

Politecnico Di Torino



**Politecnico  
di Torino**

**MASTER THESIS IN ENGINEERING AND  
MANAGEMENT**

**INNOVATION MANAGEMENT AND PRODUCT DEVELOPMENT**

How can selling EV Charging Stations support an automaker with increasing adoption of its electric vehicles in Europe?

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March 2022

## Abstract

The goal of this Master Thesis in Engineering & Management is to develop a methodology aimed at understanding the role played by EV home charging stations in the automotive market across Europe. Specifically, the objective is to determine the presence of a correlation between a car manufacturer selling home chargers and adoption of its EVs. The Thesis proposes different hypotheses to be tested, such as correlation between a country's diffusion, adoption, and range anxiety, and how range anxiety is impacted by home charging stations. It also delves into the effect perceived by consumers when reacting to a carmaker offering the home charger in a bundle or unbundled offer with the EV. A survey is used to gather data from consumers, the sample being largely Italian in this Thesis with the purpose of showing the methodology. A larger sample representative of different European countries would be required for a full scale, geographically unbiased analysis. The research method also includes an interview with different Managers in Toyota Motor Europe involved with EV charging stations to understand the strategy behind OEMs offering these new products in their line-up. The answers from Toyota management and consumers are compared to find correlations, with the impact of home chargers on range anxiety being largely positive. From a first investigation it emerges that the correlation between selling home chargers and EV adoption is weak, and OEM's strategy is rather focused on reacting to the threat posed by energy and mobility companies, which with the rise of EVs will tend to monetize most of the automotive value chain all the way from energy generation to leasing of the car. The Thesis ends with several recommendations on how to follow and improve the proposed methodology, such as taking into consideration government incentives, income inequality among European nations and avoiding geographical biases.

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## 1. Introduction

This Master Thesis project seeks to explore the action taken in recent years by large auto manufacturers in Europe, the likes of Toyota Motor Europe, Jaguar, KIA, Volkswagen Group and Hyundai Motor Europe, to vertically integrate and start offering Charging Stations for electric vehicles (EVs) in their lineup. This new business model arises from the transition the auto industry is experiencing from traditional gasoline-based vehicles towards electric powered vehicles.

The reasons why automakers are vertically integrating downwards to sell EV Chargers can be several. The obvious advantage is that they can benefit from direct sales revenue through selling these products to consumers, but this may not be the only benefit. Another advantage can be the ability to offer an integrated package to customers, possibly driving up the demand for an automaker's electric vehicles. This Thesis will largely overlook the benefit of direct revenues and margins from selling chargers, and rather focus on whether and how selling EV chargers can help an automaker experience greater adoption of its electric vehicles.

The reason behind separating chargers' direct sales revenue from the project's scope is that it is very easy to observe, and anyone with access to a Sales Report can retrieve this information without struggle. However, it's far more complex to determine the effect that an automaker selling EV chargers has on consumers' perception of its EVs, which is why it's more suitable to remove the direct monetary returns from the equation. Indeed, if there happens to be a correlation between a carmaker vertical integration into chargers and its EV adoption, and this impact is considerable, it is surely worth exploring.

An in-depth analysis of this topic at a European level would require an extensive and thorough examination of expectations and views from each country in the continent. However, due to the limited means to achieve this, this Thesis will rather act as a pilot project and aim at providing a methodology over which further research can be based on in the future. In other words, it will be an initial small-scale implementation that to be used to prove the viability of a project idea, rather than offer concrete results. For this reason, the target audience in this Thesis will be Italian consumers.

Data and information for this project will be derived both externally through research and internally from an internship experience at Toyota Motor Europe in the Aftersales (Value Chain) department, responsible, among other things, for accessories including EV charging stations. The Thesis starts with an overview of the current Electric Vehicle situation in Europe, and the role of EV Chargers in this market. It then moves to formulate a hypothesis in Chapter 3, which also serves to define the objectives in greater detail. Subsequently, Chapter 4 will be dedicated to explaining the method used to test the hypothesis, followed by Chapter 5 where data and findings will be presented and analyzed. A discussion will follow, where the main conclusions will be drawn.

The terms “car manufacturer”, “automaker” and “OEM” will be used interchangeably in this project, and the same holds true for “home charger”, “private EV charger” and “wallbox”. Indeed any “charger” mentioned in the Thesis is to be considered as a private one, unless specified as a “public charger”.

## 2. Overview

### 2.1 Reflection - Internship at Toyota Motor Europe

Before delving into an overview of the EV market, it's worth dedicating a paragraph to the background which drove the interest in developing this project. The idea originates during an internship in the Aftersales department (called Value Chain) at Toyota Motor Europe (TME) in Brussels. Specifically, in the team responsible for managing commercial aspects of TME's charging stations line-up, acting as a point of contact between National Marketing & Sales Companies (NMSCs) and suppliers. However, as the market stands today, most OEMs have not defined a proper strategy aimed at building a connected EV ecosystem, and the relative novelty of the product leaves plenty of room for these companies to be creative. After all, this is the first time in history that car manufacturers can position one of their products directly in consumer's homes, which could create opportunity for further integration. Despite this, at first glance it could appear most OEMs started selling chargers following the market trend created by companies like Tesla, whose EV ecosystem driven strategy is more visible and

defined. Whether OEMs' charger's strategy today is simply to benefit from additional turnover or to create an EV ecosystem might not be the same across the car manufacturing industry. What is sure is that most OEMs still need to grasp the potential benefits of charging stations and their role in the new mobility market. This Thesis is aimed at clearing some of these uncertainties, through exploring the role of charging stations in offsetting consumers anxieties and potentially leading to an increase in OEMs EV sales and the creation of a true EV ecosystem.

## 2.2 Electric vehicles (EVs) in the European market

When one talks about electric vehicles (EVs) it is not a single type of car, there are several types of EV. The first is the Hybrid Electric Vehicles (HEVs) such as the Toyota Prius which has both a fuel-based engine and an electric motor with a battery that self-recharges every time the driver brakes and cannot be recharged by electricity coming from an external source. Plug in Hybrid Electric Vehicles (PHEVs) instead possess an electric motor that can be recharged through an external plug, although they still have a fuel-based internal combustion engine (ICE). Finally, Battery Electric Vehicles (BEVs) are fully electric, freeing them of the ICE, fuel tank and exhaust pipe. BEVs are exclusively charged externally through a Charging Station and examples of this type of vehicle include the Tesla Model 3 and Model Y, and the Toyota bZ4X.

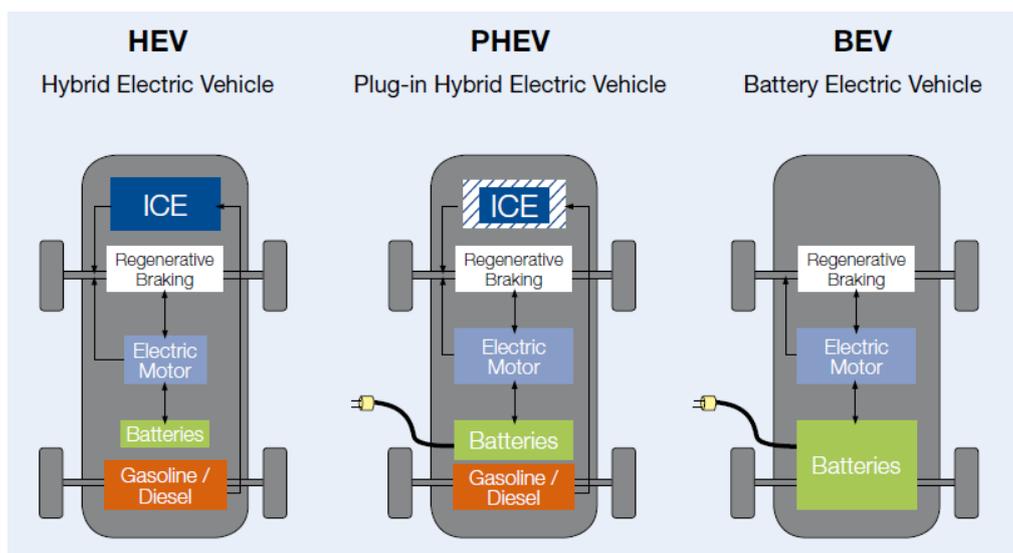


Figure 2.1.1 - Types of electric vehicles, HEV (left), PHEV (centre), BEV (right)

Between January and March 2021, 56% of all cars sold by Toyota Motor Europe (TME) in Europe were hybrids (HEVs and PHEVs), and if we consider just Western Europe this number rises to 67%. In recent years, carmakers (especially Toyota) have largely preferred to produce hybrids out of all EVs, since they act as a bridge between fuel-based vehicles and BEVs, and models of PHEVs have outnumbered those of BEVs in the market every year since 2015. Simply put, demand for hybrids has been higher in Europe than for BEVs. However, this is changing fast, car production plans in Europe until 2028 show that there are 28 PHEV new car models planned against 86 BEVs. The Covid crisis has accelerated the transition to electric vehicles, especially driven by the economic incentives put forward by Governments in Europe to encourage the population to transition to these greener vehicles. BEVs sales in the EU have increased by 59.1% from the 1<sup>st</sup> quarter 2020 to the 1<sup>st</sup> quarter 2021, (146,185 units in 1<sup>st</sup> quarter 2021), with some large countries such as Germany and Italy experiencing a 149% and 145.6% respective increase in the same period. PHEVs at the same time have experienced an even larger growth at +175% at the EU level (208,386 units in the 1<sup>st</sup> quarter 2021). Even more interestingly, in Norway in June 2021, 84,9% of total new vehicles sold were of the PHEV and BEV types. While these numbers of PHEVs and BEVs are impressive, they don't quite come close to the almost 600,000 units of HEVs sold in the 1<sup>st</sup> quarter of 2021 at EU level. As mentioned, the important difference between HEVs, PHEVs and BEVs is that the first doesn't require external electrical charging, whereas the latter two do.

### New passenger car registrations in the EU by alternative fuel type

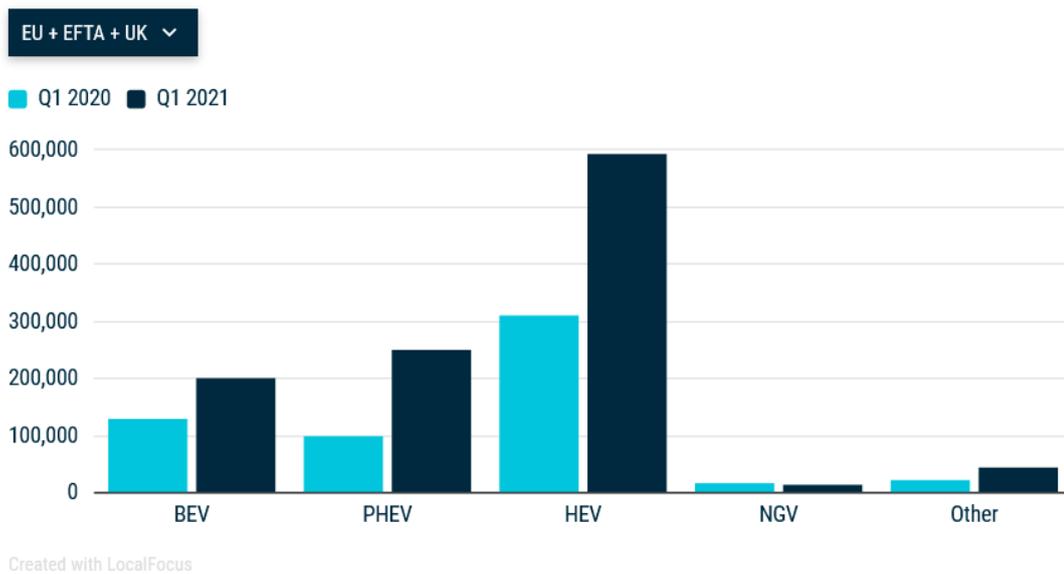


Figure 2.1.2 - EU+EFTA+UK vehicle adoption first quarter 2020 vs first quarter 2021

But what is the reason why HEVs are still selling in higher numbers? This could be due to the comfort of having to rely solely on the traditional Petrol Stations for refilling (which everyone is familiar with), while still having a greener and more efficient vehicle. In a survey carried out in 2018, 49% of Italians and 46% of Spaniards were concerned about the availability of recharge points, whereas this number was much lower in places like Sweden (25%). At the end of 2018 there were 92,000 Petrol Stations in the EU + Norway, Switzerland, and Turkey (each with 8 pumps on average, so 736,000 pumps), whereas the number of public EV charging points in September 2020 amounted to around 250,000 in the EU+UK. However, it would be incorrect to compare these two numbers. For starters the number of PHEVs and BEVs as a percentage of the total cars on European roads is still very low at about 1,3%, which explains the lower number of recharge points. Secondly, many of these public chargers (61%) are of the slower AC type which can take up to 8 hours depending on the kW output, whereas the rest are made up of faster DC chargers, which generally take less than an hour. If we compare these times with the time it takes to refill a gasoline vehicle (3-5 minutes), it becomes clear that a lot more gasoline cars can be refilled in one day by 1 pump compared to EVs by 1 charging station. The density of charging stations also varies greatly among European countries. According to EV volume predictions in Europe, an estimation of the public charging points that will be needed in 2024 reaches 1 million units. This number seems

very high considering the current 250,000 units (approx.) and the chicken and egg problem is often cited as an obstacle for increased diffusion of EVs as well as charging points. Such problem describes the reluctance of investors to devoting capital to building charging infrastructure when currently there is no large market for electric vehicles. At the same time customers thinking of adopting a PHEV or a BEV are concerned about charging access points, and in some countries (like Italy and Spain) this is a strong factor hindering new purchases.

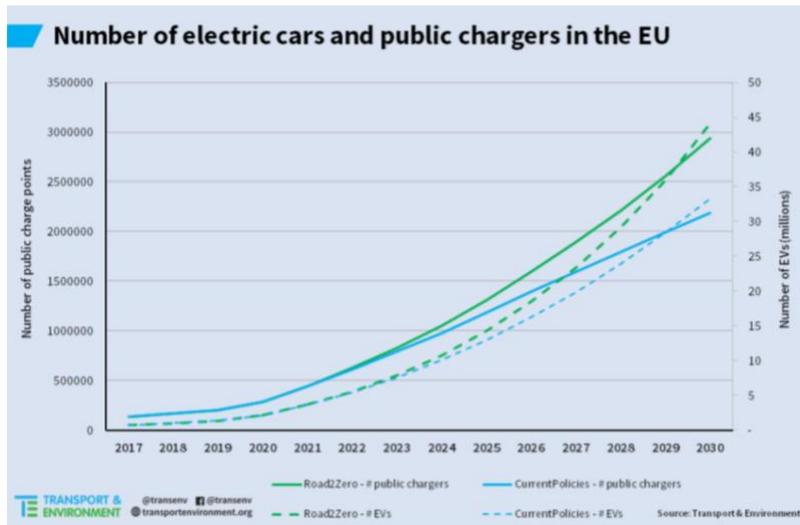


Figure 2.1.3: Forecast of the number of EV public charging points in Europe

Perhaps it's worth spending some time exploring people's "common beliefs". After all adoption of new products involves trying something new, and novelty means uncertainty for the customers. This brings us to the next chapter.

### 2.3 Common beliefs on EVs

Ever since their conception, electric vehicles have been plagued by negative common beliefs (as it's common with paradigm-shifting new products), some of these true and some less so. Indeed, range of EVs with a single charge is generally lower than an average gasoline car (although the gap has been narrowing) and charging stations are less diffused than gas stations. It's worth mentioning that the range of some modern BEVs already rivals the range of gasoline cars, with most BEVs having a range of 200-490km (average gasoline vehicles reach up to 482km), however this EV range is "ideal", and shortens greatly by the simple use of, for instance, air conditioning. Price on the other hand might be turning on EVs favor, as several

costs related to maintenance of the internal combustion engine are spared on EVs and the only major cost is related to changing the battery in case of defectiveness, which is in any case rare. Operating an EV is also cheaper than a gasoline car, with costs of recharge being about 50% on average, although this changes widely depending on the location. Sale price is also an interesting case. Being the supply of BEVs still low in relative terms, recent popularity of high end EVs such as Tesla Model S and Model X have contributed to skewing the average in that direction, leading to the common belief that EVs are more expensive to purchase. However, there are plenty of BEVs such as Dacia Spring, Fiat 500 E, Seat Mii and many others which are below or in line with the average price of a gasoline car. In any case, it's undeniable that negative beliefs on EVs are widespread, and as long as this is the case sales volumes will be limited.

Consumers' anxieties about owning a PHEV or a BEV will be key factors to be explored in this Thesis and will pave the way towards understanding the role of home chargers and their impact on EV perception. In particular, the most famous anxiety related to EVs is Range Anxiety, defined as "the fear that a vehicle has insufficient range to reach its destination and would thus strand the vehicle's occupants". The term has become linked with BEVs because it's widely acknowledged to be one of the major barriers of mass adoption for these vehicles. Of course, range and fear of not finding charging points are directly intertwined, as the lack of public charging stations will make it more likely for a person to worry about the range of a single charge. BEVs with higher ranges regularly score higher in the Overall Customer Satisfaction Index, as they provide greater peace of mind to their driver.

## 2.4 EV Charging Stations

### 2.4.1 Charging Stations overview

Understanding EVs is key as they drive the need for chargers, but with this being said, EV charging stations are the focus of this thesis and this chapter offers an explanation of these new and fascinating products. EV charging stations are pieces of equipment which supply electrical power to plug-in vehicles such as PHEVs and BEVs, with the objective of charging their batteries. As previously mentioned, EV chargers can provide AC and DC charging. AC

charging stations can recharge a vehicle using maximum 22kW of power output if 3-phase electricity supply is available, although most flats and residential homes in Europe are likely to possess single-phase electricity, which limits the output to 7,4kW and elongates charging time. In Italy, standard electricity supply in residential homes is fixed at 3kW, making EV recharging at home tediously slow. Figure 2.3.1 shows different types of Charging Stations, in this case belonging to TME's lineup.



Figure 2.3.1 - Types of AC Charging Station, Not Connected (left), Connected (centre), with double socket for Dealers (right)

On the other hand, DC chargers are also called Fast Chargers because their output can reach 150 – 350kW of power. Of course, this makes the latter chargers much more expensive, and not appropriate for residential homes due to the excessive power output (again, most houses have single phase electricity, supporting 7,4kW maximum).



Figure 2.3.2 - Types of DC Charging Stations

For this reason, all home chargers are AC Charging Stations, generally in the form of wallboxes, products that can be placed on a wall or on a pole next to the car parking spot. These Wall Boxes (Figure 2.3.1) can be connected or not, depending on whether they have

connectivity capabilities which allow the user to connect to the backend services through a Smartphone App. This allows the user to schedule sessions, share the wallbox with other people, monetize recharging, lock, and unlock the charger and monitor each session. Naturally, connected chargers are more expensive, averaging around 700€ in Europe, with non-connected chargers being closer to 500€. How Home Charging Stations are sold depends on the company, most car companies sell them as a separate accessory product, others sell it as a bundle offer with the vehicle sold. An additional cost for home chargers is installation, which averages 1000€ in Europe. Home Chargers are also not a viable product for all users, depending on the type of house homeowners live in. If a person lives in a single house or possesses private parking or a garage, then the Wall Box can easily be installed. However, if a person lives in a flat in the city center with no private parking, then possessing a Wall Box likely will not be feasible. Nonetheless, across Europe the lion share of electricity used for recharging plug-in vehicles (PHEVs and BEVs) already comes from home charging, as the image 2.3.3 illustrates.

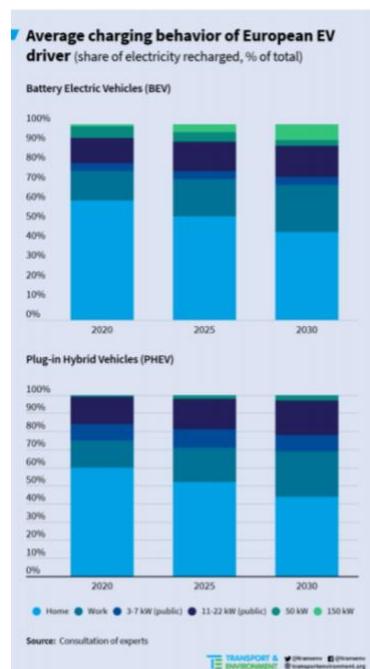


Figure 2.3.3 - Average Charging Behaviour of European Drivers

It's worth mentioning that charging from home does not necessarily require a Home Charger. A cable called Mode 2 is available for charging a vehicle directly from a house plug, which is a

far more economical solution as it requires no additional purchases. The problem with charging from a house socket is that charging time are automatically increased, by around 3 times, bringing the average to around 19 hours for a 60-kWh battery vehicle.

What makes charging stations such an interesting product from a business point of view however, is that they offer opportunities which were unparalleled until today in the automotive industry. As mentioned, it is the first time a product directly sold by automotive companies is entering consumers' homes to the extent that it's connected to the power system of the house. Also, it presents very new benefits for the customers, first and foremost the ability of charging directly from the comfort of their home and during the night, instead of going to a gas station, but also the ability to derive revenue from sharing the charger.

#### 2.4.2 Industry differences and margins

Businesses selling charging stations in the market are several. These include OEMs such as Toyota, Volkswagen, BMW, Jaguar, KIA etc., but also Energy Companies such as Enel X and Engie, industrial providers, and charging stations manufactures such as Wallbox and EVbox. The way OEMs such as Toyota Motor Europe are organized, is through a centralized entity selecting and purchasing the products, which are then sold to national companies and then resold to dealerships. Only then do dealerships sell the product to end-customers. A benefit of this process is that OEMs can offer a coherent lineup in different markets and have a coordinated pan European strategy. However, a problem with this process is that each entity in the chain needs to take a certain margin to pay for logistics, storage etc., making retail price higher as a result. This is a problem that an individual seller in a certain market, rather than a multinational, does not have, as it can cut several steps and offer a lower and more competitive retail price, despite having only a local reach.

Another question to consider is the direct relationship between a car battery and home electricity. Businesses such as energy provider companies are in a perfect position to offer deals based on combining their charging stations with an energy offers, thereby increasing demand of their products.

What OEMs can do however, is offer the charger in a combined (bundle) offer with a PHEV or a BEV, potentially increasing attractiveness of the vehicle as a result of having an attractive offer as a whole. OEMs can also build competitive advantage in the home chargers' market through the creation of a superior customer journey, by relying on their unique position as providers of the vehicle. In this case, it is crucial for OEMs to develop a smooth experience between dealership, installer, and customer. Home Chargers are relatively new products in the market, and consumers generally have low familiarity with them, which increases the need for excellent customer service and guidance, something OEMs can influence through their dealers and installation partners.

As mentioned in earlier chapters, the objective of OEMs should be to create a viable EV ecosystem, of which the car and charger are mere components of, but are not the full story. In fact, the EV ecosystem is so important that the next chapter will be fully dedicated to it.

## 2.5 EV Ecosystem

The term "electric vehicle ecosystem" is thrown out a lot today, and it's worth specifying its meaning as it's key to understand the direction companies manufacturing EVs are heading towards and how they differ from the strategy adopted with gasoline cars.

An EV ecosystem can help driving up EV adoption and maximizing the benefits of owning an EV for a consumer, but can also create benefits for an OEM. A strong difference in EV strategy with respect to gasoline and Diesel vehicle strategy is the underlying importance of connectivity, which has become a basic requirement for EVs. Connectivity impacts both comfort and range anxiety, as owners can monitor the state of the battery, find public chargers while combining this with their vehicle location, monitor and share charging, lock, unlock etc. This creates a digital platform called EV ecosystem, which can potentially benefit from an indirect network effect. OEMs can benefit from an EV ecosystem in many ways, such as offering flat subscription or pay-per-use subscription, developing EVs based on modular architecture to support mass customization which will drive up EV adoption and create closer relationships between customer and OEM through digital channels. Another important aspect of this ecosystem is the interaction with other players outside the OEM, for example an OEM's Smartphone APP can direct to any public charger, where plugs are standardized (at least in

Europe). This connectivity among internal and external factors at the heart of the EV ecosystem allows for data sharing which can provide insight to an OEM to improve customer service.

Connectivity is not the only component of the EV ecosystem, albeit a very important one that allows for connecting each component. A very quick visit to Tesla's website will give a clear representation of what such ecosystem can become. It is interesting to analyze the product lineup Tesla has in place. It is foremost an EV manufacturer, but also provides batteries, charging stations and solar panels. A consumer having them all can produce electricity at home through roof panels, store such energy in a battery and use the home charger to recharge his vehicle or other people's plug-in vehicles for profit, or even choose to resell stored energy to the grid. Meanwhile all this process can be monitored and altered comfortably from a smartphone APP. Tesla is by no means perfect, and still lags behind other OEMs in terms of customer service, but it has a clear idea when it comes to building an EV ecosystem.

### 3. Hypothesis

The overall objective of this thesis is to build a methodology aimed at understanding whether including EV charging stations in a carmaker's offer can lead to an increase in adoption of its BEVs in Europe. To build up to this specific topic, some hypotheses need to be tested.

#### 3.1 Hypothesis 1: Diffusion level's impact on Range Anxiety

Europe is not a single country, it's made up of sovereign states with different cultures and economic models, resulting in different adoption levels of BEVs. It was stated in Chapter 2 that BEVs and PHEVs composed 84.9% of new car registrations in June 2021 in Norway. This is not an anomaly for the country, as it reached 82% in January 21, 79% in February 21 and 84.8% in March 21. In 2020, BEVs themselves made up 54.3% of all cars sold in Norway. Such levels of adoption place Norway comfortably in the "Early Majority" section of the s-curve. In fact, "Early Majority" is defined as "a stage in the diffusion of a new technology that represents the first sizable segment of a population to adopt the innovation."

However, the same cannot be said for all European nations. For example, in Poland, the share of new plug-in (BEVs + PHEVs) vehicles registered was 0.44% of the total in 2020. Therefore, while the numbers are increasing for Poland too, it's clear that the country finds itself at a much earlier stage of the s-curve than Norway, with adopters in the country largely belonging to the “Early Adopters” category (Figure 3.1.1). Most countries in Europe find themselves between Norway and Poland on the s-curve, but what all of this means is that consumers from different countries have different perceptions of electric vehicles. A consumer in a stage of Early Majority will be more attentive to price, ease of use and design when looking at purchasing a BEV, whereas one in a stage of Early Adopters will prioritize ancillary features and factors that help them increase their confidence with the product.

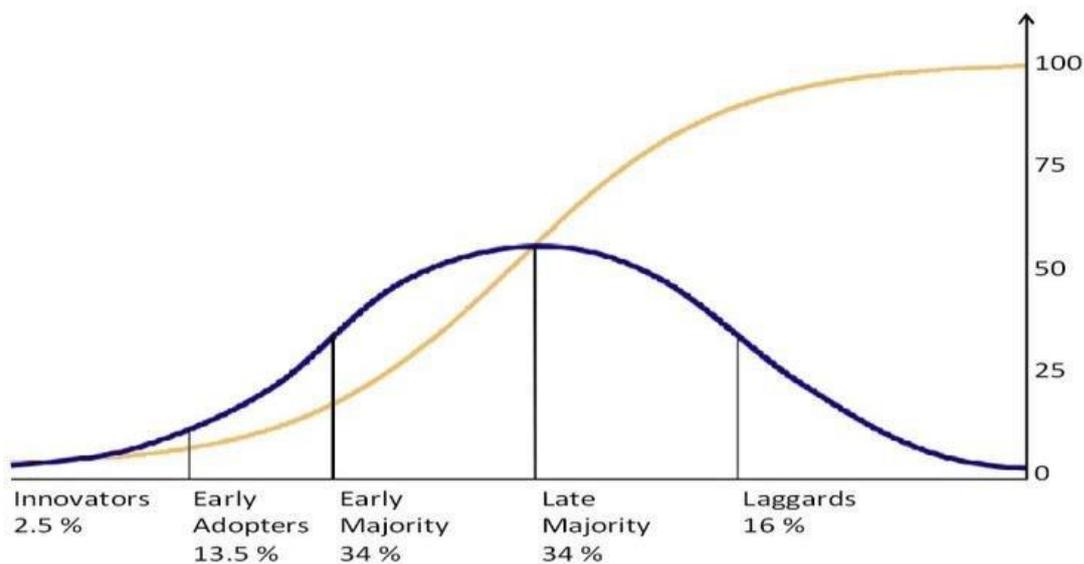


Figure 3.1.1 - The s-curve of adoption (cumulative in yellow)

The *first hypothesis* is that Range Anxiety is inversely correlated with respect to the diffusion level of EVs in a country. This means that in a country such as Norway with high levels of BEV and PHEV diffusion, these fears will be lower than in a country like Poland. Larger BEV diffusion translates into a higher number of public charging stations (see Figure 3.1.2), which are likely to reduce Range Anxiety as the distance between each is reduced. A further assumption here is that a consumer in a country in the “Early Majority” stage feels more confident about BEV as a product due to greater exposure, hence making Range Anxiety lower

in theory. It's important to note that this doesn't mean total demand for home chargers will be lower in countries with high BEV diffusion, since higher numbers of plug-in vehicles lead to higher demand for home chargers, as they offer additional comfort to owners despite any anxiety.

This Thesis is aimed at providing a methodology rather than offering results. Since the target audience will largely be Italian consumers, comparisons between countries in terms of diffusion and range anxiety such as *Hypothesis 1* will not be explored, but they should nonetheless be taken into consideration for a more extensive research.

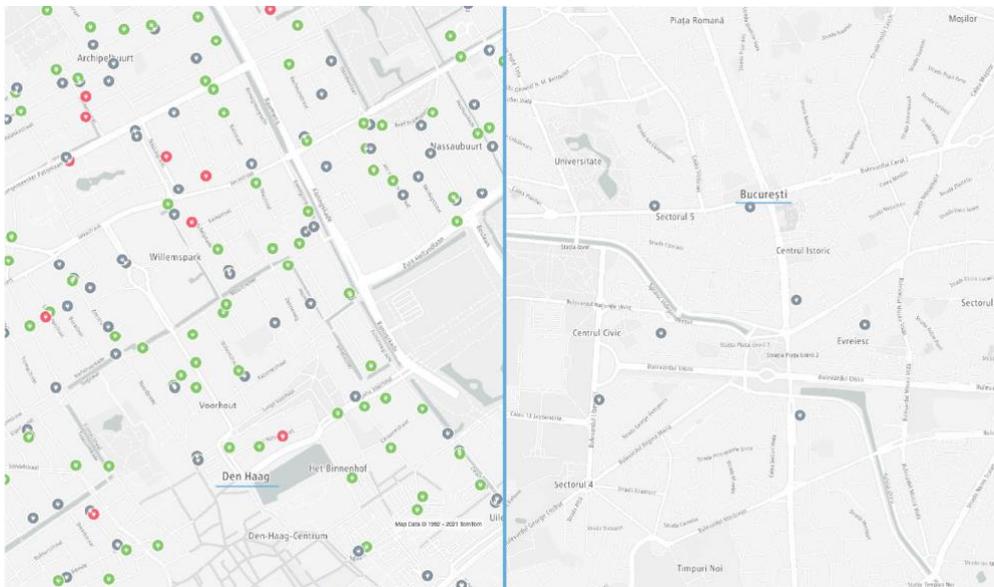


Figure 3.1.2 - Charging Infrastructure in Europe varies greatly e.g. between Amsterdam, Netherlands (left) and Bucharest, Romania (right)

### 3.2 Hypothesis 2: Impact of Range anxiety on Vehicle Adoption

Previous research has been conducted on range anxiety and the numbers of public charging points, so this thesis is instead to focus on how and if owning a home charger can offset this anxiety, hence leading to higher levels of adoption for BEVs. The objective is to try quantifying this anxiety and understand its correlation to plug-in vehicles' adoption. Presumably, this correlation will be inverse, meaning the greater the consumers' range anxiety, the smaller will be the chance of them adopting a PHEV or BEV.

Once again, due to the limited scope of the Thesis, countries will not be compared in terms of range anxiety and EV adoption. But the understanding of this correlation is key to understanding the difference in perception between high adoption and low adoption countries in Europe.

### 3.3 Hypothesis 3: Impact of home charger on Range Anxiety

The question is whether owning a home charging station will help decreasing range anxiety for a consumer. The 3<sup>rd</sup> *hypothesis* says that it will, at least partially, since most charging will be done overnight, ensuring more than 200km of range per full charge on the subsequent day. This range is more than enough for an average trip in the same city or local region and possessing a home charger ensures a reliable charging access point, as most people will return to their homes daily. Of course, some people need to car frequent longer trips or commutes, in which case a home charger offers little relief. These people are likely to consider the impact of the home charger on their lives relatively mild, although they are expected to represent only a minor part of the population.

### 3.4 Hypothesis 4: Importance of brand consistency

The last question that needs to be explored is whether it matters to consumers if their home charger belongs to the same brand as the vehicle they own or are willing to purchase. Here it's important to note that across Europe, the plug Type 2 ensures standardization among plugs for electric vehicles (Figure 3.4), therefore compatibility of BEV and charger is not a factor to be taken in consideration when it comes to hardware. Software is trickier, but in general a home charger which allows for connectivity can host any appropriate backend, not just the one from the company that sold it. For the purpose of simplicity, it will be assumed that compatibility is not an issue for either hardware or software in this thesis.



Figure 3.4 - Types of plugs. The EU enforces Type 2 for all plugs including Tesla's

The 4<sup>th</sup> hypothesis is that there is a positive correlation between a car company selling home chargers and adoption of its BEVs if these products are tied together through a bundled offer. If the home charger is included in the price of the BEV when it's being purchased, the correlation is likely to be positive since the price of the vehicle will include the added value of the charger. On the other hand, if the Home Charger is sold as a bundle with the BEV but the two prices are summed, then the correlation is likely to be weaker and dependent on the additional convenience offered to the customer in terms of service. The benefit of having additional value of the charger at the same price has disappeared, but the option to purchase a charger with the vehicle can give a dealership the opportunity to offer a coherent customer service, in terms of guidance to installation, warranty procedure and assistance. Offering a charger as a bundle with the car can also give an OEM the opportunity to set up an ecosystem, Tesla gives a great example of this, often combining an EV, home charger, battery and solar panels in their line-up. As a remark, it should be stated that the possibility of purchasing the charger as a bundle is assumed to be presented to consumers as an option, in order not to discourage customers who only need or desire the BEV.

If instead the home charger is sold as a separate accessory to the BEV and therefore bought independently from the vehicle, the hypothesis is that the correlation will depend solely on the customer's feelings and expectations about the brand. In other words, if the customer associates their specific car brand with reliability, then the same expectations will be carried over to the home charger. On the other hand, if the car brand is associated with low quality,

this will likely also reflect on the customer's expectation of the home charger. Different customer segments have different preferences, meaning some customers will prefer reliability and others will prefer saving money on a lower quality product. It will therefore be important to understand consumers' level of appreciation of their car brand, to see how this would translate into inclination to adopt a home charger of the same brand. This assumes that there is a degree of complementarity between the home charger and the BEV, which is something to be tested.

To conclude, this thesis presents several *hypotheses* that would need to be tested for an accurate European-level investigation. Firstly, the correlation between experiencing range anxiety and adopting a BEV will need to be examined and quantified. Secondly the effect of owning a Home Charger on range anxiety will need to be evaluated. Lastly, the hypothesis is that correlation between a carmaker selling home chargers and adoption of its BEVs is positive to various degrees depending on whether the charger is sold as a bundled product or not. If the charger is sold separately to the BEV as an accessory, then the hypothesis is that complementarity between the two will depend on the perceived image of the brand.

## 4. Method

Now that the context of Home Chargers and Electric Vehicles has been explored and the different *hypotheses* are defined, Chapter 4 will dive into the methods to be used to test each hypothesis.

The first method, aimed at understanding consumers' point of view and needs, will be a survey, with questions specifically designed in such way to provide an answer to all the main hypotheses identified in the previous Chapter. The target audience of the survey should be European citizens and residents. However, as this Thesis acts as a pilot project, the survey will be mainly directed at Italian consumers. Europe is intended as the continent rather than the EU, therefore will include countries such as UK and Turkey, markets which are in any case part of the European Toyota subsidiary: Toyota Motor Europe. The second method will be an interview with Toyota Managers. The interviewees need to be in some way involved with EVs

and charging stations project. Including both external consumers (through the survey) and internal employees (through the interviews) in the investigation is key to understanding both sides of the story, to appreciate the reasons behind offering charging stations in carmaker's offers and the perceived effect this has on consumers, and whether this matches carmakers' expectations. As Chapter 4 will mostly focus on the methods applied to the consumer survey, the last subchapter (4.6) will be fully dedicated to the interviews.

The introductory questions of the survey will be aimed at understanding the gender and nationality of the respondents, as well as what type of car they own or drive most often. The options here will be: Gasoline car, Diesel, GPL/LPG, Methane, Hybrid (HEV), Hybrid Plug-in (PHEV), Battery Electric Vehicle (BEV), Other. The purpose of this question is to build the ground up for the next questions, but also to find correlations with other pieces of data coming from the following questions. It can also provide some insight on the current level of diffusion of electric vehicles or hybrids. The question will look like this:

*Which type of car do you own/drive most often?*

- *Gasoline car*
- *Diesel car*
- *GPL/LPG*
- *Methane*
- *Hybrid electric (HEV, no external recharging)*
- *Hybrid Plug-in electric (PHEV, can be charged externally)*
- *Fully electric car (BEV)*
- *I never drive a car*
- *Other*

As part of the introductory questions, the following question is aimed at understanding the current views the respondent has on BEVs and whether he/she would consider purchasing one as their next vehicle, or if not, why. This question is not aimed at quantifying the level of Range Anxiety every respondent has when considering a BEV, but rather at understanding

whether Range Anxiety is the main barrier to BEV's widespread adoption according to consumers.

*What is the main reason you are skeptical about purchasing a fully electric vehicle as your next car?*

- *Range of the vehicle*
- *Finding charge points*
- *Charge is too slow*
- *Price*
- *Aesthetics*
- *Performance*
- *I am not skeptical*
- *I own an electric vehicle right now*
- *Other:*

Respondents will have the chance to select one or more options.

#### 4.1 Diffusion level's impact on Range Anxiety

Reducing geographical bias is key to obtaining meaningful information to test the hypotheses. As mentioned in Chapter 3.1, the populations from different countries in Europe are part of different segments when it comes to BEVs, Early Adopters or Early Majority, which possess different needs and expectations. To tackle this problem, for an extensive research the consumer survey should be aimed at obtaining data from different countries in Europe, with a minimum number of respondents from each target country. It's not important to obtain data from every single country in the continent, but rather from selected countries which cover the key segments: low adoption and diffusion such as Poland, medium adoption and diffusion level such as UK and Germany, and high levels of adoption and diffusion such as Norway and the Netherlands.

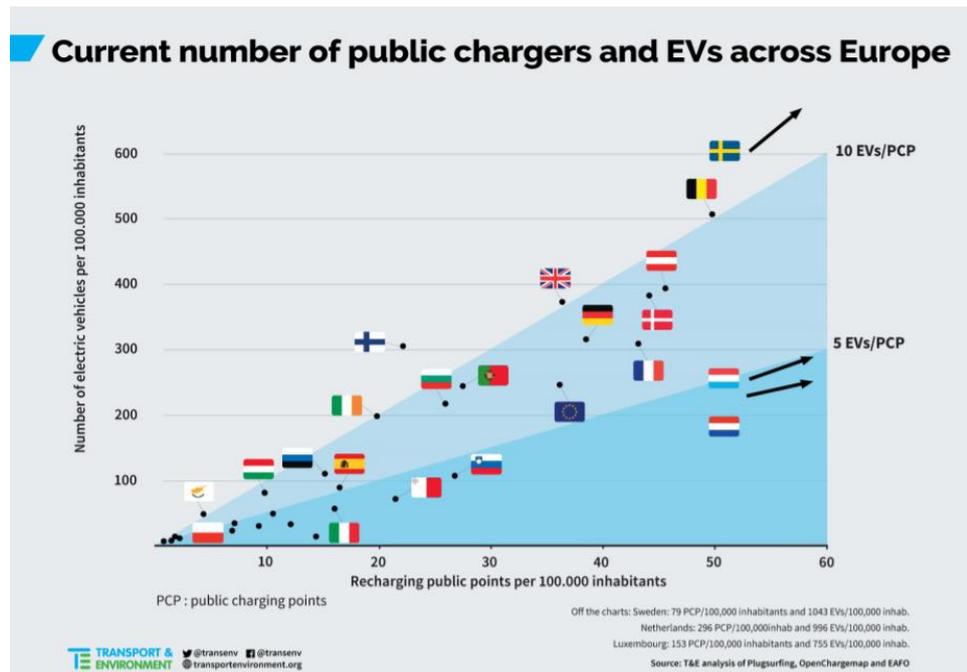


Figure 4.1: Number of EVs vs Number of Public Chargers per EU country (2020)

Particular attention should go in making sure the survey is completed by citizens of different European countries, trying to cover the main segments as much as possible. The data should then be compared with the level of BEV adoption in each country to determine the validity of the first hypothesis: that countries with higher levels of BEV adoption suffer from Range Anxiety to a lesser degree. The respondents will be asked to input their country at the beginning of the survey.

#### 4.2 Impact of Range anxiety on Vehicle Adoption

The *second hypothesis* stated that Range Anxiety is inversely proportional to BEV adoption. This is relatively easy to test, as the respondents of the survey will be directly asked to what extent Range Anxiety plays an important role in their decision to purchase a BEV, by providing a grade from 1 to 10. The question can be found below:

*To what extent is the limited range and availability of public Charging Stations stopping you from purchasing a fully electric vehicle as your next car?*

This question is directly aimed at quantifying Range Anxiety for consumers, hence ignoring other problems people associate with plug-in vehicles.

### 4.3 Impact of Home Charger on Range Anxiety

Following the question in Chapter 4.2, the size of Range Anxiety and its impact on BEV Adoption should be understood. The next point to explore is whether a home charger can offset this anxiety. The main problem with obtaining this data is that not all respondents might possess a detached, semi-detached home, private parking, a private garage or even a car. If a respondent does not own a private parking of some type, then a home charger cannot be installed, as it would have to be in a public parking space which is illegal. Another issue is that some respondents will consider the price of the charger as a factor in their decision making, but this defies the purpose of the survey which is aimed at understanding specifically Range Anxiety and how to offset it, so price's influence should be eliminated. To reduce the complexity of the survey and the number of follow up questions, the next questions will start with these assumptions:

*Assuming you have a private parking, which gives you the possibility to install a Home Charger...*

Following this, the questions used to test the second hypothesis will be:

*How much more reassured would you feel about owning an electric vehicle if you had a home charger which can recharge your car when at home?*

As a result, it's possible to quantify how much a home charger truly reassures a consumer suffering from Range Anxiety. The respondent will be asked to provide an answer between 1 and 10, where 1 means that the Home Charger doesn't reassure them at all, whereas 10 means they feel completely reassured.

## 4.4 Importance of Brand consistency

### 4.4.1 How the product is sold

This chapter is important to understand whether it matters to consumers if the charger they purchase belongs to the same brand of the car they own or are willing to buy. For reference, it will be assumed that the next vehicle purchased by the respondent will be of the same brand as the current one. The first question that will be asked in the survey is simply:

*How important is it to you that the Home Charger be of the same brand of your vehicle?*

Subsequently, one needs to understand how the way a Charger is sold to the end customer affects their likeliness to adopt a new EV from the specific OEM. As previously stated, a charger can be sold as a bundled product with the vehicle or as a separate product. This therefore requires two questions, which will be as follows:

*How much more likely are you to buy an electric car from a certain carmaker if a Home Charger (price: 800€) is included in the price of the car?*

And:

*How much more likely are you to buy an electric car from a certain carmaker if the same Home Charger is not included in the price of the car but you can purchase the two together?*

### 4.4.2 Link with car brand

The following method is aimed at understanding whether there is any correlation between offering a home charger and experiencing higher plug-in vehicle adoption for a carmaker selling the two products separately. The question below aims at understanding which characteristic the respondent associates with the brand of the car they currently own, and whether they would like the charger to reflect the same characteristic. There is no reason to assume that qualities associated to a certain car brand will be reflected on the home charger sold under the same brand. However, the important aspect to understand is customers'

feelings about the brand, which are the main drivers of adoption and will link a certain product to its brand in any case. The question will be as follows:

*What's the first word that comes to your mind when you think of your car's brand?*

- *Luxurious*
- *Comfortable*
- *Reliable*
- *Economical*
- *Fuel Efficient*
- *Decent*
- *Other:*

This question will be followed by:

*How important to you is that your Home Charger reflects the same characteristic?*

This will make it clearer whether consumers wish for the charger to reflect the brand of the car they own, and is an analysis completely based on consumers' feelings.

#### 4.5 Rogers' Adoption Criteria

This subchapter contains an additional method to provide further examination for the hypotheses at large. This method comes from Rogers' Adoption Criteria. According to Rogers, adoption occurs in 5 steps, namely through awareness, interest, evaluation, trial, and adoption, in this order. Applying his theories to the impact a home charger can have on the adoption of a BEV, the decision to adopt becomes associated with:

1. **Advantage** - How owning a Charging Station can increase the benefits of owning a BEV of the same carmaker
2. **Compatibility** – Is the same carmaker's charger "more compatible" with my EV than other chargers? Is it more compatible with my electricity system, house etc?

3. **Complexity** – Can owning a Home Charger make owning a BEV less complex?
4. **Trialability** – Can a carmaker selling Home Charger make it easier to trial a BEV?
5. **Observability** – Can owning a charger make it easier for a consumer to understand if the purchase of a BEV was right?

If owning a charging station from the same carmaker can improve one or more of these 5 points for the consumer without sacrificing any, then the hypothesis that selling Home Chargers helps a carmaker increase adoption of its BEVs is correct.

#### 4.5.1 Advantage

The first Roger's adoption criterion drives the question of whether owning a Home Charger could increase the benefit of owning a plug-in vehicle for a customer. To test this, the respondent of the survey needs to understand the main advantages of owning a BEV, and only then can he/she be asked whether owning a Home Charger can increase any of these. The only realistic benefit of owning such vehicle which is somehow linked with a charger is that charging a car in the comfort of your home without going to a station is something which cannot be done with gasoline, methane, hydrogen, or other fuels. The home charger for EVs simply connects to the house electricity, whereas other fuels would require tanks for storage and more complex safety systems. Such question will look like this:

*An advantage of owning a fully electric car is that through a Home Charger you can simply charge the vehicle in the comfort of your home without going to a station, how much would you quantify this additional benefit?*

This question is important as the previous questions mainly involved the idea of Range Anxiety and how a Home Charger can offset such fear. On the other hand, this question puts aside Range Anxiety, and instead directly tackles the comfort of charging at home.

Another possible advantage of owning a Home Charging Station is that the owner can monetize charging sessions by other people such as neighbours (although this can only be done through a Connected Charger). The problem here is that monetization doesn't increase

the advantages of owning a PHEV or a BEV, since a consumer could simply purchase a charger and only use it for allowing third parties to charge their vehicles for a fee. Therefore, no question about this will be included in the survey.

#### 4.5.2 Compatibility

As previously stated in Chapter 2, the standard plug in Europe is the Type 2, therefore, differently from places like the US, plug compatibility is not an issue as it works with all plug-in EVs from all brands. This means a carmaker cannot produce plug-in vehicles that are solely compatible with its own chargers, legality aside it would likely be a bad idea as it would make its cars incompatible with all other public chargers. Another interesting factor to consider regarding compatibility is the backend system of the connected chargers. As previously stated, one of the most frequent types of wallboxes is the connected type, such as the ABL Connected Ready Wall Box, which allow for connection to a Smartphone App to provide lock, unlock, remote diagnostics, scheduling etc. Generally, a carmaker will provide backend connection directly through its Smartphone App, for example a Connected Toyota Wall Box will connect to the MyToyota App and so on. However, the hardware of the charger can connect to any backend service that is installed on it, therefore even if a charger is purchased from a different company, the carmaker's App can still connect to it if the right backend service is installed. One could think of the compatibility of a certain home charger with the house electricity system or space. Some carmakers only offer wallboxes with a certain output, such as 22kW, which only reaches this maximum output with 3-phase electricity, which most residential homes generally do not possess. One could therefore say that if a carmaker offers different power outputs for their chargers, they can benefit from this additional compatibility factor. For sake of simplicity, it's better to avoid posing a question in the survey regarding this topic, to avoid diverging extensively from the core of the thesis.

#### 4.5.3 Complexity

Can owning a charging station make owning a BEV less complex? If complexity is intended as the difficulty of accessing charging points, then the answer is likely positive as a Home Charger

readily available at the user's house. This matter has already been explored previously through other survey questions and is largely included in the question in Chapter 4.5.1, therefore it's not worth repeating as it would add very little additional value. The level of complexity of a home charger with respect to a public one could be thought of as lower since it doesn't require a payment procedure to charge, unlocking can be simpler and public chargers vary in design and to a smaller extent in functionality. However, regardless of the difference in complexity, users can easily build a level of familiarity with EV chargers, just like they have with petrol stations, and complexity is very unlikely to change the opinion of a possible adopter.

#### 4.5.4 Trialability

Trialability refers to the process carried out by a consumer of trying and testing a certain product, and how this process can affect their choice of adoption. This is not applicable in this Thesis since the sale of home chargers is completely unrelated to the trialability of a PHEV or BEV. Therefore, no question will be asked on the survey regarding this.

#### 4.5.5 Observability

Can owning a charger make it easier for a consumer to understand if the purchase of a plug-in vehicle was worth the money? Owning a home charger can be thought of as an additional comfort for the owner of a plug-in, when compared to owning a vehicle based on a different fuel ( although even PHEVs still need to refill gasoline). Therefore, through owning a home charger, a new plug-in vehicle adopter can see the full picture of the benefits of owning such vehicle, which might have otherwise not been possible without a Charger. This gives the plug-in owner greater observability over whether the purchase was a positive choice. However, the additional observability gained through the charger will not provide any additional value towards the adoption of the vehicle, since it's already been purchased, therefore no question on this topic will be present in the survey.

### 4.6 Final Survey

The survey should be created in different languages to ensure its questions are well comprehended by different nationality respondents in Europe. Ideally, to cover the main adoption and diffusion segments, there should be a survey in Polish to represent low adoption and diffusion countries in Eastern Europe, a survey in Italian and/or Spanish to represent southern Europe's trends, and one in English and/or German to represent the medium adoption level countries.

#### 4.7 Interview with Toyota Management

Unlike the survey, which is aimed at obtaining mostly quantitative data (aside from a comment section), the interview will largely provide qualitative data. The aim is to interview at least 3 TME employees with management positions which are at least involved in the charging stations and EV projects. For increased diversity of thought, the plan is to interview managers from the EV Planning Team, EV Alliance Team and Aftersales which are all involved in the project. The objective is to understand their respective viewpoint on the role of charging stations in OEMs' strategy and the mobility market of the future. Of course, this will be linked back to the connection between an OEM offering chargers and EV adoption.

The questions to be asked will be the following:

- 1 What are the main reasons an OEM would want to sell charging stations in your opinion? Is it just for additional revenue?
- 2 Why should a customer (owning a Toyota vehicle) buy a charger from Toyota rather than a different company?
- 3 Do you think that selling chargers can help Toyota/any OEM increase their sales of electric vehicles? How?

## 5. Results

### 5.1 Survey results overview

Across the various platforms on which the survey was shared, it was completed by 350 people. The Polish, English and Italian surveys were sent out to consumers, although Italian citizens were the main focus.

The bar chart below shows the number of respondents by country. Italy by far represents the lion share of the survey responses, followed by Poland, UK and Germany. Most notably, finding respondents from Nordic countries (Denmark, Sweden, Norway, Finland) was a huge challenge during the response collection.

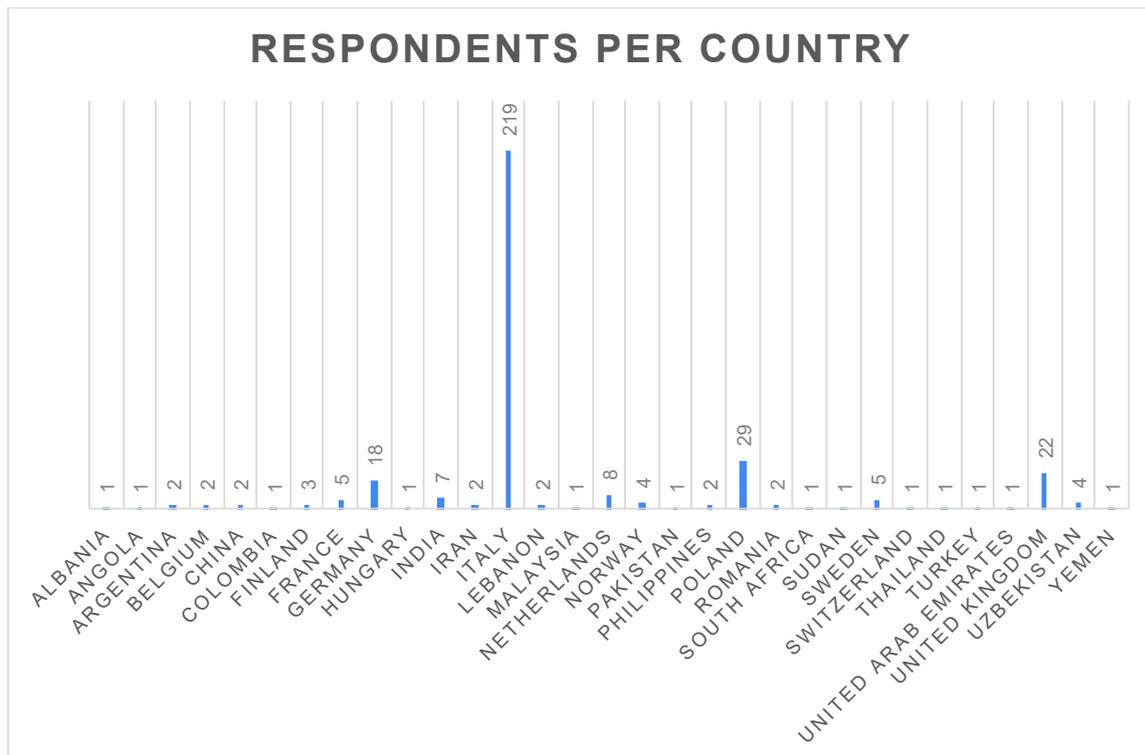


Figure 5.1.1 – Respondents per country. Source: survey

If only European respondents are considered, then the bar charts becomes:

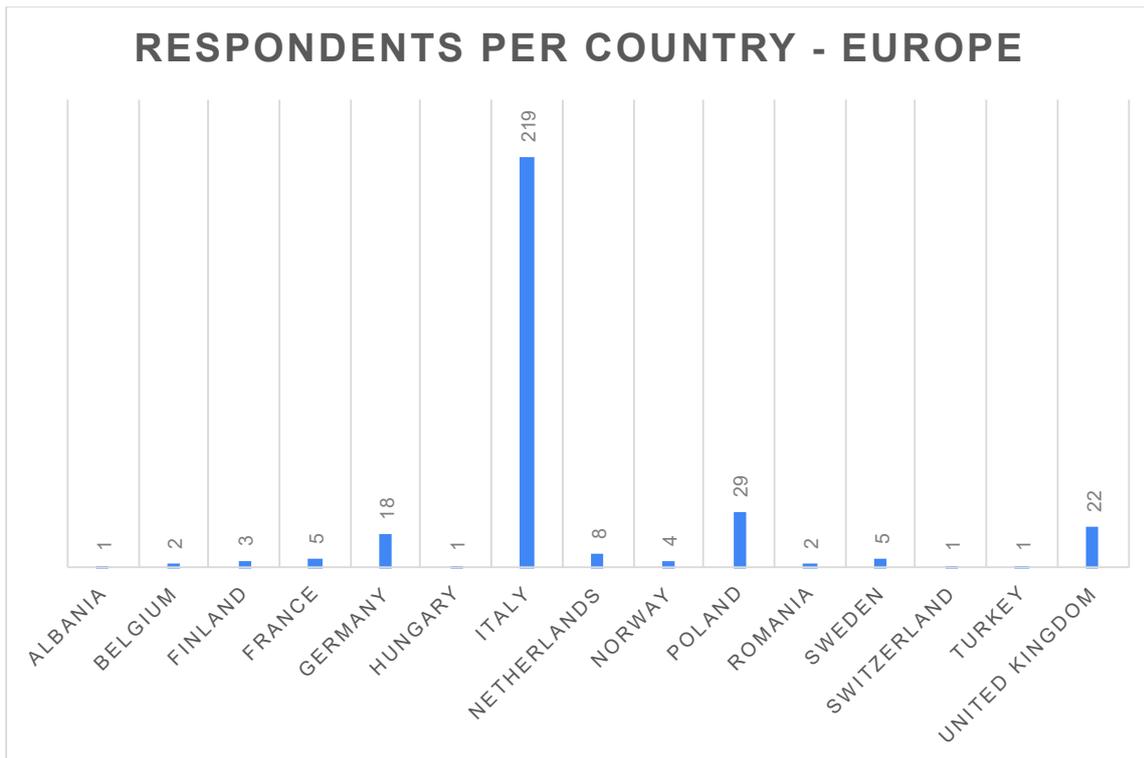


Figure 5.1.2 Respondents per country in Europe. Source: survey

Of course, having such uneven responses creates geographical biases. For this reason, as previously mentioned, this Thesis will only consider Italy for the analysis. A consistent research at European level should of course reflect different countries in a similar manner and with an adequate level of respondents, such as Italy's.

The table below shows the 5 countries/regions that should be considered for the survey results analysis, with 2020 information on number of plug-in vehicles and newly registered plug-in vehicles. The reason to consider 2020 instead of 2021 is first due to Data availability, and secondly due to this part of the project being written in November 2021, hence before the end of the year.

	<b>Total Plug-in vehicles in circulation 2020</b>	<b>% Of total circulating cars 2020 (diffusion)</b>	<b>Newly registered plug-in vehicles 2020</b>	<b>% Of total new registered cars 2020 (adoption)</b>
<b>Italy</b>	99,257	0.27%	59,404	4.3%
<b>UK</b>	899,805	2.84%	108,025	10.7%
<b>Germany</b>	633,420	1.32%	394,632	13.5%
<b>Poland</b>	12,030	0.04%	1,902	0.44%
<b>Nordics+Netherlands</b>		6.3%		35.5%

Table 5.1.4

## 5.2 EV diffusion impact on Range anxiety

The 1<sup>st</sup> Hypothesis in Chapter 3 referred to the correlation between EV diffusion and range anxiety in a country. It was estimated that the correlation between the two would be inversely proportional, because of consumers in high diffusion countries having become accustomed with EVs, increasing their confidence in the products. High diffusion countries also have more public chargers, hence decreasing the anxiety of not finding chargers.

The question in the survey which addressed this query was:

*What are the main reasons you are sceptical about purchasing a fully electric car next?*

This question was a way to measure range anxiety. The countries with the highest percentage of respondents who replied “Range (in Km)” and “Finding charging points” would be associated with experiencing greater range anxiety.

### 5.2.1 Car usage - Italy

Table 5.1.4 says Italy has a plug-in cars diffusion of 0.27%, whereas 3.81% of the respondents had drove an electric vehicle or PHEV.

The graph below shows the distribution of vehicles owned from the Italian respondents:

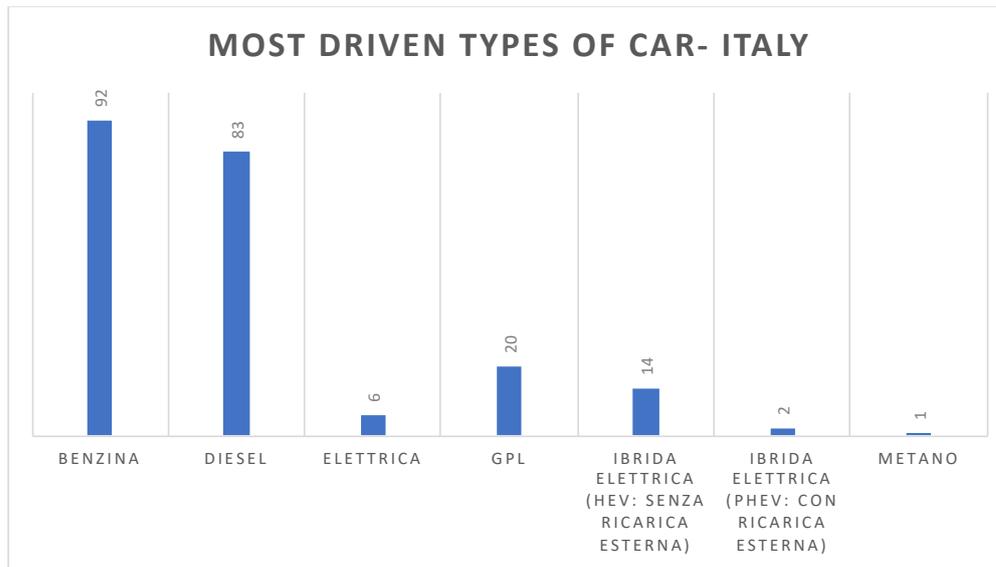


Figure 5.2.1: Italian respondents type of car usage

8 respondents out of 192 possess a plug-in vehicle (electric or PHEV), meaning 4% of the total. This is higher than the official number reported in Table 5.1.4.

### 5.2.2 Car usage - UK, Germany, Poland, Nordics

Unfortunately, these countries didn't receive enough respondents on the survey to be represented sufficiently when it comes to cars distribution. Something interesting to notice was the high level of Diesel cars among Polish respondents. Diesel cars produce more noxious gases and particulates than Gasoline car, and in recent years Europe has moved towards cutting down on the number of Diesel cars in the streets to a greater extent than Gasoline cars. However, Western Europe has been exporting dirty second-hand Diesel vehicles to Poland, with 350,000 of these being exported from Germany to Poland in 2017 alone. This might partially explain the high number of Diesel cars and low number of new EVs (low EV adoption) in Poland, as the first represents a more economically viable option (especially used vehicles) for a country with a relatively low GDP per capita as compared to the western Europe. Being EVs largely a novelty in the automotive world, the number of used EVs on sale is by far lower than Diesel and gasoline cars. This is something that should be taken into account if a full scale European analysis were to be launched.

### 5.2.3 Diffusion vs Range anxiety

Table 5.2.3.1 below represents the number and percentage of survey respondents who replied that range and/or having too few charging points are the main reasons for skepticism on buying an electric car as their next vehicle. In the same way, the number and percentage of respondents who replied that they are not skeptical about purchasing an EV next is also shown.

	Range + Not enough charging points	Not skeptical	% Range + Not enough charging points	% Not skeptical
<b>Italy</b>	158/219	28/219	72.1%	12.8%

Table 5.2.3.1: Degree of Range Anxiety and EV scepticism in Italy

If we consider the respondents who replied that range and number of charging points are their main reason for scepticism, we can convey that they suffer to some degree from Range Anxiety.

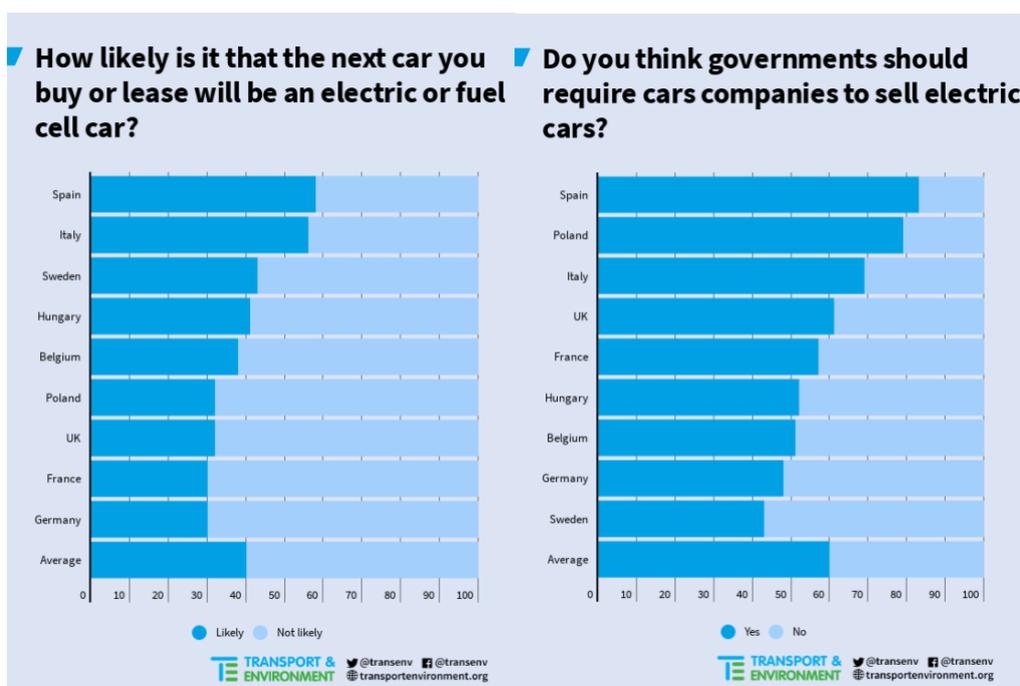


Figure 5.2.3.2: EV scepticism in different European countries, likeliness to purchase EV as next car and government EV incentives (data from 2018)

As indicated by the Method in Chapter 4.1, this should be the end of the analysis for *Hypothesis 1*. However, there is a big factor that has thus far not been considered and could have an impact on the data: the age of respondents.

The pie-charts below show the age distributions among respondents of Italian survey respondents. People aged 40 to 70 represent about 2/3 of the Italian respondents, with respondents aged 20-30 largely representing the rest.

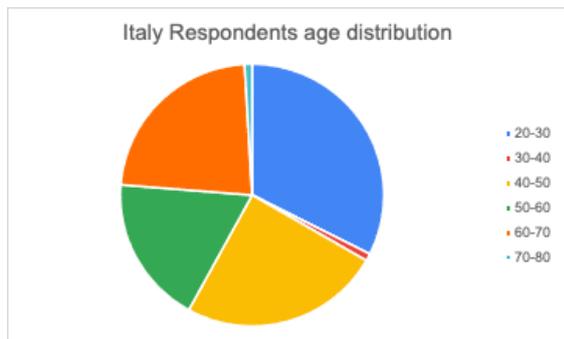


Figure 5.2.3.3: Age distribution among respondents

Interestingly, if only the younger range (20-40 years old) respondents are considered for Italy, the percentage stating range and access to charging points as their main reason for skepticism is 75.3% and the percentage not skeptical at all is 12.7%. This is in line with the total average scoring, 72.1% and 12.8% respectively, so it appears age does not have a large impact on respondents' opinions on EVs, at least among Italian respondents.

### 5.3 Range anxiety impact on EV adoption

The 2<sup>nd</sup> hypothesis in Chapter 3 described the correlation between range anxiety and EV adoption. EV adoption is somewhat correlated to EV diffusion described in Chapter 5.2, as greater EV adoption leads to greater diffusion. Despite this, it's still worth analyzing both since opinions on EV adoption could have mutated as of recently (likely as a result of Government incentives in 2020/2021), not giving enough time for diffusion to pick up.

*Hypothesis 2* estimated that range anxiety is inversely correlated to EV adoption in a country. To do this, we refer to the number of EV purchased as a percentage of the total in the first half of 2021.

The question in the survey which addressed this query was:

*To what extent is the issue of not finding enough charging points stopping you from purchasing an electric vehicle as your next car?*

Respondents were asked to provide a score from 1 to 10, 1 being “not stopping them from purchasing an EV”, and 10 being “stopping them from purchasing an EV”, hence maximum level of range anxiety. The graphs below show the trend in Italy, which for an extensive analysis should create at an European level.

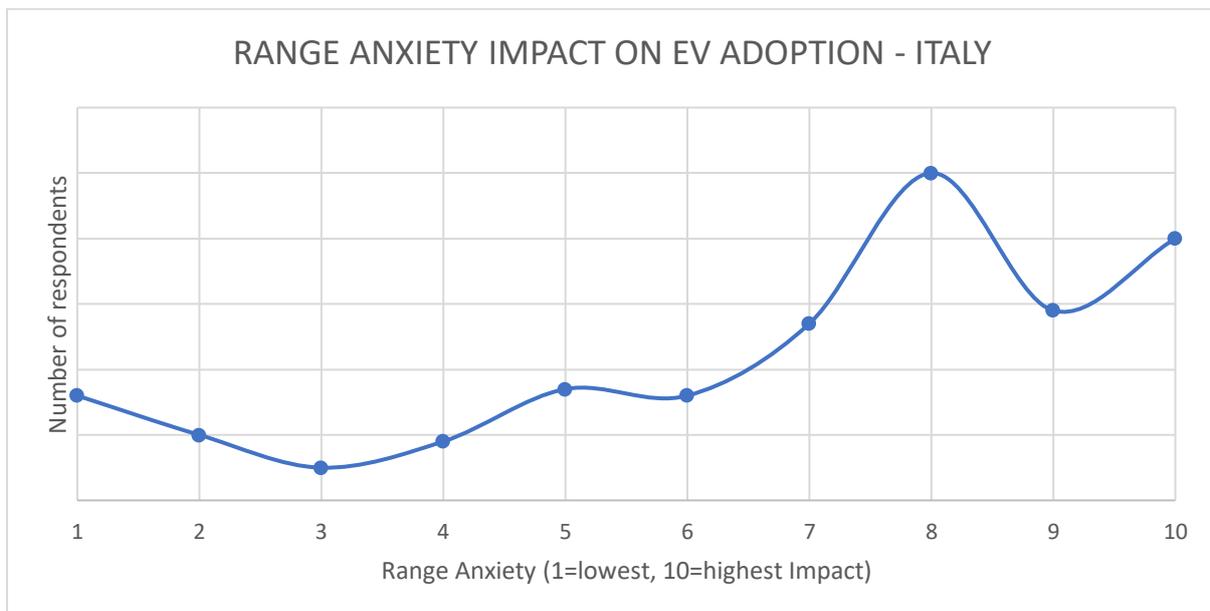


Figure 5.3.1: Level of Range Anxiety among Italy respondents

When looking at data from the Italian respondents, there is a clear upward trend, with an impact of 8 being the most popular. This generally shows that Range Anxiety is a big player among respondents when considering EV adoption.

#### 5.4 Home charger’s impact on range anxiety

The 3<sup>rd</sup> Hypothesis was aimed at understanding whether owning a Home Charging Station will help decreasing range anxiety for a consumer. The relevant question on the survey was:

*How much more reassured would you feel about owning an electric vehicle if you had a Home Charger which can recharge your car when at home*

The 3<sup>rd</sup> Hypothesis stated that owning a home charger would reassure users with range anxiety, more so in countries with low EV diffusion and adoption than the rest.

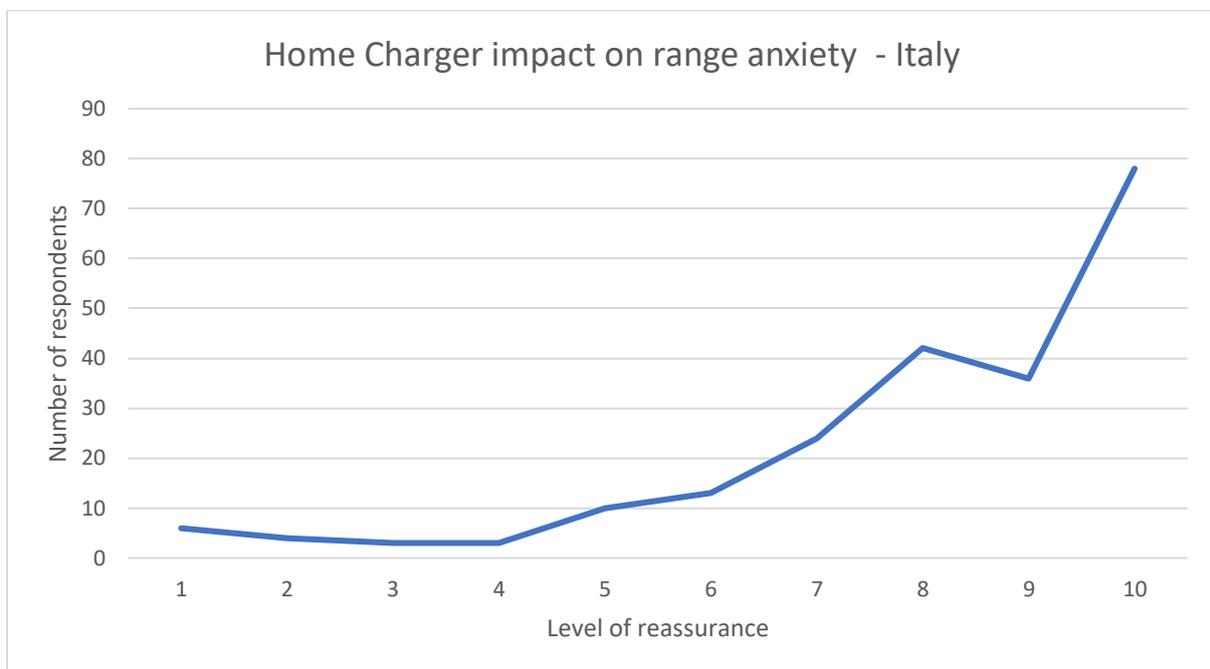


Figure 5.4.1: Level of reassurance to range anxiety given by a home charger

Respondents were then asked to explain the reasoning behind their input, and many mentioned the ability to plan sessions, flexibility and comfort as main drivers. Several specifically mentioned the difficulty in finding chargers which would be eased by a home charger. On the other hand, some respondents show a degree of skepticism towards EVs, mentioning the high levels of CO<sub>2</sub> released when considering the whole production cycle, long recharge times (in Italy home power supply is fixed at 3kW for example) and price. When referring to the home charger specifically, having the device in your garage doesn't help with long voyages, which offers another source of skepticism.

## 5.5 Bundle offer and brand consistency

The 4<sup>th</sup> hypothesis stated the following: there is a positive correlation between a car company selling Home Chargers and adoption of its BEVs if these products are tied together through a bundled offer, correlation is weaker if prices are summed but sold together, but nonetheless present as it is assumed customers will prefer an integrated service.

The first question in the survey which can provide insight for the 4<sup>th</sup> hypothesis is the following:

*How much more likely are you to buy an electric car from a certain carmaker if a home charger (price: 800€) is INCLUDED in the price of the car?*

Regarding this question, it is assumed that the monetary advantage is important to the customer. It is then useful to separate the monetary benefit from the rest of the value added provided by a bundle offer, to evaluate the perceived benefit in customer service that comes from purchasing a charger from the same dealer. The following question helped achieve this:

*How much more likely are you to buy an electric vehicle from a certain carmaker if it sells home chargers as well?*

If we compare Italy's results for these two questions, we obtain the following:

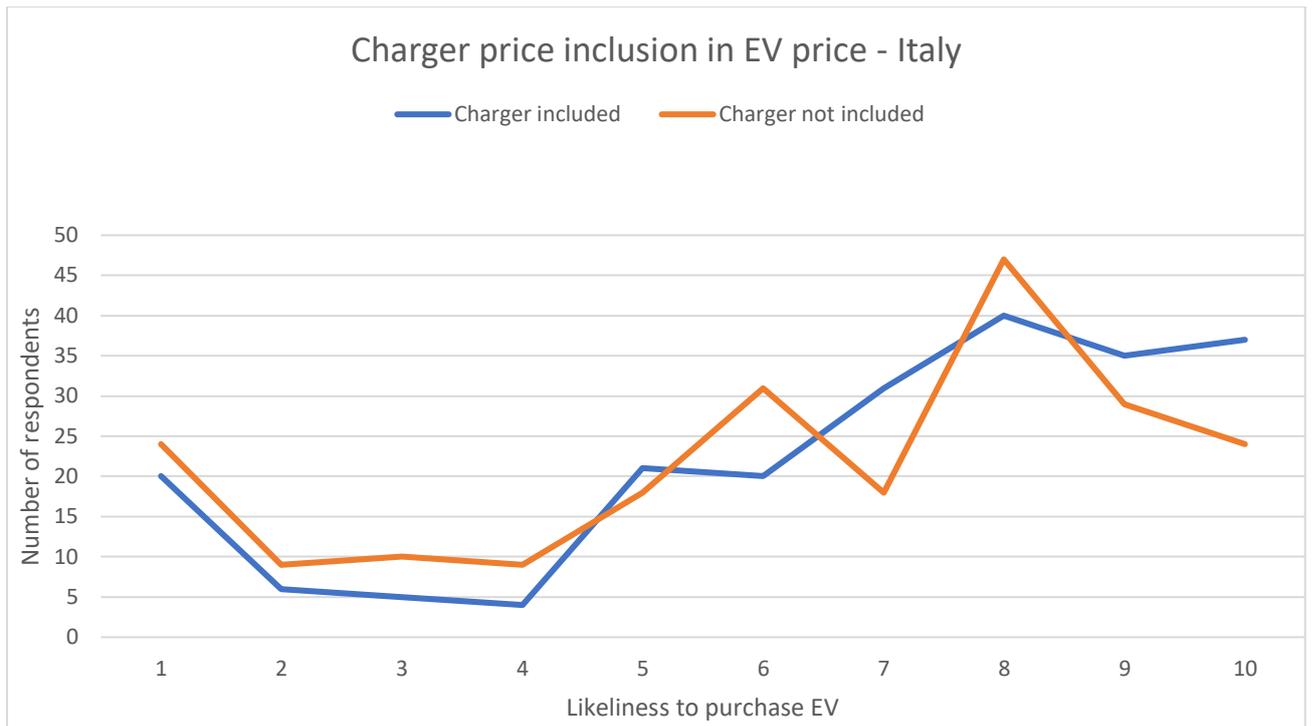


Figure 5.5.1: Likelihood to purchase EV with price of charger included and not included in car price

Interestingly, the results are not too different for the two options. The shape of the curve is largely similar in both graphs, although a higher number of respondents scored 9 and 10 for option 1. This could mean the monetary benefit of saving around 800 Euro is not a priority for Italian consumers, and the benefit of accessing the charger through the same purchase channel of the car is in fact the main driver.

To understand the importance of brand consistence for consumers, the next question was included in the survey:

*How important is it to you that the Home Charger be of the same brand of your vehicle?  
(Ignoring any compatibility issue)*

This question is aimed at separating brand from the rest, hence ignoring any type of customer service associated with purchasing from the same carmaker. In other words, this question singles out customer loyalty to one's car brand.

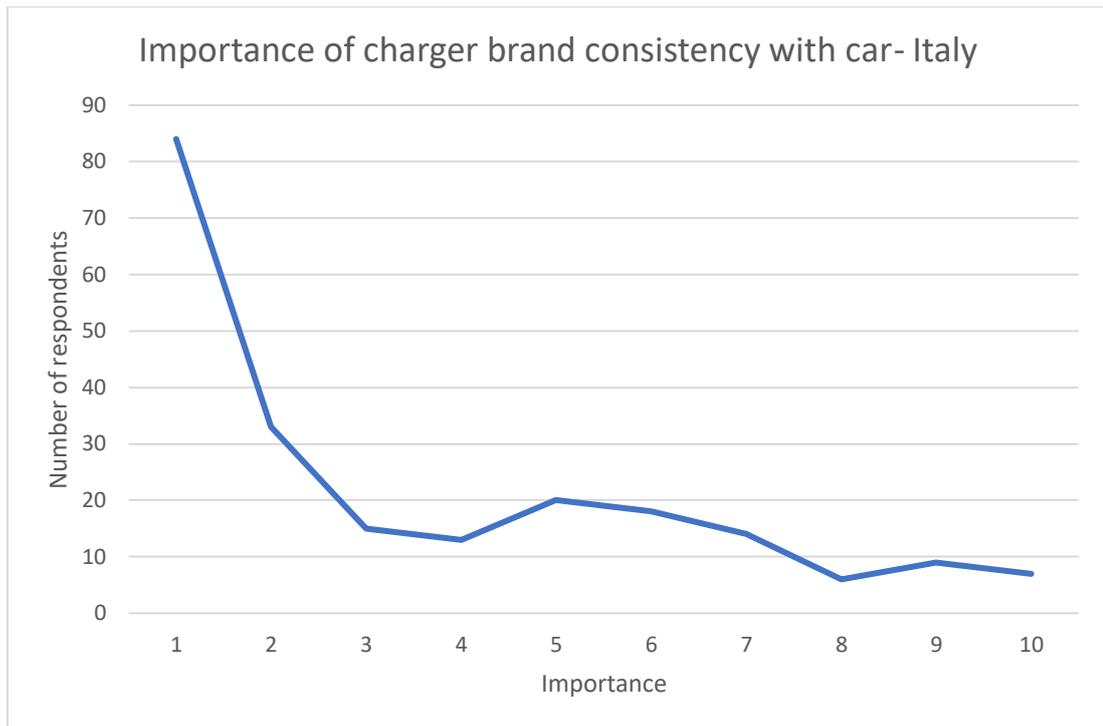


Figure 5.5.2: Importance to customers that charger be of the same brand as their car

Looking at the results, the trend is strongly negative, highlighting the little interest Italian respondents show in brand consistency between car and charger. When compared to the previous graph, which shows a positive trend for both options, it can be deduced that neither price and brand are the main drivers of consumers interest in purchasing a home charger, which means that factors such as flexibility and comfort that come from purchasing as a bundle are the greatest benefit for consumers.

Respondents were then asked to express the first words that come to mind when they think of their car and its brand. The words that were selected the most for both Italian respondents and the rest were: Comfort, Reliability and Low cost, in this order. They were then asked whether they consider important for the characteristics they selected to be aspects of their home charger also. A customer will likely associate the qualities of its car brand to all the brand products. The question was the following:

*How important to you is that your Home Charger reflects the same characteristic?*

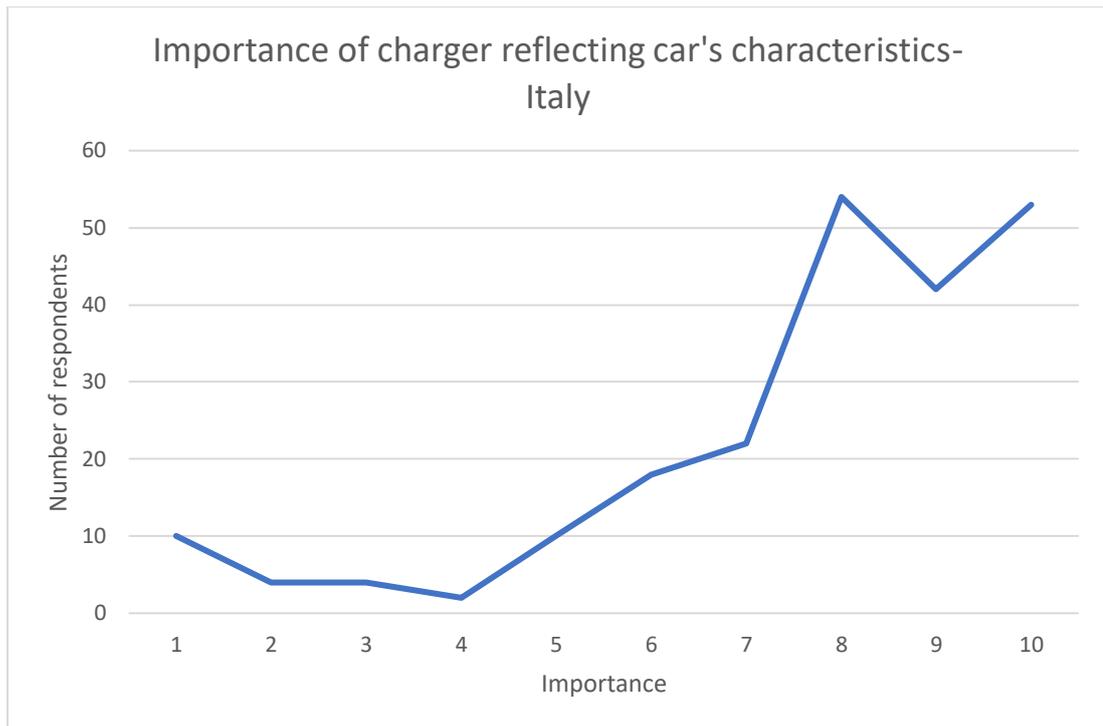


Figure 5.5.3 Importance to customers of home charger having the same qualities as their car

When looking at Italian respondents, the trend is overwhelmingly positive. This in theory should make consumers more likely to purchase the home charger from the same brand, as long as they have a positive view of the brand. This can go both ways, and a good experience with a home charger and car from a certain brand can surely influence the likeliness to purchase a new EV from the same carmaker. This highlights the importance positive customer experience has on customer retention.

### 5.6 Roger's Adoption Criteria

Survey respondents were asked a last question related to an advantage of owning a home charger. Relating to the Roger's Adoption Criteria, if the home charger can create a strong benefit for a PHEV or BEV owner, then the latter's adoption will be impacted positively.

The question was as follows:

*An advantage of owning a fully electric car is that through a Home Charger you can charge the vehicle in the comfort of your home without going to a station, how much does this additional benefit matter to you?*

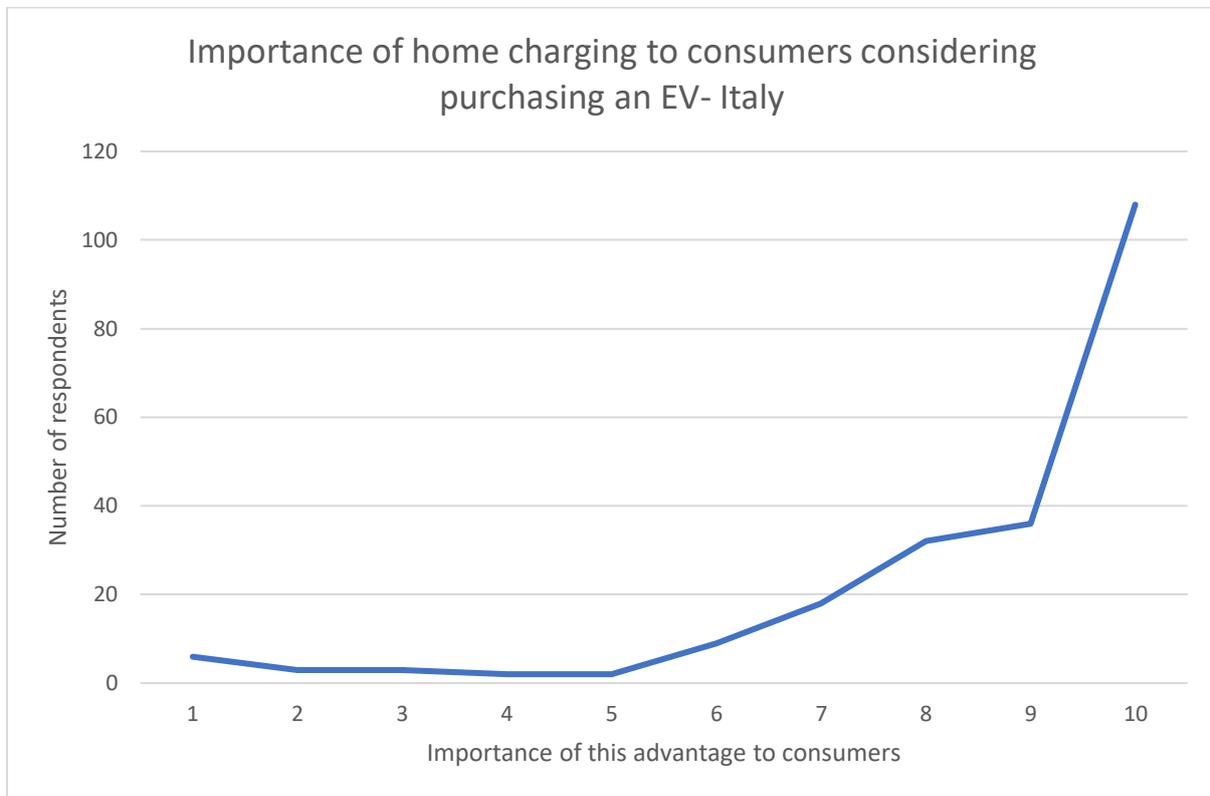


Figure 5.6.1 Importance of the “home charging” advantage to Italian consumers

Italian respondents reacted very positively to this question, meaning the benefit of home charging is of great importance to consumers. The other countries also show a positive trend, with the highest number of votes in the 8-9-10 region of the x-axis. Unfortunately, while Roger’s Adoption Criteria can tell us that this benefit (home charging) could lead to higher adoption of EVs, it doesn’t specify that it should be from the same carmaker. A Toyota BEV owner can purchase a home charger from any brand and benefit the same.

## 5.7 Interview with Toyota Management

Four Toyota Motor Europe (TME) Managers were invited to participate in an interview. To be eligible for participation, each would have to be involved with charging stations to some degree. The Aftersales department was the first obvious choice, since chargers are sold as

accessories at TME and this department is responsible for operations regarding the phase following the sale of the car, all accessories included.

The *transcript* of each interview can be found below in Appendix 2 and should be consulted for a clearer understanding of this analysis.

The list of the interviewees can also be found in Appendix 2.

### 5.7.1 Question 1 analysis

The first question allows to understand the priorities according to each interviewee. In the case of Interviewee 1 and 4, the priority is to stay ahead of the competition, mentioning Energy Providers as the biggest threat to OEMs. If Energy Providers can partner with mobility companies and offer leasing of EVs, this enables them to offer a complete package ranging from energy generation, to charging, to the vehicle, monetizing the value chain and squeezing OEMs margins in the process. This thesis has often highlighted the importance of offering an integrated service to the customer, both through a bundled offer and by creating an “EV Ecosystem”. The current state of the market is therefore a race between OEMs, Energy Providers and Mobility companies to be able to offer an integrated package. This explains why OEMs are not the only companies vertically integrating into charging, but energy companies such as Shell and Enel are doing the same downwards.

To interviewee 2 instead, the home charger represents foremost an opportunity to remain close to the customer in the long run, through the connectivity services offered by smart chargers. Interviewee 3 also mentions the charger as a way of retaining touchpoints with the customer, but then dives into more strategic reasons, highlighting the control a charger can give to an OEM over charging and therefore both over EV and energy provision.

### 5.7.2 Question 2 analysis

The second question delves into the reasons why a customer would want to buy a charger from Toyota rather than any other company. Interviewee 1 mentions the quality that is assured by the testing and approval phase carried out by Toyota when selecting suppliers, but also the convenience of the bundle offer with the EV. Interviewee 2, 3 and 4 instead start by affirming that Toyota’s charging station offer should ideally be competitive on its own,

through a price coherent with market expectations, and in combination with a leasing offer. Interviewee 3 mentions the high quality of Toyota's aftersales service as a reason for consumers to purchase the charger, and the idea is reinforced by Interviewee 2, highlighting that having a solid charger backend which offers peace of mind can be key for customer retention. Interviewee 4 underscores the opportunity that comes from offering an integrated service. Indeed, purchasing an EV comes with a lot of complexities, such as different Apps for different features like monitoring charging and battery, finding and sharing chargers, monetization. If all these services are purchased from a single OEM, then the OEM can offer a single integrated App, which is strongly beneficial to the customer.

### 5.7.3 Question 3 analysis

Question 3 is related to the correlation between selling chargers and experiencing an increase of EV adoption by an OEM. Interviewee 1 mentions how the charger can have an active role in tackling range anxiety, which is a main barrier of adoption of EVs, although government grants and incentives are likely to play an even greater role. According to interviewee 2 instead, the sale of chargers can lead to an increased adoption of Toyota EVs but in the long term, as long as the service offered through the connected and aftersales services are convenient and offer a good customer experience. Interviewee 3 and 4 are more skeptical regarding a direct correlation and see the charger as a mere piece of the EV ecosystem, albeit a key one.

### 5.7.4 Overall correlations from the interviews

The answers provided by the 4 TME employees offer some key insights into how different departments and roles prioritize and make decisions in the company. To clarify, in Toyota, Interviewee 4 (Department Head) is in a higher position than the rest, followed by Interviewee 1 (Senior Manager), and then by 2 and 3 (Manager/ Project Manager). Interestingly, Interviewee 1 and 4 have a more strategic approach and both talk about competition (energy providers) and the risk of OEMs seeing their margins squeezed in the future. Interviewees 2 and 3 instead have more operational roles as they are more directly involved with the actual

products, and therefore devote more effort into explaining the opportunity created by home chargers, through the backend and customer service. This reflects the different priorities held at different positions.

On the other hand, interviewee 1 and 2 belong to the same department (Aftersales) and 3 and 4 to another (EV Planning). In fact, the interviewees from EV Planning both mention the ability to offer an EV ecosystem as being key in ensuring competitiveness, and the charger as being a sole part of this ecosystem. The employees from Aftersales instead see the charger more as an accessory (as it is being treated in the department).

## 6 Discussion & Conclusion

This thesis started with a clear scope: to offer a methodology aimed at understanding the correlation between an automaker's addition of EV charging stations in their line-up, and customer adoption of their EVs. The 4 different hypotheses were directed at deconstructing this complex topic first into the role played by range anxiety, how it's influenced by EV diffusion and its impact on consumer EV adoption, concluding with the effect an EV home charger can have. The 4<sup>th</sup> hypothesis then tied this effect to the home charger offer of a specific carmaker, looking at a car owner's interest in brand consistency and potential correlation between charger and EV adoption from the same carmaker. These hypotheses are consumer centric, which is why a survey with European consumers as target audience is to be used as method of data gathering. One flaw of the method presented in the Thesis is that other aspects such as Government incentives and average income are largely ignored, although they most likely have an impact on EV adoption. An extensive analysis on the topic should therefore also consider these differences between European countries.

This project isn't solely limited to clarifying the impact of home chargers on consumers, however. The thesis title specifically asks "how" an OEM can support its EV sales with charging stations. 4 Toyota Motor Europe managers from 2 different departments were interviewed, with the objective of understanding the strategic role of chargers from a carmaker perspective. This mode of investigation had a more qualitative approach, unlike the survey. Thanks to the interviews it was understood that, from a carmaker's viewpoint, a home

charger not only represents a key component of the EV ecosystem which can ensure greater customer service and in return customer retention, but it's also a reaction OEMs are having due to changes in the mobility sector. It's a reaction to energy companies which, pairing up with mobility companies (offering car leases for instance), can offer a complete package from energy generation and provision, all the way to recharging and vehicle leasing. This means that car manufacturers are no longer able to monetize the full automotive value chain, but only vehicle manufacturing, which significantly decreases turnover potential compared to the present-day situation. An extreme vision of this dynamic would entail that OEMs no longer sell directly to end customers, but only to energy/mobility companies, giving the latter monopsony power. Considering this competitive threat, it is no wonder carmakers are striving to vertically integrate upwards into EV recharging and assumedly, energy generation (as already shown by Tesla with its solar panels offer).

There are links between the information provided by the respondents and the Toyota Managers that were interviewed. For instance, Italian respondents reacted positively when asked whether a carmaker should include chargers in their line-up, and whether a bundle offer would be of interest to them. This is in line with the goal of creating an inclusive experience which is often cited by the interviewees when referring to the EV ecosystem. An inclusive package integrating EV and charger would help respondents relieve their range anxiety and is therefore linked with increased adoption derived from an improved customer experience. Of course, an EV ecosystem also requires other aspects such as connectivity between its components, but the bundle offer certainly represents an attractive offer for consumers, and this is something both the survey respondents and internal interviewees can agree on.

There were also some differences between the information gathered from Toyota and externally. For example, respondents' data seemed to point at a positive correlation between a carmaker offering chargers and their EV adoption, something the Toyota interviewees discredit, largely stating that including chargers in the offer will not have a big impact on a carmaker's EV sales. Surely, offering a charger can help a carmaker build a successful EV ecosystem, which is likely to increase customer retention in the long term due to positive customer experience, but this correlation does not seem to be the prior reason for a carmaker

to include chargers, according to the interviewees. For an in depth analysis of the topic, it would be insightful to interview employees from other companies than Toyota, and possibly even from energy and mobility companies to understand their point of view and the role the home charger plays in their strategy.

In conclusion, the next and last paragraph is dedicated to answering the thesis' title directly.

*How can selling EV Charging Stations support an automaker with increasing adoption of its electric vehicles in Europe?*

To answer this question properly, the method here presented should be adopted at a much larger scale, including other European countries from different adoption and diffusion levels, but the data from Italian respondents can at least offer a glimpse of the answer. From the results gathered in the Thesis, the answer to the title is: it can't, at least not directly. The problem with the title is that it's inquiring about only a side of the story, and this became clearer throughout the project. The main objective of offering EV chargers for a carmaker is not to increase the appeal of its electric vehicles, although offering a strong integrated customer service embodied by an EV ecosystem can surely increase customer retention and repeated purchase. The objective of OEMs is to remain competitive in a world that is changing and be able to monetize the new automotive value chain created by the rise of EVs. The survey analysis confirms that, although consumers reacted positively to home chargers and the impact on range anxiety is positive, the importance of brand consistency between vehicle and charger is weak. Consumers on average want their charger to reflect the same characteristics as their car (mainly reliability) and want their car brand to sell chargers, but this if anything would increase adoption of a carmaker's chargers, not its EVs. All in all, there is no sign of a strong correlation between an OEM selling chargers and adoption on its EVs. The conclusion is that, even if there is a correlation between a carmaker offering chargers and their EV adoption, it is likely not due to brand consistency but rather to a solid customer service and complete EV ecosystem that increases customer retention, the home charger here is a mere component of this ecosystem. Increasing adoption of their EVs does not explain the vertical integration OEMs are going through, but this is also a hypothesis which should be confirmed by a larger and more in-depth research at European level.

The method presented in this Thesis was successful at deconstructing this complex issue and identifying the key elements and hypotheses to be tested. It can be improved by taking into account Government Incentives and average income in each country, by analyzing a larger sample reflecting European countries without geographical biases and by interviewing employees in different OEMs and energy/mobility companies.

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## 8 Appendix

### APPENDIX 1: Survey screenshots

Survey in English fully screenshot. Last two pictures show the first page of the Italian and Polish language survey. Question order and type is the same throughout the different languages.

# Home Charger for Electric Vehicles



Hi, as part of my master thesis I would like to understand your perspective on Home Chargers. A Home Charger is a device which can be installed in a garage or private parking, against the wall or on a pole, and charges the vehicle about 3 times faster (6 to 8 hours) than charging through a house socket. Cost for these products can range from 400€ to more than 1200€.  
P.S.: This survey contains a completion code for SurveySwap.io

Image title



How old are you? \*

- 0-10
- 10-20
- 20-30
- 30-40
- 40-50
- 50-60
- 60-70
- 70-80
- More

What country are you from? \*

1. Afghanistan
2. Akrotiri
3. Albania
4. Algeria
5. American Samoa
6. Andorra

Which type of car do you own / drive most often? \*

- Gasoline car
- Diesel car
- GPL / LPG
- Methane
- Electric Hybrid (HEV: no outside recharge)
- Electric Hybrid (PHEV: with outside recharge)
- Fully electric (BEV)
- I never drive a car
- Other...

To what extent is the issue of not finding enough charging points stopping you from purchasing an electric vehicle as your next car? \*

1 2 3 4 5 6 7 8 9 10

I don't mind that at all           It's the major issue

What are the main reasons you are skeptical about purchasing a fully electric car next? (Select one or more) \*

Range (in Km)

# Home Charger



Assuming you have a private parking which gives you the possibility to install a Home Charger.

How much more reassured would you feel about owning an electric vehicle if you had a Home Charger which can recharge your car when at home? \*

1 2 3 4 5 6 7 8 9 10

Not reassured at all           Completely reassured

Could you explain why?

Long answer text

How important is it to you that the Home Charger be of the same brand of your vehicle? (ignoring any compatibility issue) \*

1 2 3 4 5 6 7 8 9 10

Not important at all           Very important

How much more likely are you to buy an electric car from a certain carmaker if a Home Charger (price: 800€) is INCLUDED in the price of the car? \*

1 2 3 4 5 6 7 8 9 10

How much more likely are you to buy an electric vehicle from a certain carmaker if it sells home chargers as well? \*

1 2 3 4 5 6 7 8 9 10

Nor more likely at all           Much more likely

What are the first words that come to your mind when you think of your current car and its brand? \*

- Luxurious
- Comfortable
- Reliable
- Economical
- Fuel-efficient
- Decent
- Other...

How important to you is that your Home Charger reflects the same characteristic? \*

1 2 3 4 5 6 7 8 9 10

Not important at all           Very important

- Economical
- Fuel-efficient
- Decent
- Other...

How important to you is that your Home Charger reflects the same characteristic? \*

1 2 3 4 5 6 7 8 9 10

Not important at all           Very important

An advantage of owning a fully electric car is that through a Home Charger you can charge the vehicle in the comfort of your home without going to a station, how much does this additional benefit matter to you? \*

1 2 3 4 5 6 7 8 9 10

Not at all           A lot

Do you have some additional comments?

Long answer text

## Ładowarka domowa do pojazdów elektrycznych

Cześć, w ramach mojej pracy magisterskiej chciałbym zrozumieć Twoje spojrzenie na ładowarki domowe. Ładowarka domowa to urządzenie, które można zamontować w garażu lub na prywatnym parkingu, na ścianie lub na słupie i ładuje pojazd około 3 razy szybciej (6 do 8 godzin) niż ładowanie z gniazdka w domu. Koszt tych produktów może wynosić od 1840 złotych do ponad 5520 złotych.

\* Required



## Caricatore Domestico Per Auto Elettriche

Ciao! Per la mia tesi di laurea magistrale vorrei capire il tuo punto di vista sui caricatori domestici per auto elettriche. Questi sono dispositivi che possono essere installati in un garage, box o parcheggio privato, su una parete o su un palo, e possono ricaricare la macchina circa 3 volte più velocemente rispetto alla ricarica tramite presa domestica (6/8 ore circa). Il costo di questi caricatori può variare da 400€ a più di 1200€.

\* Required



## APPENDIX 2: Interviews

### **Interviewee 1: Vincent Tabel, Senior Manager in Aftersales, Toyota Motor Europe.**

*1. What are the main reasons an OEM would want to sell charging stations in your opinion? Is it just for additional revenue?*

Direct revenue and profit can be good reasons. But it's also important to retain the customer, if you leave the customer buying another wallbox from say, an Energy Provider, they will acquire customer data, build a relationship with the customer and then try to sell them an EV (some energy providers rent out EVs). This creates the risk that in the future he (the customer) will buy from an energy provider instead, who already has an advantage today due to offers linked with energy provision.

*2. Why should a customer (owning a Toyota/ any OEM) buy a charger from Toyota rather than a different company?*

Quality is definitely a reason, all products we sell need to be approved, including the wallbox. The bundle offer makes it easier for a customer to purchase the wallbox, and this can create piece of mind.

*3. Do you think that selling chargers can help Toyota/any OEM increase their sales of electric vehicles? How?*

The biggest issue for EVs is range and availability of chargers, so if you have the charger at home you can reduce range anxiety. However, it will be Government grants and taxation which will push this (EV Sales) to a larger extent.

### **Interviewee 2: Peter De Co, Manager in Aftersales, Toyota Motor Europe.**

*1. What are the main reasons Toyota would want to sell charging stations in your opinion? Is it just for additional revenue?*

A charging station can enable Toyota to stay close to the customer. Through the Wallbox backend services you can stay connected to the customer in the long run, maximizing value throughout vehicle lifetime.

*2. Why should a Toyota owner buy a charger from Toyota rather than from a different company?*

Our offer should be competitive in the market and that's what we strive for. Secondly, there is a direct link between customer and Toyota in terms of servicing, and a Toyota owner will have contacts with the dealer and network. Again, the backend of the charger is key, as it can represent an additional connection between dealer and customer, allowing to deliver the best possible solution. A Toyota owner will be more likely to purchase a Toyota charger if the company has been successful at establishing a relationship, but also if it's able to offer convenience and peace of mind.

*3. Do you think that selling chargers can help Toyota increase sales of its electric vehicles? How?*

It can, if we offer a package with reliable backend that provides added value to the customer. We also need to have very good foundations that provide real peace of mind to customers, and here the Wallbox and its backend play a role. If these requirements are fulfilled then it could result in additional EV sales, especially in cases where the customer has had a good experience in the long run using the services, in that case they will likely buy another one (EV). Supplying a robust offer is key, including the EV but also additional components like the Wallbox and its backend. This will mean he (the customer) goes back to same brand, which supports customer retention.

**Interviewee 3: Despoina Chatzikyriakou, Project Manager in EV Planning, Toyota Motor Europe.**

1. *What are the main reasons Toyota would want to sell charging stations in your opinion? Is it just for additional revenue?*

There are several reasons. Revenue is the most important if you think of chargers in the sense of an accessory. Customer service is also a reason, customers prefer to obtain everything from car seller, and chargers allow us to retain touchpoints with the customer.

Another reason is strategic, with the new role of charging at home, every person with an EV charger becomes a more active user. Energy utility and charging are very regulated, and the charger is a way to control the charging of the car, so whoever can control charging has the ability to increase revenue. It is key that we are represented in this market integrated with energy utility. Charging at home also gives flexibility, and flexibility has an important market.

2. *Why should a Toyota owner buy a charger from Toyota rather than from a different company?*

If done properly, it can be included into leasing programs, lowering the price offer and making it more competitive. Second, in case there is a problem with a charger Toyota needs to offer solid customer support, and Toyota has a good reputation with Aftersales operation.

3. *Do you think that selling chargers can help Toyota increase sales of its electric vehicles? How?*

Not directly. When it comes to EVs, it's barely about the car but about the ecosystem. The charger is just a part of this ecosystem, connectivity is another as the customer wants to easily recharge the car and be connected. Selling the charger is the bare minimum an OEM can do, a successful company would sell you everything from the car, to the charger, to batteries and potentially to solar panels.

**Interviewee 4: Ian C. Smith, Head of EV New Business Development, Toyota Motor Europe.**

1. *What are the main reasons Toyota would want to sell charging stations in your opinion? Is it just for additional revenue?*

EV profit margins are smaller than HV (Hybrids, represent a large share of Toyota vehicle sales in Europe), and therefore we need to sell charging and solar to make up for it. Energy companies today take care of energy generation, energy storage (batteries), home and en-route charging, flexibility and grid balancing provision. Energy Consumption goes up by 60% if we charge at home. Today in the automotive value chain OEMs monetize it all, but with EVs Energy provider companies take control of parts of the value chain. Some companies such as E.ON are already generating electricity, partnering with charging and mobility companies and leasing BEVs. Therefore, the big risk is that Energy and Mobility partnerships will squeeze OEMs in the middle

2. *Why should a Toyota owner buy a charger from Toyota rather than from a different company?*

Ideally, we would have a compelling offer. What most consumers don't like about EVs is the complexity involved with purchasing one, you need to have different apps for different things, like charging, finding chargers, monitoring your vehicle etc. Customers would appreciate a single app to do everything, and that's something an OEM can provide if it sells the EV, charger and connected services.

3. *Do you think that selling chargers can help Toyota increase sales of its electric vehicles? How?*

It wouldn't directly lead to a greater volume of sales but would surely improve the customer service.