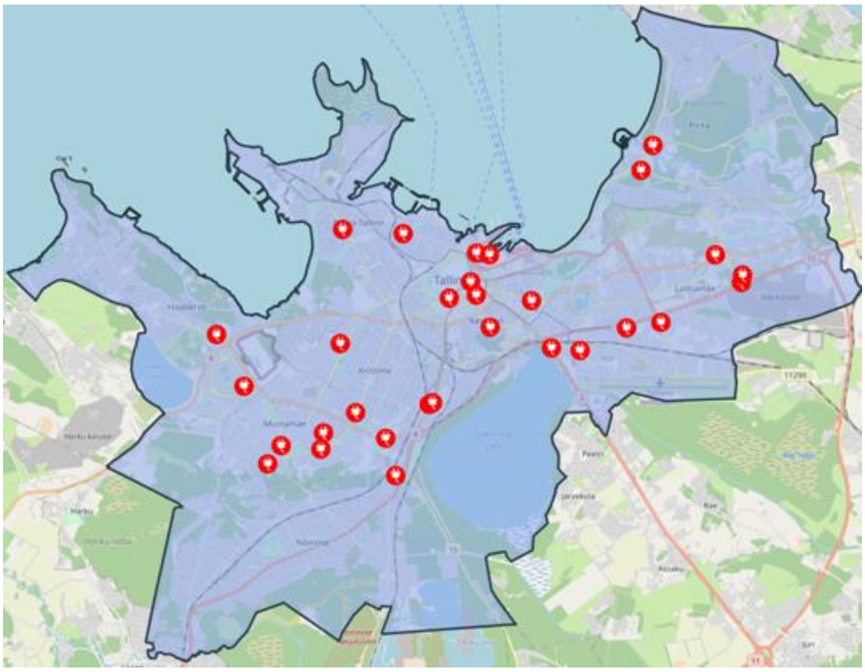

Figure 44. Currently existing charging stations in Tallin (Source: Open Charge Map, June 2020)

5.2.4.3 Percentage of distribution of charging poles by kind of connectors (AC or DC) and rated power

Connector type	Count of charging poles	%
AC and DC	34	71%
Only AC	5	10%
Only DC	9	19%
Total	48	100%

Table 19. Distribution of charging stations by current type in Tallinn

Power	AC	DC
22 kW	46%	-
35 kW	-	24%
45 kW	-	10%
50 kW	-	18%
62,5 kW	-	1%
161 kW	-	1%

Table 20. Distribution of charging stations by power in Tallinn

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5.2.4.4 Level of interoperability and V2G predisposition of charging stations

None of the charging stations have a V2G functionality.

5.2.4.5 Nr of charging service providers

4 public charging service providers

5.2.5 Saragossa

5.2.5.1 Nr of public charging stations and Nr of private for public use charging stations

Availability	Number of charging stations	Number of connectors
Public	15	n.a.

Table 21. Existing charging stations in Saragossa

5.2.5.2 Location of public and private for public use charging stations (GIS map)

Figure 45. Currently existing charging stations in Saragossa (Source: Open Charge Map, June 2020)

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5.2.6 Bursa

5.2.6.1 Nr of public charging stations and Nr of private for public use charging stations

Availability	Number of charging stations	Number of connectors
Public	37	65

Table. Existing charging station in Bursa

5.2.6.2 Location of public and private for public use charging stations (GIS map)

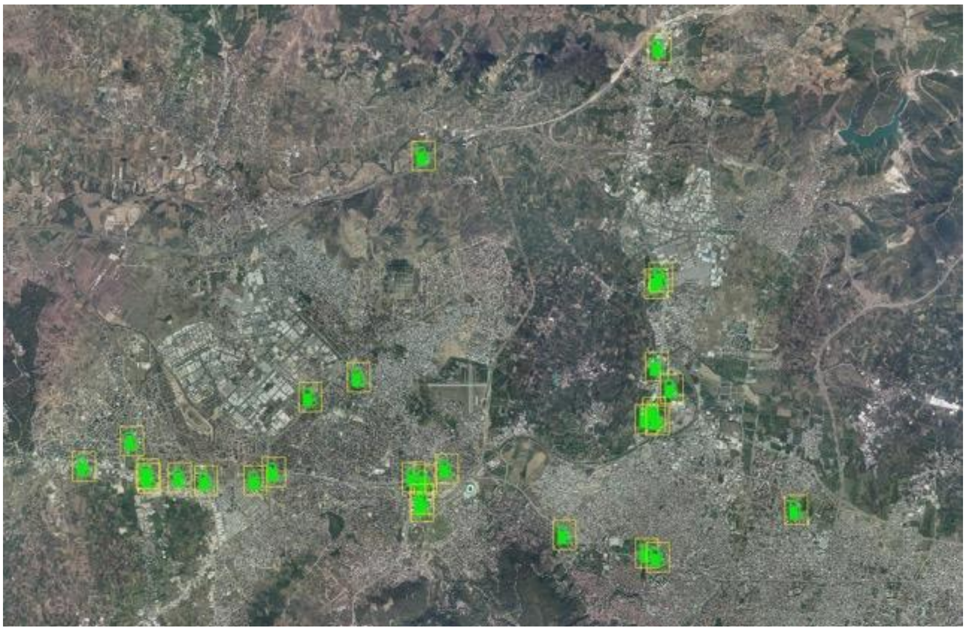

Figure 46. Current existing charging stations in Bursa

5.2.6.3 Percentage of distribution of charging poles by kind of connectors (AC or DC) and rated power

Connector type	Count of charging poles	%
AC	59	91%
DC	6	9%
Total	65	100%

Table 22. Distribution of charging stations by current type in Bursa

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Power	AC	DC
≤22 kW	66%	-
≥22 kW	3%	-
n.a	22%	-
45 kW	-	3%
50 kW	-	3%
100 kW	-	3%

Table 23. Distribution of charging stations by power in Bursa

5.2.6.4 Nr of charging service providers

5 public charging service providers

5.2.7 Norderney

5.2.7.1 Nr of public charging stations and Nr of private for public use charging stations

Availability	Number of charging stations	Number of connectors
Public	7	14

Table 24. Existing charging station in Norderney

5.2.7.2 Location of public and private for public use charging stations (GIS map)

Figure 47. Currently existing charging stations in Norderney (by Stadtwerke Norderney)

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Figure 48. Currently existing charging stations in Norderney (by EWE Vertrieb)

5.2.7.3 Percentage of distribution of charging poles by kind of connectors (AC or DC) and rated power

Connector type	Count of charging poles	%
AC	14	100%

Table 25. Distribution of charging points by connectors type in Norderney.

5.2.7.4 Level of interoperability and V2G predisposition of charging stations

All charging stations are fully interoperable.

All the charging stations have a V2G functionality.

5.2.7.5 Nr of charging service providers

Currently, two service providers are present (Stadtwerke Norderney and EWE Vertrieb)

5.2.7.6 Distribution of energy charged per charging session

The average energy demand measured per charging session in 2020 is around 20,16 kWh, while the average load of a charging session is about 4 kW. The trend presented in Figure 49 is compliant to one observed in Figure 35 for charging station installed in Europe in a similar location (i.e. on street).

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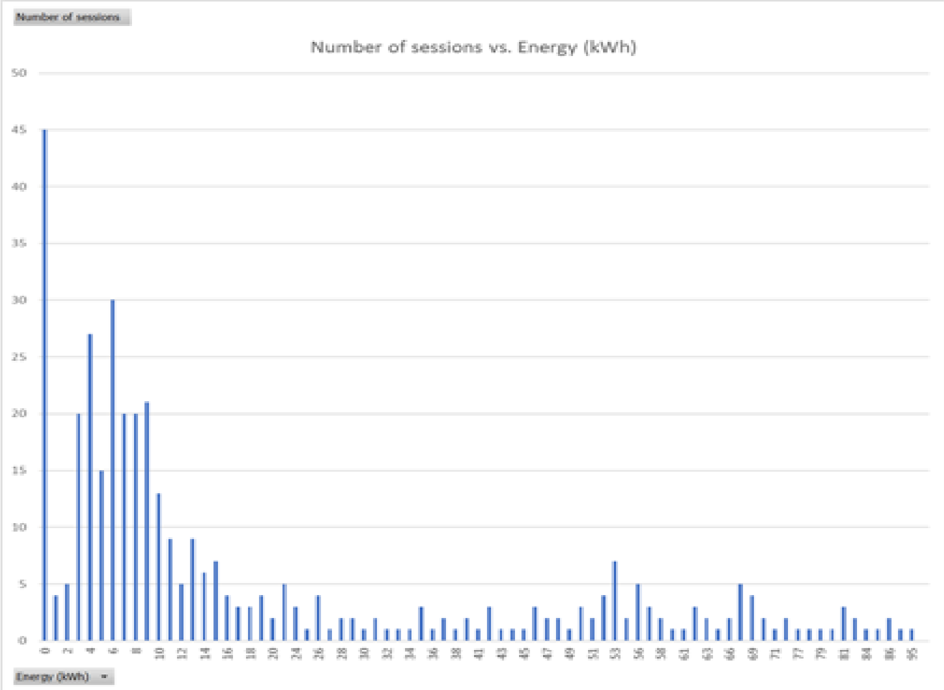

Figure 49. Distribution of sessions with regard to energy charged in Norderney

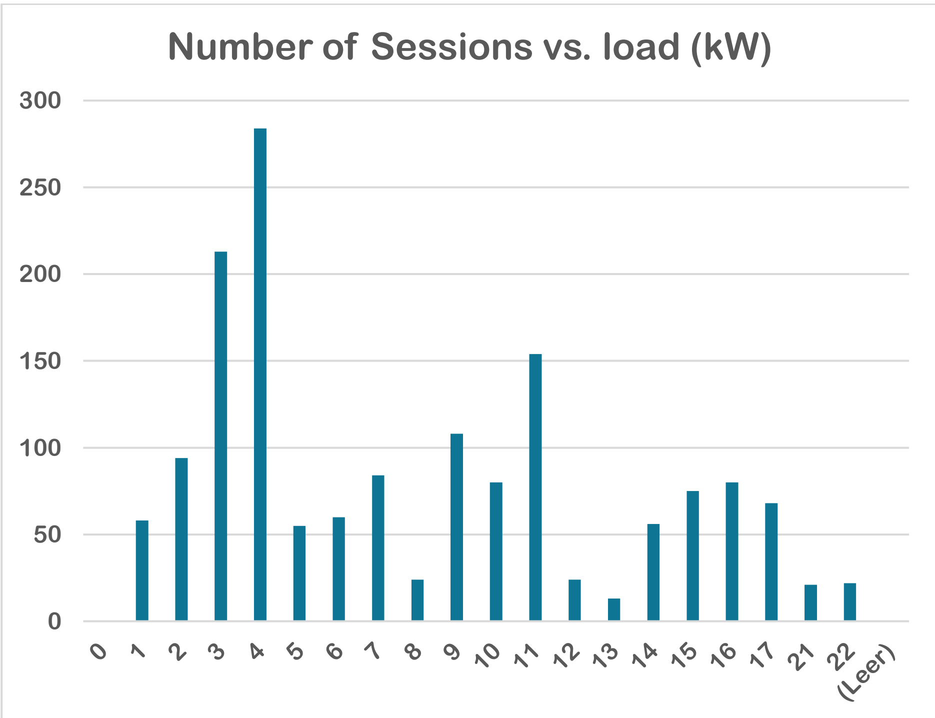

Figure 50. Distribution of sessions with regard to load in Norderney

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5.2.7.7 Distribution of duration of charging session

The average duration of measured for the charging sessions in 2020 is about 7,61 hours. In this case, the charing events have a duration a little bit greater than one pointed out at European level in Table 12. **Erreur ! Source du renvoi introuvable.**

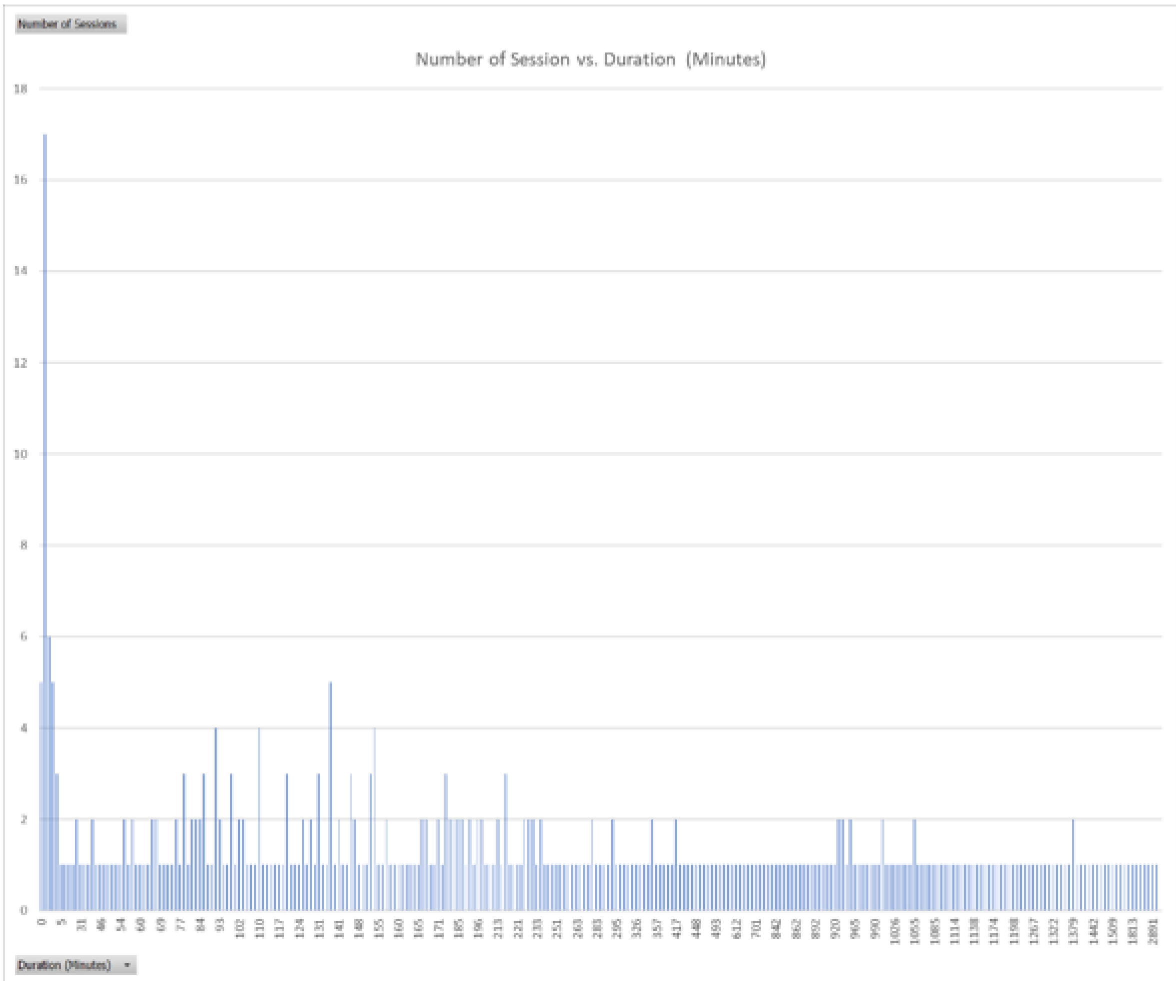

Figure 51. Distribution of session duration in Norderney

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6. EV USERS CHARACTERIZATION

In this section some mutual characteristics among EV users are extracted to better identify the focus group of users (current and future customers). For that purpose, an analysis of the existing literature has been performed for some European countries and other extra-EU countries pointing out the main social, cultural and economic characteristics. The description of the main leading factors in EVs marketing at the EU and international level are also presented. As better highlighted later, both profiling of EV users and the identification of the leading factor in the marketing of EV are based on data from national or international surveys. In all cases, these surveys are based on questionnaires used to characterize the users from the socio-economic and cultural point of view. Such user characterization allows to better address the EV deployment according to user perception on electromobility based on its socio-economic and cultural background.

6.1 Profiling of EV users

6.1.1 EV users in European Nordic Countries

The profiling of EV users in European Nordic Countries was performed by (Benjamin K. Sovacoola et al, 2018) to collect data on the demographics of electric mobility, the primary method was a structured questionnaire (an online survey) consisting of three parts with 44 total questions involving around 5000 people.

The first part asked about the vehicle background and the existing mobility patterns of respondents, namely how often they drive or use other forms of transport, how far, how much they are willing to pay for a new car, etc. The second part asked respondents what they valued most (or least) when they considered future purchases and forms of mobility, such as acceleration, size, safety, etc. as well as some questions specifically about electric vehicles (such as charging availability, range, battery life, and so on), asking them to rate these features according to a five-point type scale ranging from very unimportant to very important. The final part of the survey asked respondents for basic demographic information such as age, gender, education, and occupation as well as more sensitive questions about income, political affiliation, and environmental values (among others).

Distribution of this survey was online and anonymous, with a research design intended to minimize dishonesty and promote candor in the following Nordic countries: Denmark, Finland, Iceland, Norway and Sweden.

In Figure 52 the results of the survey are presented in different demographic charts. According to these charts, the users of EV are almost equally from both genders and there is also a portion of non-binary users for this facility.

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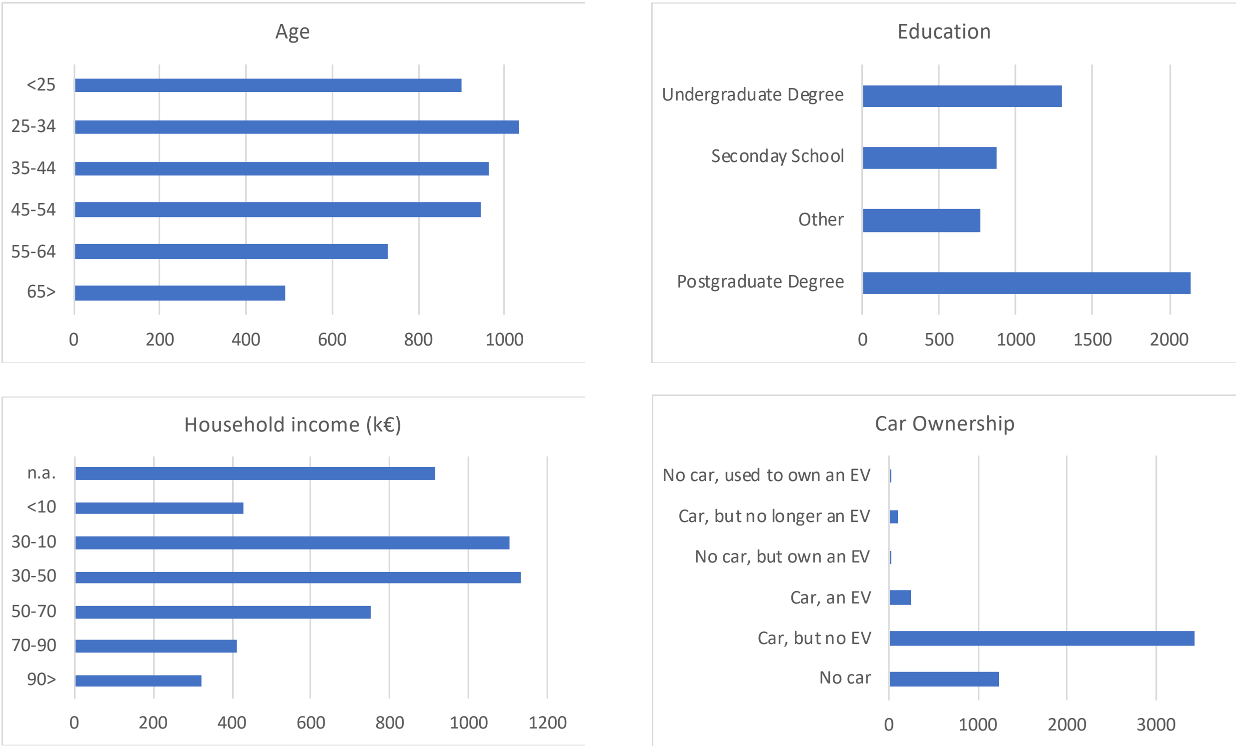

Figure 52. Demographic characteristics of Nordic survey respondents (Benjamin K. Sovacoola et al, 2018).

The following main characteristics can be extracted from the figure above and the study:

- The youngsters are the biggest fans of EV with an age range between 25 to 34 years old.
- A very notable amount of EV users are occupied in private sector.
- Social-democrats, socialists (green party) and liberals are together forming more than half of EV users.
- The largest group of EV users hold a post-graduate degree. And the second largest group are under-graduates. Which together form almost 75% of the users (3/4 users hold a university degree)
- Most of EV users have an income between 50 to 70 k€ annually (even if many people do not feel secure to talk about this factor)
- Most EV users drive EV to short distances like going to work during their daily routines (less than 20km/day)
- Almost 75% of EV users own a non-EV car.

6.1.2 EV users in United States

The profiling of EV users in US was performed by (Scott Hardman et al, 2016) where the distinction between two groups of adopters is considered (high-end adopters and low-end adopters) assuming differences in the price and features of the vehicles owned: Nissan Leaf for the low-end adopters and Tesla for the high-end adopters. The questionnaire was targeted towards North American owners of BEVs by the end of 2014,

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considering that 39% of the BEVs worldwide was used in the United States. Nevertheless, the questionnaire was left open to all BEV owners across the world. Between July and December 2014, 340 fully completed surveys were collected.

The method in which owners were recruited to participate in the questionnaire was via online forums and the study divided the online questionnaire into three sections:

- The first part gathers socio-economic data,
- The second part collects psychographic information,
- The final section asks for information on respondents' opinions of their vehicle's attributes, and also asks them about their future BEV purchase intentions.

The socio-economic profile of the respondents was measured to understand if there are any statistically significant differences between low-end and high-end adopters. Questions were meant to understand socio-economic profiles of the respondents and concerned gender, age, income, level of education and the number of cars in the household.

The following main characteristics are pointed out in the study:

- The sample is mostly male (92.6%).
- Age is spread widely, however most respondents are middle aged with 73.8% of the sample between 35 and 64 years of age.
- Level of education is high with 16.4% holding a PhD or equivalent, 28.1% with a master's degree or equivalent and 40.6% with a bachelors or equivalent (This means that 85.1% of the sample has received a University level education.)
- Level of income within the sample is high, with 76.5% earning more than $90,000 per year.

Finally, the number of vehicles per household resulted in this sample is 2.5, which is higher than the US average of 1.9 in 2014.

6.1.3 EV users in California

The study presented by (Jae Hyun Lee et al., 2019) comes from multiple cross-sectional questionnaire surveys conducted by the Plug-in Hybrid & Electric Vehicle research Center at University of California. The study also includes data of PEV buyers in California from 2012–2017 gathering responses from 18000 PEV. However, the study does not include all 18000 respondents, but only 11037, since some of them did not provide complete socio-demographic information.

In the study, 4 main representative clusters were identified (see also Table 26**Erreur ! Source du renvoi introuvable.**):

1. High-income families representing the largest cluster with 47.9%, formed by higher income, middle aged, mostly male, home owning, highly educated households and with more people in the household.
2. The second cluster (Mid/high income old families) accounts for 26.9%. They had mid/high income, education and number of drivers in households. In particular, households in the second cluster were older home owning households.

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3. The third cluster (Mid/high income young families) accounts for 19.6%. It had some differences with respect to the second one, even if the households in this cluster were similar in terms of income, education, and number of drivers in households. Moreover, the third cluster is formed by younger households of which half rent and half own their home.
4. Middle income renters representing the smaller cluster (5% percent of PEV owners). People in this cluster were middle aged, middle income, almost all male, with fewer people in the households, fewer cars, and mostly renting their house. Annual household income for this cluster is on average compared to the California state median.

	High income families	Mid/high income old families	Mid/high income young families	Middle income renters
Nr of PEV buyers	4676	2500	1786	425
Income (k$)	252.2	127.5	127.3	71.1
Age	43.5	53.5	30.7	47.2
Proportion of Females	0.24	0.26	0.33	0.48
Proportion of home owners	0.92	0.96	0.55	0.26
Nr of vehicles	2.60	2.44	2.15	1.56
Nr of people in Household	3.23	2.54	2.79	1.74
Nr of Drivers	2.28	2.12	2.01	1.48
Education*	2.52	2.07	2.18	2.08

Table 26. Socio-demographic characteristics of four clusters (Jae Hyun Lee et al.; 2019)

6.1.4 EV users in Sweden

The study presented by Iana Vassilev et al. (2017) tried to gather knowledge about the demographic characteristics of current electric vehicle owners in Sweden and to collect information related to their car preferences, main use of the electric car, etc. The study is based on 399 surveys in 2015, sent to EV owners, reaching a response rate of 62% (i.e. 247 responses were received). The questions included in the survey could be divided into four different groups:

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- Questions about the drivers personal and household characteristics: age and gender, place of living, type of home, composition of the household (number of children, ages, etc.), educational levels and average income, etc.
- Questions for targeting the EV drivers' motivation and use of their electric vehicle, for instance: main reasons for purchasing the electric vehicle; level of satisfaction with their EV, etc.
- Questions for gathering information on EV driving and charging patterns: average distance travelled per day; when the electric vehicle is charged (divided in weekend and week days); the location for charging the vehicle (e.g. at work, at home); etc.
- Questions for targeting information about the technical specifications of the EVs as for example, the vehicles battery capacity.

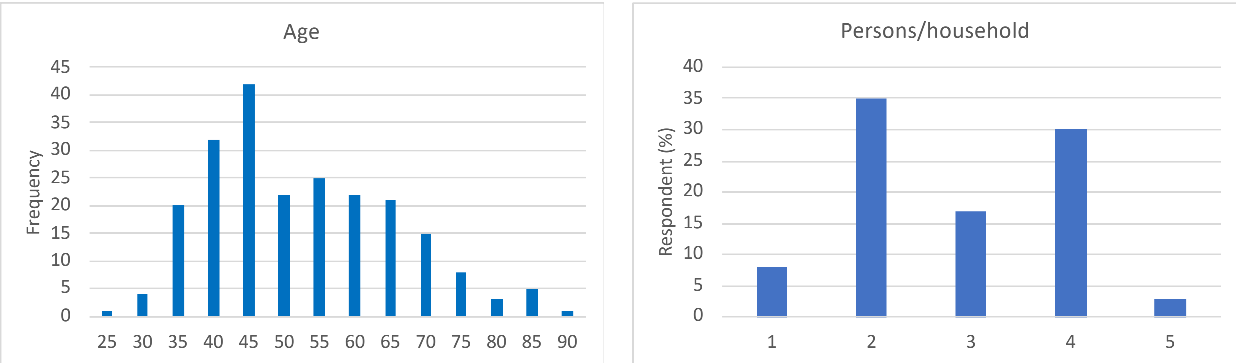

Figure 53. Some social characteristics of EV owners in the survey (Iana Vassilev et al., 2017)

The following main conclusions can be extracted from the figure above and the study:

- Starting with the gender of the survey respondents, out of the 247 respondents, 48 (19%) were female while 199 (81%) were male.
- Most of the respondents are between 40 and 45 years of age. However, the resulting plot is a right-skewed distribution where the groups of 35 and 50 to 65 were almost equally represented and a lower and rather uniform distribution for the age groups of 35, 50, 55, 60 and 65 years old.
- Regarding the EV owners income levels. Responses were divided into three groups: lower than 50 000 SEK (approx. 5350 EUR); between 50 000 and100 000 SEK (approx. 10700 EUR); and above 100 000 SEK. The income-related responses indicate that the current EV owners in Sweden belong to the rather higher end since 53% of the respondents answered that their monthly salaries were between 50 000 100 000 SEK and 26% of the EV drivers had salaries of more than 100 000 SEK/month.
- About the education levels of the household members above the age of 18, 189 of the respondents (76.5%) indicated to have a University degree showing a high level of education among the early adopters of EVs.

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- Current EV owners in Sweden live in 2- member families (35%) or families with 4 members (30%).
- The main use of EVs among early adopters; respondents were asked if they use their cars for private purposes or for work related matters. Of the total 247 respondents, 80% answered they use the electric vehicle only for private purposes; 1% responded that the cars are used for work related activities; and finally, 19% of the drivers use the EVs for both, work and private purposes.
- The total number of vehicles (including ICE vehicles) in the household; 36 (14.5%) stated to only have one vehicle in the household, being that vehicle electric. 39 (56%) EV owners responded to have two vehicles in the household, in 8 of these households (5.7%) both vehicles were electric. Among the respondents, there were 71 (28.7%) with 3 vehicles per household; 11 of which (15.5%) where 2 out of the 3 vehicles were electric. Moreover, out of the 210 respondents with more than one vehicle, 186 (88.6%) answered they “would definitely consider using only an electric vehicle in the near future”.
- The level of satisfaction among existing EV drivers; 69% of the respondents are very satisfied with their EVs; 29% are satisfied; and only 1% are not satisfied or not satisfied at all
- The overall low electricity prices in Sweden make electric vehicles very attractive, especially to the younger groups with relatively low income (50 123 SEK/household as average for the group 26-35 years old). Less than 20% of the respondents in all age groups selected any of the other provided reasons (design, incentives, safety, others). Surprisingly, the group with the highest percentage of respondents (20%) that chose design of the car as one of the reasons for choosing an electric vehicle, was the group of 71-75 year old, where all other age groups show a very low interest in the design of the vehicles.

6.2 Comparison of different studies

Regarding the gender there is a noticeable difference between Nordic countries and The United States. In a country like Sweden female EV owners are holding 10% more of the total number of EV users in comparison to California. This might be because of the progressive situation of Nordic countries towards gender equality.

Another aspect of this comparison is the age of EV users in the two contexts. In contrast with California and the US in general, the age of EV users in countries of the northern Europe are much less (30 for Nordic countries and 50 for the US) and unlike Nordic countries, in the US these statistics are quite spread.

The income of EV owners in the Nordic countries is between 50-70 k€ annually, while In the US the average income of EV buyers is more than 90 k$ dollars per year. In the US, high income families were 55.6% of PEV buyers in 2012 and 40.4% in 2017. Though the proportion of new PEV adopters in this group is shirking, the absolute number of adopters in this cluster is increasing as the market grows (and may continue to do so until 2023). Mid/high income old families have been relatively stable in terms of year to year cluster size. Mid/high income young families are increasing and have grown from 10.8% in 2012 to 24.2% of adopters in 2017. Middle income renters are the smallest cluster at 2.1% in 2012 and 7.9% in 2017 which indicates this cluster has experienced the fastest growth.

Identifying these heterogenous PEV adopters is an important contribution for policymakers, automakers, and academics. Much of the existing literature on PEV adoption identifies the buyers as being homogenous. By showing that the market consists of several types of early adopters policymakers, automakers, and researchers can begin to consider the needs of each group and develop a market environment that will enable all of these consumers to purchase and use PEVs. This is while, the government in the Nordic context

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provides more opportunity by giving incentives to the citizens regarding the feasibility of EV purchase. The overall low electricity prices in Sweden make electric vehicles very attractive, especially to the younger groups with relatively low income (50123 SEK/household as average for the group 26-35).

One similarity between these two contexts of Europe and the US is the percentage of university degree holders among the current EV users, which is about 80 to 85%.

Number of vehicles per household in the US sample is 2.5, that is higher than the US average of 1.9 (US Department of Transportation, 2009). While this number for Nordic countries is at least two vehicles per household (from which one is non EV) for 75% of the sample.

All in all, the results characterize the typical EV owner in Sweden as male, with medium-high income, highly educated, living in a 2 or 4-member family and in houses usually located in areas with low population density. The main use of the EVs is for private purposes, and although usually owning a second car, EVs are used as the primary vehicle. EV owners are very satisfied or satisfied with their electric car and the majority would consider using only electric vehicles in the near future. No major differences were found between female and male EV owners, regarding their motivation for choosing an electric car, for both gender groups, environment and cost efficiency were the main reasons selected. The identified characteristics of current EV owners should serve to other countries with similar conditions and in their initial stage of implementation, to know what to expect in terms of early adopters. The current distances driven by Swedish EV owners (between 30 and 100 km/day) and the charging occurring at night and mainly at home, could be used as a valid argument to help reduce the range anxiety considered as a major barrier to mass adoption of EVs.

Additionally, based on the insights provided in this study regarding the place and time of the day charging, the results from the simulation model suggested that controlled charging schemes should be adopted in order to allow high EV penetration levels on local distribution networks. Moreover, it was found that load shifting strategies should be developed in order to prevent overload the electric grids during evening peak hours, when most EV drivers come home and plug their vehicles to charge. In order to achieve a sustainable use of EVs, national and local governments should focus on providing support for the planning of location of charging stations in densely populated areas, e.g. slow charging stations should be located in parking garages and areas close to the driver's homes where the cars can be left charging at night.

On the other hand, in the Nordic countries, there is an influence between gender and car ownership, kilometers driven, and experience with and ownership of electric vehicles, all orientated towards men, as well as education (associated with similar attributes). Occupation and employment also influence stated preferences: car ownership is associated with employment as well as occupation, with those working for non-profit organizations most likely to own electric vehicles and academics at universities most associated with interest in owning an electric vehicle to us indicating the importance of willingness to pay extra (non-governmental organizations) and the availability of information (academics). The influence of age is more distinct, with ownership of electric vehicles concentrated among the younger middle aged (those25–44 years of age) and high preferences for the safety and cost savings attributes of vehicles. Interestingly, and contrary to some of the literature, indicates that larger families also say they prefer to own electric vehicles, and household size correlates to car ownership and greater daily travel needs.

Stating the results pointed out in the comparison of the different studies, it can be finally noticed that in most of the cases analyzed an of EV users or an EV early adopter is approximatively identified by an high yearly income, an high level of education (most of them have an University degree), while EV ownership is spread in middle aged people as summarized in the following table:

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Income	60-90k€
Education	High level (University degree)
Age	30-65 years

Table 27. Some common characteristics of EV users and early adopters.

6.3 Main leading factors in the marketing of EV

The sections below show the reasons by that costumers chose to purchase an electric vehicle. These factors are studied in different countries to point out the leading factors influencing the diffusion of EV by the user perspective. Among them specifically Japan (progressive in the use of EV in Asia), Germany (a representative of European countries) and Sweden (one of the early adopters in EU) are chosen to be studied in details. Finally, a short overview for other EU and non-EU countries is also presented.

6.3.1 Japan

According to the results pointed out by (McKinsey & co, 2013) in Figure 54, over half of EV buyers named fuel efficiency as a reason for getting an electric vehicle, while half mentioned available subsidies. Interestingly, nearly half said that they bought one just because it's an electric vehicle, validating the assumption that many electric vehicle buyers are somewhat just predisposed to do so. Moreover, few electric vehicle buyers have mentioned price or design as a consideration.

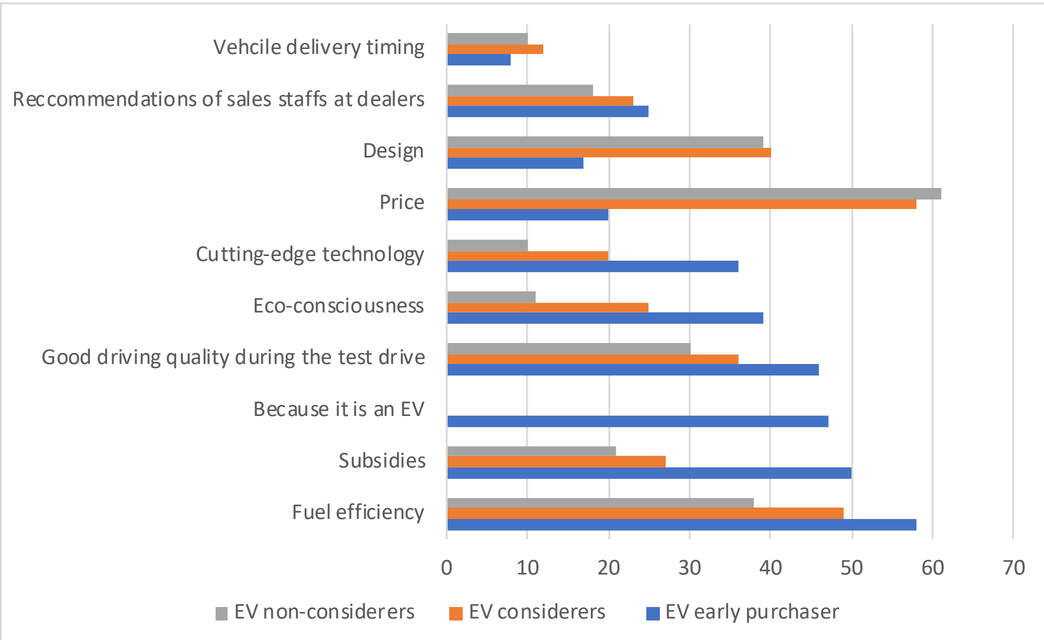

Figure 54. Reasons for purchase last vehicle by costumers in Japan (McKinsey & co, 2013)

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In segmenting early EV purchasers in Japan the strong presence of “Green Tech Savvies” can be observed, who are people who love cars and new technologies and who are also environmentally conscious. Green Tech Savvies tend to have high incomes, live in their own houses and own more than two cars. they also have science or technology backgrounds, higher level of education and larger families with kids at home. They are socially active and love cars and driving. They avidly gather information about cars through various sources, are willing to buy new technology and tend to drive only shorter distances. They aspire to contribute to protecting the environment, usually have solar panels on their houses and strive to live a sustainable life.

6.3.2 Germany

In a relatively similar research, done in the context of Germany (Trommer, Jarass and Kolarova, 2015), the results of the survey are presented in Figure 55.

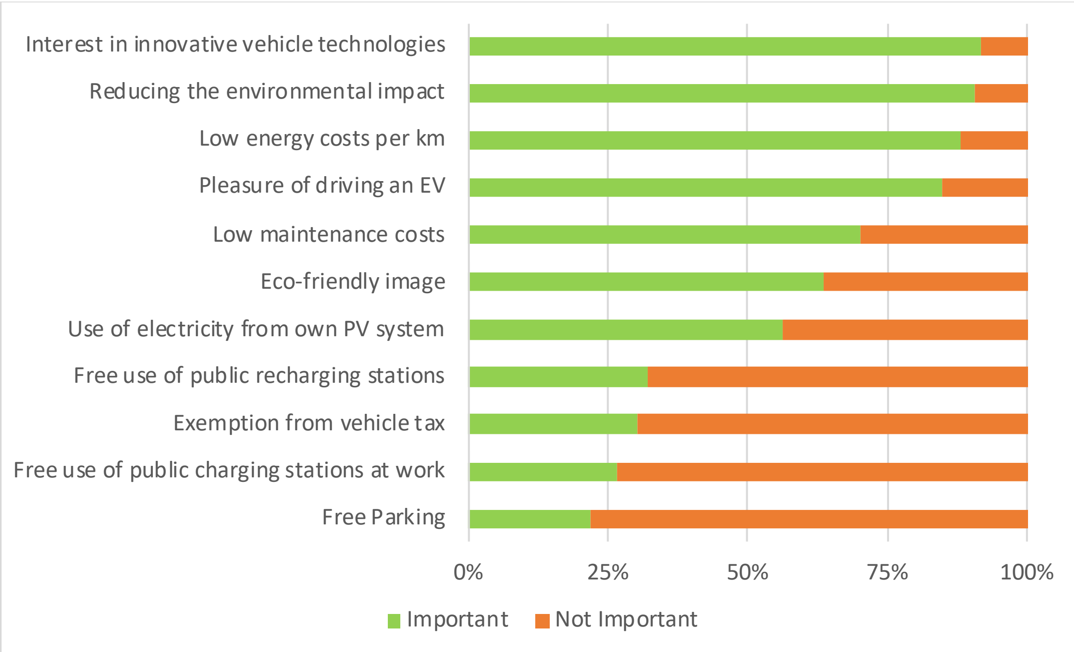

Figure 55. Relevancy of factors influencing the decision of buying an EV in Germany (Trommer, Jarass and Kolarova, 2015)

In the case of Germany, what is visible is the first 5 reasons including Interest in innovative vehicles and pleasure of driving an EV (just like Japan), reducing environmental impact and low energy and maintenance costs are the most popular reasons to buy EV among a German community. Lower influence is instead due to the indirect costs of having an EV like vehicle tax, price for charging EV by using public charging stations and the cost for parking the PV.

6.3.3 Sweden

As can be observed before, the pros of buying an EV are almost similar in every context, like for example the reduced environmental impact of EV. In a study done in Sweden context (Iana Vassilev et al., 2017) these

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results were divided by the gender of the users and these results are showing the same interests in listing the most important to the least. However, a slight difference can be seen among the two sexes considering environmental and economic reasons.

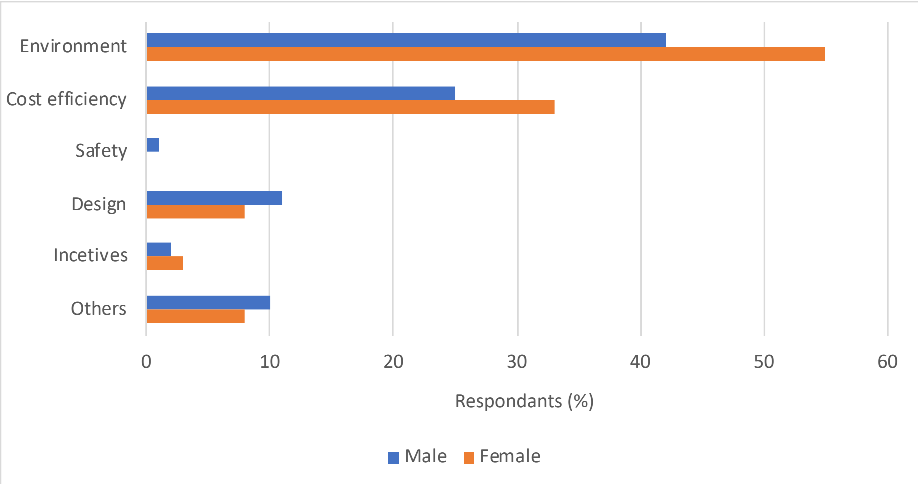

Figure 56. Main reasons for buying an EV by gender in Sweden (Iana Vassilev et al., 2017)

Comparing different contexts show the similarity between the behavior of users. The main difference usually is on the stressing of each of the factors (the most important ones are different for each context, depending on the social and economic aspects of it). However, as already pointed out for Germany incentives or tax reduction seem not affect or influence people in buying EV.

6.3.4 Other Countries

In the study presented by Deloitte (2018) the priority of factors changes depending on the culture and the economic context of that country. Costumer concerns contain all the factors that are listed based on the percentage for each one of the countries below (Figure 57).

According to this study, the four most important costumer concerns among BEV users are driving range, cost premium, lack of infrastructure and time to charge. This result appears to be common in all countries, but differences can be observed in the level of importance of each aspect country by country. For instance, regarding the statistics of Italian consumers in Italy, the most important factor is lack of infrastructure and then at the second place, cost premium of the electric vehicles. With slightly the same percentage, time required to charge is in the fourth place of importance for Italians. Differently German people focus more attention on the driving range, while lack of charging infrastructure is less important probably due to a larger diffusion of charging station in the country.

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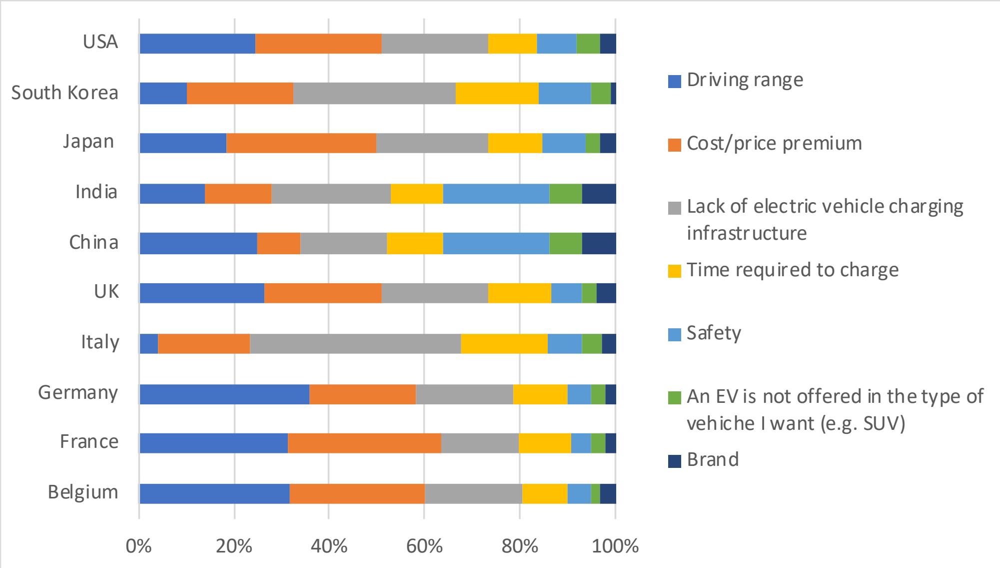

Figure 57. Main factors for buying an EV in different countries (Deloitte, 2018)

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7. CONCLUSIONS

The deliverable D.2.1 is aimed at investigating the current framework and the potential of electric mobility in Europe along with the clustering of current and potential EV users.

According to this goal, the deliverable D2.1 firstly identified the evolution of the EV market to point out the trend of the electromobility for passenger cars and light duty (commercial) vehicle (LDV) in different EU countries. The analysis highlighted how the EV market evolution is still at an early stage in most of the EU countries, despite an increasing trend in the last five years, since the EV market penetration does not goes over 2-3% of the whole market both for passenger cars and LDV. As a result, the number of circulating EV in most of the EU countries is still strongly limited (i.e. <1% for passenger cars and <0.6% for LDV). Some exceptions for Nordic countries (like Norway and The Netherlands), where market share is greater than 10% in 2019 reveals however the potential for a further diffusion in Europe.

Stating this situation of market stagnation, the increase of the EV market and its diffusion can be promoted by analyzing the current user's driving behaviour (as daily distance travelled, number of daily trips and daily travel time) and parking habits. A literature and data analysis, based on national and local surveys, pointed out that mobility needs can be favorable captured by EV, especially at the metropolitan and city level where driving range are shorter. In fact, daily distance travelled per person by car is generally within the range of 40-50 km at national level for most of the EU countries with average daily trips ranging between 2.3 and 3.26. While, daily distance is reduced at 20-25 km when people are travelling within EU cities. This result is promising for a diffusion of EV, since present driving ranges of EVs in the market are significantly higher.

In addition, an analysis of the parking habits for drivers shows that active parking time (i.e. the time when the car is parked after a trip) for cars' drivers are usually up to 2.5 hours per day in most of EU countries, and up to around 4 hours per day for cars travelling in EU cities. This result, considering the short distance travelled by person which corresponds to a low energy consumption for EV, reflects the potentiality to recharge EV also during active parking time, promoting the diffusion of charging infrastructures.

These results are based on national or local mobility surveys, which could be affected by a degree of uncertainty because data can be biased by personal evaluations of the interviewed persons which might underestimate or omit some information. Therefore, a more detailed analysis based on Floating Car Data was carried out. The data used in this approach focus better the driver behaviour since origin/destination relations, speeds and distances are precisely evaluated for each vehicle monitored by onboard GPS receiver. This analysis confirms the trends reported by the surveys for metropolitan areas and cities. In particular, a specific FCD analysis performed for the city of Turin highlights how the average daily distance travelled by passenger cars and LDV are close to 15km and 24km, respectively. Also the average daily parking time in pay parking areas confirms that total active parking (i.e. the time when the car is parked after a trip) are within the range from 2 to 3 hours.

All the results mentioned above match with ones from the analysis of the use of the existing charging infrastructure. In fact, as pointed out by the past European project Green eMotion (where more than 2,500 charging points installed across EU to supply electricity for roughly 2,000 EVs were considered), the average daily charging time for EV is within the range from 2.5 to 4 hour. This result is not so far from the average daily active parking time for EV travelling in cities, ensuring the potentiality for the diffusion of charging infrastructures and consequently of EV. Moreover, electricity demand to charge EV is generally lower than 15kWh per charging session with average values within 5 to 10kWh per charging event according to the

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location of the charging station (i.e. on street, household, etc.). This also confirms the low energy demand due to the short daily distance travelled by person and by EV passenger cars. Additionally, starting time for EV charging is also influenced by the location of the charging station. In fact, households and public parking register most frequent charging events after midday. Differently, charging on street and on office parking present more events during daytime (7.00-19.00).

Results presented at EU level are also confirmed for some partner's cities where data on the use of the existing charging infrastructure were available.

Finally, this deliverable also presents a literature analysis of the EV-users and EV early adopters characterization. In particular, profiling of EV users and early adopters and the description of main leading factors in the marketing of Electric Vehicles at EU and International level are presented. This data may support the market and the decision makers in promoting EV diffusion. In particular, the analysis pointed out that in most of the analyzed cases in different context (both at EU and international level), EV users or EV early adopters are approximatively identified by an high yearly income within the range of 60-90k€ per year, an high level of education (most of them have a University degree), while EV ownership is spread in middle aged people with a wider range of 30-65 years. The main leading factors influencing these users in purchasing an EV are basically related to the higher efficiency of EV with respect to conventional cars (corresponding to lower fuel costs), the reduced environmental impact, the reduced maintenance cost of the EV, and a better standard of quality in driving an EV. In contrast, potential factors opposing people in purchasing EVs are related to the higher costs of EV compared to conventional cars, the lack of charging infrastructures and the driving range of an EV.

Notwithstanding, some of these barriers, that presently limit the diffusion of EV, can be potentially overcome. In fact, the development and diffusion of user-centric charging infrastructures -that are able to cope with people's mobility needs can strongly support the electric mobility diffusion.

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