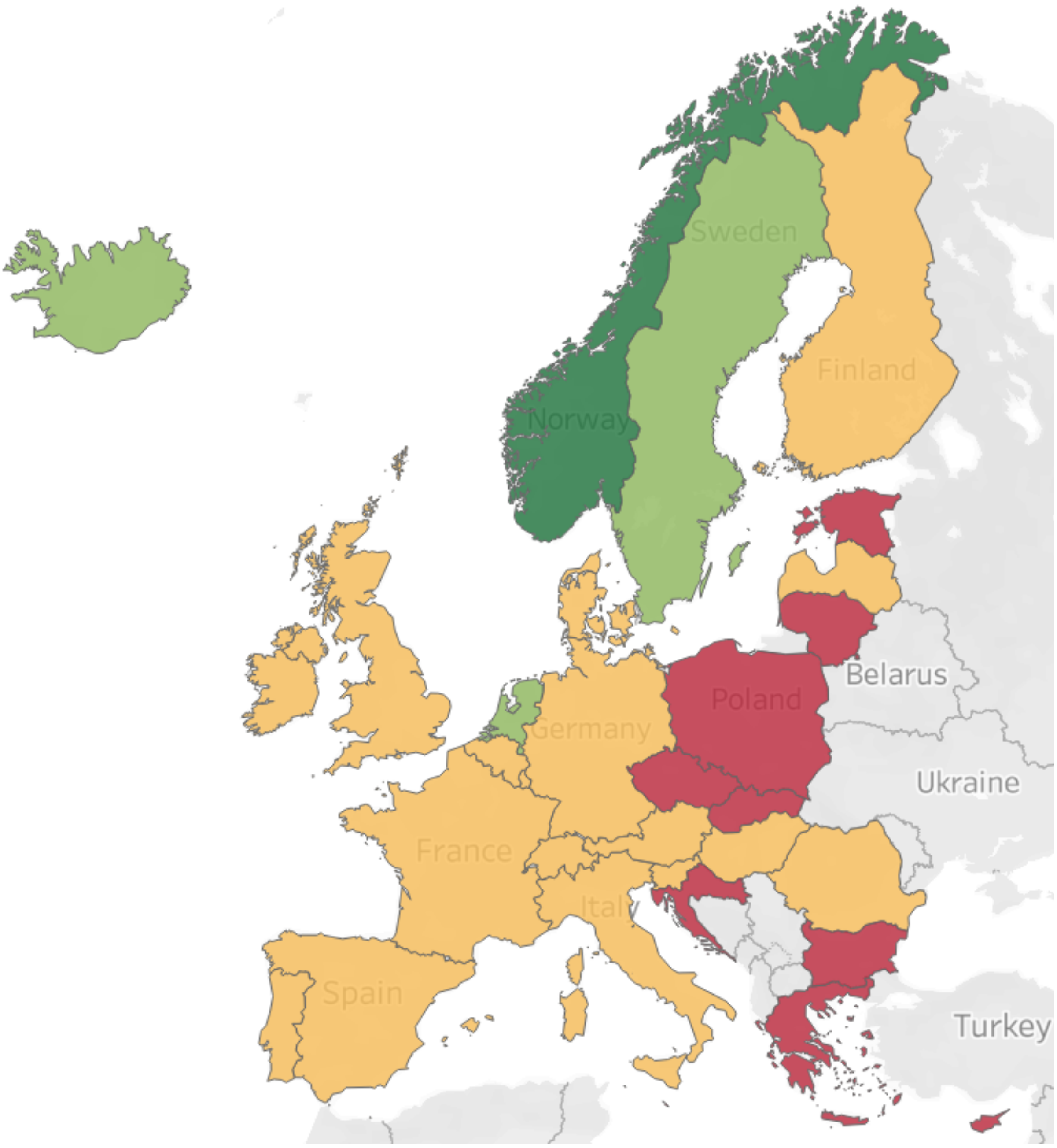
DELFT UNIVERSITY OF TECHNOLOGY

MSC THESIS

BY Steyn Muller

How do we get the adoption of electric vehicles into a higher gear in Europe?



TU Delft

How do we get the adoption of electric vehicles into a higher gear in Europe?

By

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Preface

This MSc thesis is my final work over the past year to complete the Master of Science degree in Management of Technology at Delft University of Technology. I have conducted research in, how, the adoption of electric vehicles can get accelerated in Europe.

The past year—working on this thesis—has been a challenging, ambitious and a rewarding experience. Challenging, because of the global pandemic forcing everyone to work isolated from home. Ambitious, because of taking on a research topic out of my comfort zone. And rewarding, because of everything that I have learned over the past year under the guidance of my supervisors Kornelis Blok and Enno Schröder.

My sincerest appreciation goes to their support, their positive detailed feedback on my work and elevating my research and my scientific writing to a higher level.

Steyn Muller
Den Haag, April 2022

Summary

The world is under the spell of the energy transition due to climate change. In 2015 197 parties agreed to the Paris-agreement, settings goals for limiting global warming. The transportation sector contributes for almost 25% of all global greenhouse gas emissions (GHG). A promising pathway to decrease emissions from fossil fuels in the transportation sector is to replace conventional internal combustion engines (ICE) with Battery Electric Vehicles (BEV).
This thesis analyses how the introduction of BEVs in Europe can be accelerated. Five countries were selected and categorised, based on Rogers' diffusion of innovation theory.
Based on a literature analysis, the factors influencing the adoption of the BEV were identified and selected. From these factors, an analytical research model was created. This analytical research model was applied to each country in order to compare the countries and draw conclusions. The analytical model consisted of the factors: government regulations and incentives, purchase price, total cost of ownership, charging infrastructure, model availability, consumer characteristics and BEV adoption.
The study concluded that governments have two tools to stimulate the BEV adoption: make the BEV cost effective compared to the ICE and stimulate the charging infrastructure. If it is financially more attractive to drive a BEV in a country than an ICE, this will have a major impact on BEV adoption. Making the BEV financially attractive can be done with tax measures and subsidies. In general, countries with relatively high car taxes can make BEVs more financially attractive than countries with relatively low car taxes, which results in a higher BEV adoption
In addition, a country must ensure that the charging infrastructure grows along with the BEV adoption. In general, it is a pre-condition to develop its slow charger network to stimulate BEV adoption. However, it depends on the country how the slow charger network should be set up. An indicator for this is the percentage of detached houses. If this percentage is high, a country must focus on private charging when setting up its slow charging network. With a low percentage of detached houses, a country must focus on public charging when setting up the slow charging network. Furthermore, it is expected that private parties will jump into the fast charging market. These private parties will only step in if a country has a relatively high BEV adoption, such as Norway and the Netherlands, because it is only then profitable. The study also shows that in countries with a large surface area, it is a precondition to develop its fast charging network. Therefore, when a country has a low BEV adoption, but a large surface, incentives are needed from the government to stimulate a fast charging network.
A financial attractive BEV environment and a well-developed charging infrastructure has as consequence in increasing the number of BEV models. When more BEV models enter the market in a country, consumers have more choice, and this has a stimulating effect on BEV adoption in a country.

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Acronyms

Table 1: Acronyms

Acronym	Description
AC	Alternating current. Normal power slow charging points are based on alternating current
AI	Artificial Intelligence
BEV	Battery Electric Vehicles
BIK	Benefit In Kind
CC	Consumer costs
CNG	Compressed Natural Gas
CPO	Charge point operator. Installs and maintains charge stations so drivers can charge their electric vehicles.
DC	Direct current. High power fast charging points are based on direct current
EFTA	European Free Trade Association. Is a regional trade organization and free trade area consisting of four European states: Iceland, Liechtenstein, Norway and Switzerland
EURO NCAP	European New Car Assessment Programme
EU	European Union
EV	Electric vehicles
FCEV	Fuel Cell Electric Vehicle
G	Difference in carbon dioxide emissions
GDP	Gross domestic product is the total monetary or market value of all the finished goods and services produced within a country's borders in a specific time period
GHG	Greenhouse Gas Emissions
HEV	Hybrid Electric Vehicle
ICE	Internal Combustion Engine
LPG	Liquefied Petroleum Gas
ML	Machine learning
MPV	Multi-Purpose Vehicle
NECP	National energy and climate plan
PHEV	Plug-in Hybrid Electric Vehicles
SUV	Sports Utility Vehicle
SWOT	Strengths, Weaknesses, Opportunities, and Threats
VRI	Vehicle to Refueling Index. The ratio of refueling stations per 1000 vehicles, VRI for conventional cars at 0.3 for Germany and 1.8 for Sweden.
WTP	Willingness to pay

Introduction

1 Introduction

1.1 Introduction to the research question

The world is under the spell of the energy transition due to climate change (Goldthau,2017). In December 2015, to tackle climate change, 197 parties adopted a legally binding international treaty on climate change, the so-called "Paris Agreement." Its goal is to limit global warming to well below 2 °C, preferably 1.5 °C, compared to pre-industrial levels. To achieve this long-term temperature goal, countries aim to reach global peaking of greenhouse gas (GHG) emissions as soon as possible to achieve a climate-neutral world by mid-century (UNFCCC,2015).
The European Union (EU), the world's third-largest emitter of GHG, recently presented the European Green Deal and plans to reduce emissions by at least 55% by the end of 2030. The aim of the European Green Deal is to make Europe the first continent to be climate neutral by 2050 (EU, 2019).
The transportation sector contributes almost 25% of all global (GHG) emissions (IEA, 2021).
A promising pathway to decrease emissions from fossil fuels in the transportation sector is to replace conventional internal combustion engines (ICEs) with electric vehicles (EV), coupled with decarbonized energy production (Priessner et al., 2018). Figure 1 presents sector wise distribution of greenhouse gas emissions.

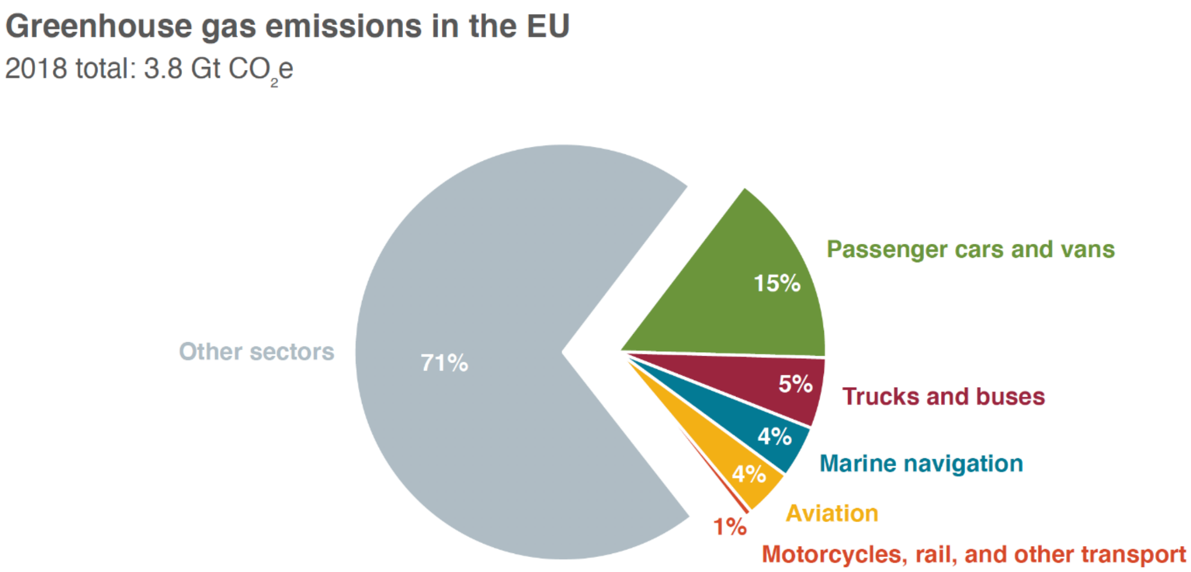


Figure 1: Greenhouse gas emissions in the European Union (EU)

EVs coupled with a low-carbon power supply have the potential to dramatically reduce transport emissions and contribute further to society's decarbonization (Zarazua De Rubens, 2019). The EU recognizes this potential for decarbonization. To meet the EU's energy and climate targets for 2030, all EU countries need to establish a 10-year integrated national energy and climate plan (NECP) for 2021–2030 (EU, 2019).
The Netherlands, for example, has said that all new passenger cars produced in 2030 must be electric to reduce carbon dioxide emissions by 49% compared to the pre-industrial era (Government, the Netherlands, 2020). As a result of this awareness, the market for EVs is growing. The EVs can be divided into battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), hybrid electric vehicles (HEVs), and fuel cell electric vehicles (FCEVs). This thesis refers only to the BEVs when "EV" is mentioned. Details about the different types of EVs and why only the BEV was selected are described in paragraph 1.4 "Type of electric vehicles".

Research in energy technologies, energy economics, sustainability, and transport policy has focused mainly on influences and underlying factors for (early) EV adoption. It focuses primarily on technological development, legislation, governmental policies, and socio-behavioral qualities of (early) adopters (Kumar et al.,2020).
The central barriers are cost (Noel et al., 2019), limited driving range, long charging times, lack of sufficient infrastructure (Ahmed et al., 2021), and availability of models (Krishna, 2021).
In literature, a predominant focus has been on comparing China, Europe, and the United States (Gersdorf et al., 2020). In Europe, many car manufacturers used to produce cars with a combustion engine, but due to the European Green Deal regulations, they are forced to invest heavily in EV scale-up and have already invested more than €30 billion in EVs (Gersdorf et al., 2020).
However, some countries in Europe are doing better in terms of EV scale-up than others. Norway became the first country in the world where the sale of electric cars has overtaken that of ICE vehicles. The Netherlands and Germany contribute almost half of the total EV market growth in Europe (Wappelhorst, 2021). Other European countries, such as Greece and Poland, contribute relatively little to the upscaling of EVs in Europe (Wappelhorst, 2021). There are, thus, significant differences in the adoption rate of EVs within Europe.
To meet the Green Deal goal that, in 2050, all new cars should have zero GHG emissions, Europe stands against a major challenge and needs to accelerate EV adoption (EU, 2019). However, if EVs are to contribute to the decarbonization of transportation successfully, they must reach mainstream consumer segments (Zarazua, 2019). The literature recognizes the importance of accelerating EV adoption but fails to indicate the factors that will contribute to the accelerated EV adoption (BCG, 2021). In this thesis, the central barriers will be quantified as far as possible and they will be compared between the five identified well and poor performing “ EV adopting” European countries, in order to identify factors which could help to get the adoption of EVs into a higher gear in Europe.

1.2 Knowledge gap

To reach the EU goal of “at least” 30 million zero-emission vehicles in the EU by 2030, each European country has its own national approach.
Extensive research, described in the literature review, has been performed to identify the factors influencing the early adoption of EV’s.
Much research has also been carried out on interrelating or influencing factors from economic, technological, geo-demographic, and psycho-social behavioral points of view on national and international levels.
The main consumer characteristics are defined as income, willingness to pay, range anxiety, and car preference. The governmental influences are financial and tax incentives and local policies giving preferences to EV users. On national and international levels, EV adoption is mainly influenced by the purchase price, total cost of ownership, the charging infrastructure, and model availability.
The recent literature has shown a shift to research on better understanding how to reach the mainstream EV adopters, which represent the majority of EV adopters, instead of the early EV adopters. To reach the goals set in the Paris Agreement and the European Green Deal, the world needs a faster move to cross the chasm to reach the majority of adopters. However, knowledge gaps on this topic exist.
Most of the current research has focused on well-performing countries, such as China and Norway. Some countries, especially in Europe, are performing better than others in terms of the EV adoption rate.
A clear understanding of the relationship between EV adoption and the incentives per country is needed. There is a lack of understanding of the influence between the independent variables and the moderating and socio-demographic variables based on geography and existing scenarios, such as electricity-generation mix, policies, infrastructure, and so forth. In this perspective, knowledge gaps exist regarding a clear understanding of which factors of each EU country significantly influence the adoption of EV for the later adopters.

1.3 Research question

Many researchers have focused on a better understanding of the underlying factors that drive or hinder early EV adoption on national and international levels. Research was performed predominantly in well-performing countries, which are frontrunners in EV adoption.
Some of the recent literature shows via interviews, the main consumer characteristics in relation to financial incentives. (Gómez Vilchez et al., 2019; Kunle et al., 2020). Quantifying research in the specific financially driven policy mechanisms in European countries in different EV adoption phases stays behind.
A research question was formulated with accompanying sub-questions to address this knowledge gap.

The research question is as follows:
How can the BEV adoption in Europe be accelerated?

A set of sub-questions was formulated to accurately answer the main research question:

1. What is the adoption rate of BEVs in Europe?
2. What are the factors influencing the BEV adoption rate?
3. How do these factors differ among countries?
4. What are the characteristics of well- and poor-performing European countries?
5. How can the upscaling of EV adoption be accelerated at a European level?

Sub-question 1:	This sub-question provides a starting point for the comparative study. It is important to indicate the current EV adoption rate in Europe and the five selected case countries. It is also important to collect information about the European passenger car fleet distribution.
Sub-question 2:	Extensive literature has indicated the factors or antecedents that are drivers of or barriers to EV adoption. This thesis identifies the factors that have influenced the EV adoption rate until now.
Sub-question 3:	It is crucial to identify the drivers of and barriers to EV adoption per case country. These factors will help identify the differences and similarities between the case countries.
Sub-question 4:	When the characteristics of the well- and poor-performing countries are known, one could draw conclusions and recommendations for these case countries.
Sub-question 5:	The outcome of the 5 different comparing countries, will give an answer how the upscaling of EV adoption be accelerated at a European level, reaching the goals set in the Paris Agreement and the European Green Deal.

1.4 Type of electric vehicles

An EV is an automobile powered entirely or partially by electricity from a rechargeable battery.

1.4.1 Battery electric vehicles (BEVs)

BEVs are vehicles fitted with a rechargeable battery as the sole power source. These vehicles have no gasoline engine at all. BEVs store electricity onboard with high-capacity battery packs. Their battery power is then used to run the electric motor and onboard electronics. BEVs are charged by electricity from an external power source, with their chargers classified according to the speed at which they recharge a battery. Due to the absence of an ICE, BEVs do not emit any harmful emissions at all.

1.4.2 Plug-in hybrid electric vehicles (PHEVs)

The PHEV combines a battery and electric motor with an economical petrol or diesel engine. As can be deduced from the name, PHEVs can be recharged by plugging into an external electricity source. In addition, They can also be powered by their onboard engines and generators, and they are able to substitute electricity from the grid for gasoline. In a PHEV, the onboard battery is usually much smaller and has a lower capacity than those found in all-electric cars, meaning that PHEVs cannot drive too far on electricity alone, requiring the combustion engine to eventually kick in.

1.4.3 Hybrid electric vehicles (HEVs)

HEVs are powered by both fossil fuels and electricity. In an HEV, electricity is generated by the car's braking system and used to recharge the battery. This process is known as "regenerative braking," whereby the electric motor helps to slow down and bring the vehicle to a stop using some of the energy normally converted to heat by the brakes. HEVs start their journeys using the electric motor. Then the ICE engine steps in as the load or speed rises. HEVs are quite similar to PHEVs, except they cannot be plugged in, generating electricity only via regenerative braking.

1.4.4 Fuel cell electric vehicles (FCEVs)

The FECV gets its electricity from a hydrogen fuel cell instead of a battery. It combines hydrogen and oxygen to produce electricity (to propel the vehicle) and water (by-product). As this chemical process powers hydrogen fuel cell cars, they do not need to be recharged and can be driven as long as a supply of hydrogen fuels them. Filling the car can take less than five minutes, with the average range of hydrogen fuel cell cars at around 450–550 km.

1.4.5 The focus of the thesis

This thesis focuses on the BEV of all the different EV types. The most promising future perspectives lie in the BEV and FCEV (Un-Noor et al., 2017) because a BEV or FCEV is a 100% zero-emission vehicle. The advantage of an FCEV is that it is filled with hydrogen within a few minutes and can be driven a longer distance compared with a BEV. However, the BEV has had a head-start on technology development and is, therefore, more accepted by the wider public (Fang, Shao, & Li, 2020).

1.5 Reading guide

The thesis consists of eight chapters and an appendix for background information.
After the preface and the summery, chapter 1 starts with the introduction, followed by a literature overview described in chapter 2.
The literature overview gives a summary of the literature on BEV adoption, from 2016-2021 and introduces the knowledge gap, which is reflected in the research questions, on which this research thesis is based on.
In chapter 3 the theoretical background is described. Based on the Diffusion of the innovation theory of Rogers and the conceptual nomological framework of Kumar, an analytical model is formulated.
In chapter 4 the methods are described and in chapter 5 the results are presented in analytical and qualitative models. The intent of Chapter 5 is to answer sub-question 1,2 and 3. In Chapter 6 the results are discussed, in relation to answer sub-question 4 and in Chapter 7 the conclusions and advise are formulated, with the intention to give an answer to the remaining sub-question 5.

2 Literature review

The adoption of EVs can be approached from numerous points of view. For this literature review, Elsevier Science Direct, Google scholar, and grey literature via Google were used to select scientific papers. The following key terms were used: electric vehicle, adoption, acceleration, and Europe. Articles published between 2016 and 2021 were selected. Researchers have applied various models and frameworks, from survey-based studies (Sovacool et al., 2018), choice experiments (Noel et al., 2019), integrated review studies, bivariate statistical analysis (Sovacool et al., 2019) to machine learning (ML), and artificial intelligence (AI; Bas et al., 2021; Achmed et al., 2021).

Many researchers have explored the technical challenges and barriers EVs face for wide-scale implementation, such as the battery capacity, the driving range, the time for fast charging, and the existence of the optimal recharging network (Künle et al., 2020; Chen et al., 2017; Berkeley et al., 2018; Bas et al., 2021; Ilieva et al., 2021; Balali et al., 2021; Habla et al., 2021; Mandys, 2021; Hoeft, 2021).

Other literature has explored social, political, and market aspects of EV adoption. These aspects range from taxation and policy incentives to consumer acceptance (Zarazua De Rubens, 2020; Nayum et al., 2016; He et al., 2018; Manca et al., 2020; Huang et al., 2021; Wang et al., 2018). Literature that explores the consumer acceptance of EVs and the determinants of purchase is vast and focuses on the profiles of EV owners and driving factors behind EV purchases (Zarazua De Rubens, 2020; Künle et al., 2020; Priessner et al., 2018; Lee et al., 2021; Kumar 2020; White et al., 2017).

Extant literature confirms that EV-buying behavior could be influenced by multiple factors, such as vehicle purchase price (Zarazua De Rubens, 2019; Bas et al., 2021; Meisam Ahmadi Ghadikolaei et al., 2021; Balali et al., 2021; Mandys, 2021), willingness to pay (WTP) (Zarazua De Rubens, 2019), the total cost of ownership (Levay et al., 2017; Palmer et al., 2018), driving experience (Skippon et al., 2016; Berkeley et al., 2018), range anxiety and charging infrastructure availability (Berkeley et al., 2018; Wolbertus et al., 2021; Ilieva et al., 2021; Calearo et al., 2021; Wenig et al., 2019), model availability in the used market (Krishna, 2021), social influence (Schuitema et al., 2013; White and Sintov, 2017), and environmental awareness (Smith et al., 2017; Ahmed et al., 2021; Mckinsey @Company, 2019; Jansson et al., 2017; Huang et al., 2021).

The literature has identified early adopters of EVs as individuals of middle-to-high income and age, typically men, with graduate or postgraduate degrees practically irrespective of geography (Zarazua de Rubens et al., 2019).

Kumar et al. (2020) performed an extensive literature review, examining 239 scientific papers, to synthesize and integrate EV adoption factors. They used an integrative qualitative review methodology and identified 23 independent variables. The three most studied independent variables were charging infrastructure, the total cost of ownership, and purchase-based incentive policies. The review drew attention to relatively neglected topics such as the availability of EV models and dealership experience, charging infrastructure resilience, and marketing strategies. Mechanisms of EV adoption was also clarified by highlighting the important mediators and moderators, such as gender, psychological characteristics, symbolic attributes, and perceived attributes. Converting the EV adoption barriers to motivators could be a challenge for governments and policymakers to improve the EV market share.

Additionally, the literature also reflects country-specific policies and ecosystems (Costa et al., 2021; Sovacool et al., 2019; Kester et al., 2019). In a comparative socio-cultural, technological, economic, political, and environmental analysis of EV adoption between France, Germany, and Norway, Kunle showed that Norway is the frontrunner and innovator and that France and Germany are early adopters. Direct monetary incentives for EV acquisition indicate a clear correlation among the selected countries (Kunle et al., 2020).

Gómez Vilchez reported results of a stated preference survey among 1,248 car owners in France, Germany, Italy, Poland, Spain, and the United Kingdom. They concluded that while the purchase price remained the crucial factor, country-specific socio-economic characteristics of consumers influenced their intention to buy an EV in Europe. The study reaffirmed the argument that incentives, especially government financial interventions, are likely critical in accelerating the widespread uptake of EVs, as European consumers still perceive EV prices to be too high (Gómez Vilchez et al., 2019).

A comparative study in several European countries (Portugal, the Czech Republic, Poland, Norway, Denmark, Spain, and Slovakia) showed that the economic payback is quite variable. It is essential to adopt policies within the EU to reach a more uniform reality among the different countries with more leveled prices and revenues (Costa et al., 2021).

To date, low-carbon transitions still have less success in passenger transport, as the petroleum-fueled mobility regime is deeply entrenched in most Western countries (Sovacool et al., 2019).

Statistics showed the EV fleet percentage of the total fleet in 2020 to be 11% in Norway, 2% in the Netherlands, 0.64% in Germany, 0,18% in Spain, and 0.03% in Poland (EAFO, 2021).

The Netherlands is ahead of most countries in the EV share in the total car park. France and Germany increased the sales percentage in 2020 much faster (RVO, 2021).

Model availability of EVs differs per country. For example, in Norway, one can buy only electric versions of the popular Volkswagen Up, whereas, in the rest of Europe, one may choose between an electric or conventional ICE model of the Volkswagen Up (Marklines, 2021).

Focusing on less-performing European countries, SWOT analysis of opportunities and threats has shown that the Polish market faces unstable and unclear regulations that may discourage producers and buyers. The EV price is much higher than that of conventional vehicles, and there are many unsolved issues with batteries and charging stations (Kowalska-Pyzalska et al., 2021).

Studies on consumer adoption of technologies have followed the Rogers framework of diffusions and innovations (Rogers 2003), categorizing consumers into stages of adoption: innovators, early adopters, early majority, late majority, and laggards (Zarazua De Rubens, 2019).

Specifically for EVs, studies have focused on the initial stages of innovation to identify the characteristics of early adopters and understand potential purchasing behavior to foster EV deployment (Langbroek et al., 2016; Lee et al., 2021). However, by definition, early adopters (13.5%) represent a minority of the market, and currently, even the global EV leader, Norway, totals only 11% of EVs on its national car fleet (Rogers,2003).

If Evs are to successfully contribute to the decarbonization of transportation, they must reach mainstream consumer segments. Using an ML model, Zarazua de Rubens identified the potential next wave of EV buyers across the five Nordic countries of Denmark, Finland, Iceland, Norway, and Sweden, showing that three consumer clusters, which account for 68% of the (sampled) population, are primed for EV adoption and represent the near-term mainstream EV market. Price is one of the main determinants in reaching these mainstream consumers, suggesting that vehicle-to-grid can contribute to EVs' attractiveness and uptake (Zarazua De Rubens, 2019).

The chicken-or-egg dilemma related to infrastructure could be the greatest bottleneck to facilitating a rapid transition to electric mobility (Wolbertus et al., 2021).

Ahmed et al. (2021) investigated the role of AI in a literature review focusing on the mass adoption of EVs. EVs still face major challenges that hinder rapid and widespread adoption due to limited driving range, long charging times, and insufficient charging infrastructure (Ahmed et al., 2021).

Broadbent performed an analysis of best practices and pitfalls in policymaking to accelerate the EV adoption rate. A key focus is the role of financial and soft incentives, like free parking or free access to toll roads, to encourage EV adoption and investment in information programs (Broadbent et al., 2017).

The Nordic region has close cooperation on a range of topics such as climate change and transportation and shares relatively strong climate policies (Kester et al., 2017). Kester et al. offered a comparative qualitative analysis of 257 semi-structured interviews across 17 cities in the Nordic regions to discuss the reasoning behind EV incentives and policy mechanisms. The following question asked was: What policy mechanisms can further accelerate the transition of electric mobility and vehicle-to-grid technology? They emphasized that strong and stable national targets accompanied by purchase price incentives and flexible local secondary benefits, in addition to more attention towards awareness and consumer information campaigns, are needed to promote EVs.

The existing literature focuses mainly on consumer characteristics in relation to financial incentives, by interviews. (Gómez Vilchez et al., 2019; Kunle et al., 2020). Quantifying research in the specific financially driven policy mechanisms in European countries in different EV adoption phases stays behind.

3 Theoretical background

3.1 Adoption of an innovation

In this thesis, the Diffusion of Innovation framework, according to Rogers (2003), is used. The diffusion of innovation explains the process in which an innovation (ideas or technology) diffuses through communication channels across a population. Rogers claims that even if a new idea is explicitly advantageous, innovation will still take years to be widely adopted, since it is a process whereby some people are more likely to adopt the innovation, which consequently can be an issue in speeding up the adoption of innovation.

Adoption means that a person is doing something differently (i.e., buying or using a new product; Rogers,2003). The key to adoption is explained via 5 characteristics of the innovation.

Is the innovation a relatively advantage? Is it compatible with the user's lifestyle? Is it difficult to learn? Is it easy to try? Is the innovation visible? So how attractive is the new product and easy to use? Diffusion is referred to as the rate of adoption, gaining momentum and spreading through a population (Rogers,2003). The result of diffusion is that the people, as part of a social system, adopt the innovation.

The time element in the diffusion process allows classifying adopter categories and drawing diffusion curves. This adopter categorization is not symmetrical in that there are three adopter categories to the left of the mean and only two to the right. The adoption of innovation usually follows a normal, bell-shaped curve when plotted over time on a frequency basis. If the cumulative number of adopters is plotted, the result is an *S*-shaped curve.

The *S*-shaped adopter distribution rises slowly at first when there are only a few adopters in each period. The curve then accelerates to a maximum until half of the individuals in the system have adopted. The *S*-shaped diffusion curve begins to level after half of the individuals in a social system have adopted. The part of the diffusion curve from about 10% adoption to 20% adoption is the heart of the diffusion process. After this point, it is often impossible to stop the further diffusion of a new product or service, even if one wishes to do so. The *S*-shaped curve describes only cases of successful innovation in which an innovation spreads to almost all of the potential adopters in a social system. Certain innovations do not display an *S*-shaped rate of adoption; for example, the new idea is applicable only to certain unique population groups.

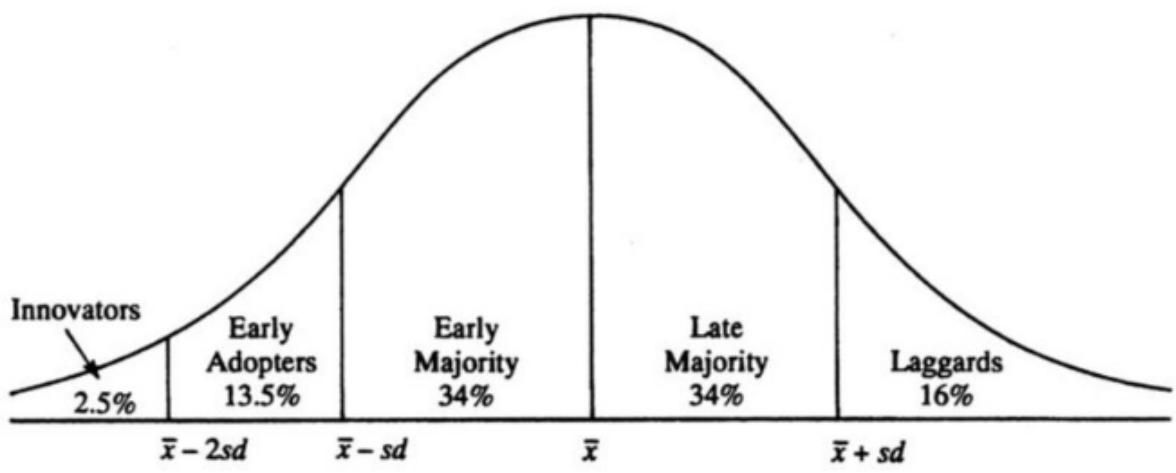


Figure 2: Adopter categorization based on innovativeness (Rogers, 2003)

3.2 Adopter categorization, according to Rogers

3.2.1 Innovators: Venturesome

"Venturesomeness" is almost an obsession with innovators. This group is characterized as risk-taking. They are part of a group. Distance is not an issue (cosmopolitans). They are relatively rich, well-educated, and intelligent and can also handle uncertainty and possible losses well (partly because they are relatively rich). They understand and can apply complex technical issues. Finally, innovators often receive little respect from the local community. The innovator plays a gatekeeping role in the flow of new ideas into a system.

3.2.2 Early adopters: Respect

Early adopters are a more integrated part of the local social system than are innovators. This group consists of locals. They have the highest degree of opinion leadership in most systems. Potential adopters look to early adopters for advice and information about an innovation. They serve as a role model for many other members of a social system. They help trigger the critical mass when they adopt an innovation. They decrease uncertainty about a new idea by adopting it and then conveying a subjective evaluation of the innovation to near-peers through interpersonal networks. In a sense, early adopters put their stamp of approval on a new idea by adopting it.

3.2.3 Early majority: Deliberate

The early majority adopt new ideas just before the average member of a system. The unique location between the very early and the relatively late adopters makes them an essential link in the diffusion process, and they constitute one-third of all members of a system. They deliberate for some time before completely adopting a new idea (indicating a long decision time).

3.2.4 Late majority: Skeptical

The late majority adopts new ideas just after the average member of a system. They are also one-third of all members of a system. The adoption can be of economic necessity or a result of increasing peer pressure. Innovations are approached with a skeptical and cautious mindset. They do not adopt until most others in their system have already done so. Peer pressure is necessary to motivate adoption among them. Their relatively scarce resources mean that most of the uncertainty about a new idea must be mitigated before the late majority feels safe to adopt.

3.2.5 Laggards: Traditional

The Laggards are the last in a social system to adopt an innovation. They possess almost no opinion leadership and are the most local of all adopter categories in their outlook. Many are near isolates in the social networks of their system. The point of reference for the laggard is the past. Laggards tend to be suspicious of innovations and change agents. Resistance to innovations on the part of laggards may be entirely rational from their viewpoint. Their resources are limited, and they must be certain that a new idea will not fail before adopting. The laggard's precarious economic position forces the individual to be highly cautious in adopting innovations.

3.3 Generalization of adopter categorization

The earlier and later adopters of innovations differ in socio-economic status, personality variables, and communication behavior, meaning that different communication channels or messages are used to reach the five adopter categories.

3.3.1 Socio-economic status

Earlier adaptors, as compared to later adopters, are homogeneous in age, have more years of formal education, are more likely to be literate, have a higher social status (income, level of living, wealth, occupational prestige, self-perceived identification with a social class), have a greater degree of upward social mobility, and have larger-sized units (farms, schools, companies, etc.).

3.3.2 Personality variables

Earlier adaptors, as compared to later adopters, have greater empathy, may be less dogmatic, have a greater ability to deal with abstractions, have greater rationality, have more intelligence, have a more favorable attitude toward change, are better able to cope with uncertainty and risk, have a more favorable attitude toward science, and have higher aspirations (for formal education, higher status, occupations, etc.).

3.3.3 Communication behavior

Earlier adaptors, as compared to later adopters, have more social participation, are more highly interconnected through interpersonal networks in their social system, are more cosmopolitan, have more contact with change agents, have greater exposure to mass media communication channels, have greater exposure to interpersonal communication channels, seek information about innovations more actively, have greater knowledge of innovations, have a higher degree of opinion leadership.

3.4 Conceptual nomological network (Kumar, 2020)

Based on an extensive literature review, Kumar developed a nomological network of EV adoption. (Kumar, 2020). A nomological network represents the concepts of interest in a study, their observable manifestations, and their interrelationships. It includes a theoretical framework for what is being measured, specifying links between different hypothetical constructs, between different observable attributes, and between hypothetical constructs and observable attributes (Cronbach et al., 1955). This framework can be divided into five categories based on the influential factors linked to EV adoption.

The five categories of the variables are as follows: independent, consequence, mediating, moderating, and socio-demographic.

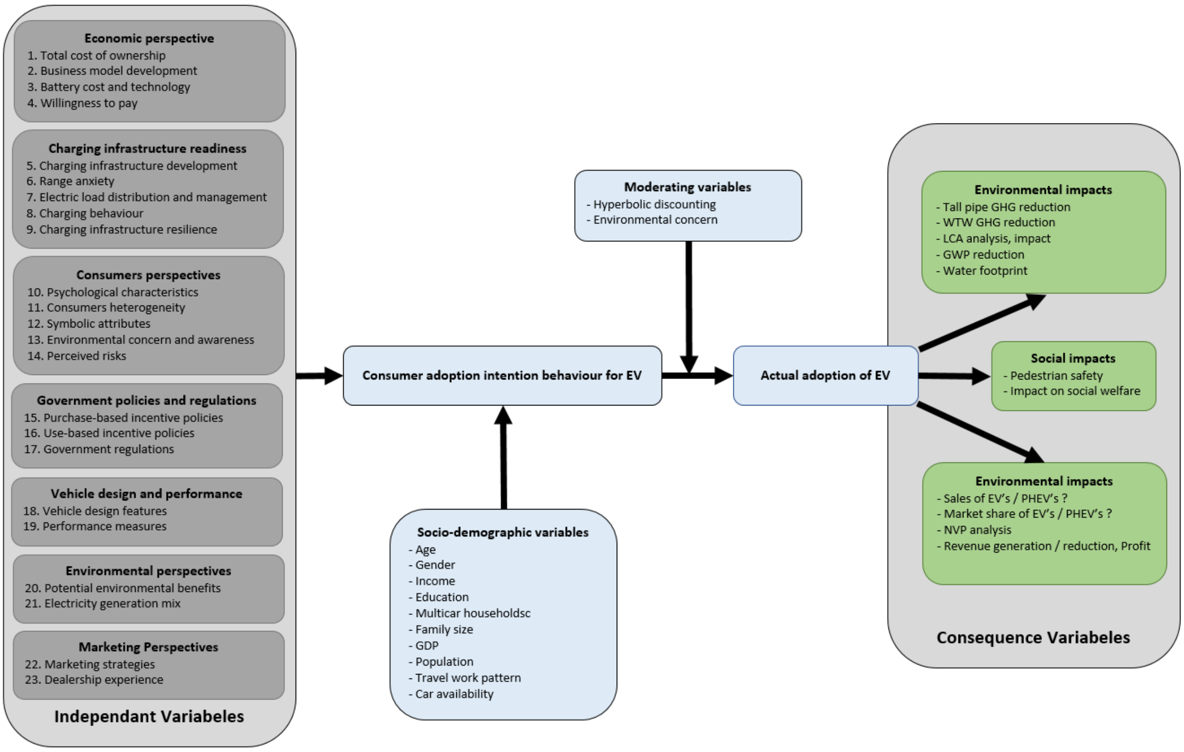


Figure 3: Conceptual nomological network of EV adoption (Kumar,2020)

3.4.1 *Independent variables*

The first category of factors is the independent variables, which are present in advance and act as barriers or motivators in EV adoption. Kumar identified 23 variables and divided into seven subcategories to provide multifaceted insights for policymakers.
The three most publicized independent variables are charging infrastructure, the total cost of ownership, and purchase-based incentive policies (Kumar, 2020).

3.4.2 *The consequence variables*

The second category of factors is the consequence variables. Three consequence variables were identified to demonstrate the sustainability impact of EV adoption. The three consequence variables are economic, environmental, and social impact.

3.4.3 *Mediating variables*

The third category of factors is the mediating variables. Mediating variables are an integral part of the relationship map and influence many variables, which, in turn, impact EV adoption. Three major types of mediating variables used to understand the mediating effect on EV purchase intention are psychological characteristics, symbolic attributes, and perceived attributes.
The perceived attributes of innovations can help in understanding the rate of diffusion. Rogers (2003) described these factors in five categories of innovations attributes: relative advantage, compatibility, complexity, trialability, and observability.

3.4.4 Moderating variables

A moderating variable is a type of variable that affects the relationship between a dependent variable and an independent variable. For example, external cost (i.e., perceived price and perceived complexity) could be considered a moderating variable between the personal norm and the intention of EV adoption (He and Zhan, 2018).
Environmental concern is a moderating variable between consumer purchase intention and the actual adoption of EV (Adnan et al., 2017).
Purchase intention to actual adoption is positively moderated by the hyperbolic discounting and the environmental concern. Hyperbolic discounting refers to the tendency of people to increasingly choose a smaller, sooner reward over a larger, later reward, as the delay occurs sooner rather than later. Apart from gender, psychological-characteristics-related factors are the second most studied moderating variables.

3.4.5 Socio-demographic variables

The socio-demographic characteristics are a distinguishing factor between adopters and non-adopters. However, a few of these variables differ in significance based on geography, culture, and country-specific conditions.
The various socio-demographic factors towards EV adoption are a higher level of education, high-income group, younger and middle-age group, gender, live in larger households, household size, travel work pattern, and car availability.

3.5 Formation of the analytical research model

The analytical research model used in this thesis is formed largely based on the Diffusion of Innovation Theory of Rogers, applied to the framework of Kumar. From the independent variables of Kumar's framework, the following variables were selected: government policies and regulations, purchase price, total cost of ownership, and model availability.
Although the potential benefits of BEVs are extensive, there are substantial upfront costs in the early stages of the transition from ICE vehicles to BEVs. The base price of a BEV is still higher than that of an ICE vehicle. National and local tax policies highly influence the total cost of ownership (TCO) of passenger cars. National and local authorities can influence BEV adoption, especially in an early stage, by reducing the one-time and operating costs of BEVs and increasing these costs for ICE vehicles.
An adequate charging infrastructure is a pre-condition for the adoption of BEVs. National and local authorities can also influence the high- and normal-power-charging infrastructure with financial incentives on private charging poles at home.
The authorities also indirectly influence model availability in their country. When the BEVs one-time and operating costs in a country are similar or lower than those of an ICE vehicle and the charging infrastructure is robust enough, car manufacturers and distributors are incentivized to increase model availability in that country.
For the consumer characteristics the socio-demographic variables of Kumar's framework, age distribution, income, and car preferences were selected. Range anxiety and willingness to pay are out of scope for this thesis because the outcome of these variables is too difficult to measure. In the questionnaire, questions were designed for the consumer characteristics and information from these interviews gave some subjective information. Details of the questions of the questionnaire are documented in the appendix (paragraph 9.10). The socio-economic status characteristics related to Rogers's adoption categories were integrated with Kumar's socio-demographic variables.

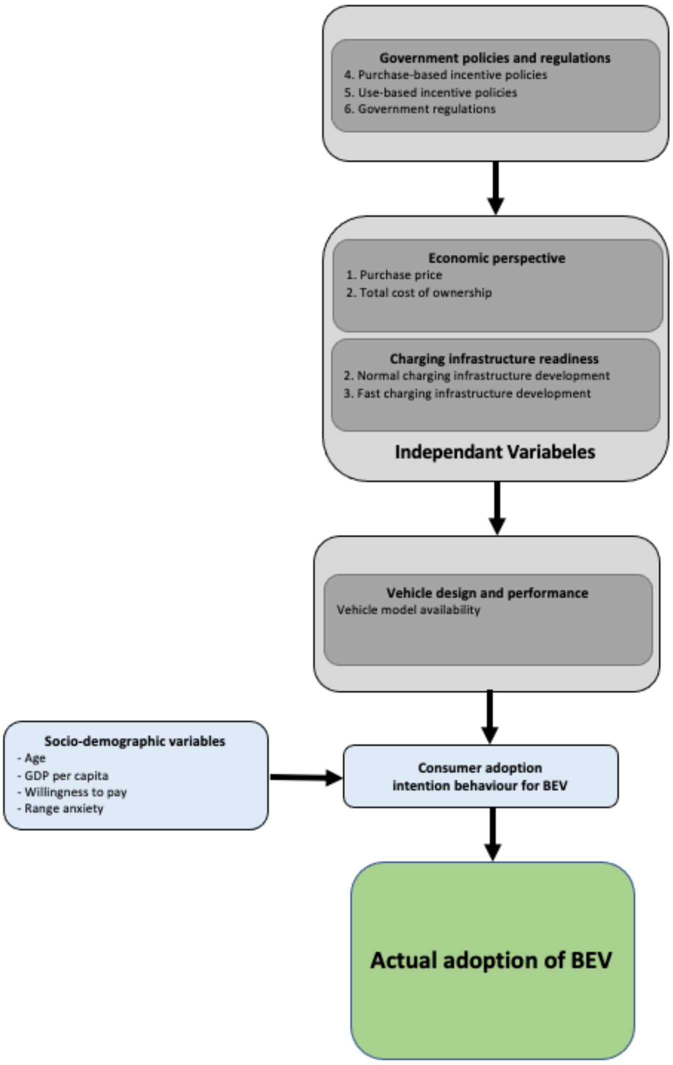


Figure 4: Analytical research model

4 Methodology

4.1 Introduction

This chapter provides an overview of the methods used to obtain the data to answer the research question.
For this thesis, mixed methods research was used. Mixed methods research is the type of research in which a researcher or a team of researchers combines elements of qualitative and quantitative research approaches (e.g., use of qualitative and quantitative viewpoints, data collection, analysis, or inference techniques) for the broad purposes of breadth and depth of understanding and corroboration (Johnson et al., 2007).

4.2 Methodology per sub-question

4.2.1 BEV adoption rate in Europe

The first sub-question deals with analyzing BEV adoption in Europe descriptively. The selected European countries for this sub-question are the countries belonging to the EU, the European Free Trade Association (EFTA), and the United Kingdom.
The BEV adoption was analyzed by the percentage of the annually newly registered BEVs relative to total newly registered passenger cars between 2009 and 2021 using data from the European Alternative Fuels Observatory (EAFO, 2021). This organization, funded by the EU, is a one-stop shop for all data and relevant information regarding alternative transport fuels in Europe. The numbers and percentages of the total BEV fleet per country can be found in the Appendix. BEV adoption in European countries is divided into the categories defined by Rogers's innovation theory (Rogers, 2003).
BEV adoption is also related to the European passenger car fleet and the passenger car age distribution. These data were retrieved from the European Automobile Manufacturers Association (ACEA, 2021b) and Eurostat (Eurostat, 2021a, 2021b).

4.2.2 Factors influencing BEV adoption

The second sub-question analyzes the factors that influence the adoption of BEVs in general.
This thesis focuses on the following factors, also outlined in Kumar's extensive literature review. These factors consist of governmental policies, regulations, and incentives, purchase price, the total cost of ownership, the charging infrastructure, the model availability and consumer characteristics such as income, GDP per capita and age distribution.
It does not focus on psychological aspects, such as the profiles of EV owners, or market aspects, such as buying behavior of BEV adoption. Willingness to pay, range anxiety, and car preferences is also out of the scope of this thesis. With the outcome of the interviews, an attempt is made to collect information on this subject.

4.2.3 How these factors differ among countries

This research aims to model certain scenarios on how the upscaling of EVs will take place from 2020 to 2030 and how the upscaling of BEVs can be accelerated in Europe. It is necessary to examine the European member states in a qualitative manner to outline the scenarios. In this way, it is possible to identify which factors are accelerating and which factors are hindering BEV adoption. However, it is not possible to examine each European member state separately, as doing so would take too much time. Therefore, two well-performing countries, one rapidly upcoming country, and two poorly performing countries were chosen.
For the five European member states, separate qualitative studies were done to investigate which factors accelerate or hinder BEV adoption. The two well-performing countries investigated in this study are Norway and the Netherlands. The two well-performing countries and one upcoming country were chosen to examine which policies and factors accelerate EV adoption. Germany was selected as

the upcoming country. Spain and Poland were chosen as poor performing countries. Both countries have a large passenger car fleet. Spain represents a south European country and Poland an east European country.
The country that performed best in terms of EV upscaling is Norway (Wappelhorst, 2021b) and is the only country that belongs to the Rogers late majority category (50%–84%). Norway accounts for 16% of the total BEVs in Europe. Furthermore, Norway has the highest registration rate (63%) of BEVs compared to new passenger cars registered in 2021. However, Norway represents only 1% of the European passenger car fleet.
The Netherlands, Sweden and Iceland are the only countries that belong to the early majority Rogers category (16%–50%). These early majority countries represent 5% of the European car fleet.
Germany was chosen because it represents the largest passenger car fleet (17%) in Europe (ACEA, 2021b), and since 2020, the most BEVs were sold in Germany (EAFO, 2020). Compared to 2019, in 2020, the German BEV market had a growth of 310%. Germany belongs to the high end of Rogers early adaptors category with 13.2% in 2021.
Moreover, Spain and Poland were chosen as the two countries in Europe that are performing poorly in terms of BEV upscaling.
Spain was slow to scale up BEVs and the charging infrastructure that accompanies them until 2019 (Wappelhorst, 2021b). However, with the help of emergency funds from the EU, Spain wants to boost the scaling-up of BEVs (Reuters, 2021). Spain also aims to establish new battery and EV factories to boost its economy. It was, therefore, interesting to investigate a country that performs poorly in terms of upscaling EVs but simultaneously has great ambitions for the BEV market.
Furthermore, a choice was made for Poland because Poland is one of the worst performers in terms of BEV upscaling in Europe (Wappelhorst, 2021b). However, Poland is one of the largest markets for passenger cars in Europe. Despite targets, strategies, the necessary legal frameworks, and a strong industry producing battery components for BEVs, the introduction of BEVs has been relatively slow so far (Wappelhorst, S. & ICCT,2020). It seems that the roll-out of the charging infrastructure in Poland is not yet steady. The poor level of charging infrastructure, therefore, seems to be the biggest factor preventing the upscaling of EVs in Poland. It was interesting to examine, in more detail, why the upscaling of BEVs is not growing steadily in Poland because Poland can be a model for other (East European) countries that are in the initial phase of introducing BEVs.
Spain belongs to the low end of the early adaptors category (2.5%-16%) with 2.8%. Poland belongs to the innovators' group (0%–2.5%).
The comparative analysis of the five countries was done using the analytical model.

4.2.3.1 ***Governmental regulations and incentives***

The base price of a BEV is still higher than that of an ICE. The total cost of ownership of passenger cars is highly influenced by national and local tax policies. National and local authorities can influence the adoption of BEVs, especially in an early stage, by reducing the one-time and operating costs of a BEV and increasing these costs for the ICE vehicles, both for private and company-owned cars. These factors are outlined in table 2.

Table 2: Governmental regulations and incentives

<table>
<tr><th></th><th></th><th colspan="3">Passenger car tax</th></tr>
<tr><td></td><td></td><td colspan="2">Privately owned
(Individual perspective)</td><td>Company owned
(employee perspective)</td></tr>
<tr><td rowspan="3">Tax payments</td><td>One-time costs</td><td>Car purchase and registration
Value-added tax
Registration tax</td><td></td><td></td></tr>
<tr><td rowspan="2">Operating costs</td><td>Car ownership
Motor vehicle tax</td><td>Consumption on energy
Fuel tax
Electricity tax</td><td>Private use of company car
Benefit-in-kind tax</td></tr>
<tr><td>Use of road infrastructure
Toll
Parking</td><td></td><td></td></tr>
<tr><td>Subsidies</td><td></td><td>Grants
Grants for low-emission cars</td><td></td><td>Grants
Grants for low-emission cars</td></tr>
</table>

4.2.3.2 The total cost of ownership (TCO)

The TCO of a passenger car is highly influenced by a country's tax regulations and incentives. In the thesis, a comparative study was performed between Norway, the Netherlands, Germany, Spain, and Poland during 2014–2020. The following variables were used for the comparative study.
The TCO was calculated with a car ownership of four years and 15,000 km of driving per year.

Analysis of car ownership was performed in three ways.

First, a comparison was made analyzing the one-time and operating cost differences. For the one-time costs, the purchase price was used and divided into the base price, the registration tax, the purchase value-added tax (VAT), and the possible purchase subsidy from the individual countries. For the operating costs, the motor vehicle or road tax and the consumer energy costs were analyzed. Insurance costs and maintenance costs were out of scope for this analysis because no reliable data could be collected from the different countries. For the consumer energy costs, the following parameters were used: the energy consumption of the compared cars according to the Worldwide Harmonized Light Vehicle Test Procedure (WLTP) standard and the petrol E95 price in the compared countries divided for the years from 2014 till 2020 and the electricity price in Euro per kWh.
The second comparison was made using the depreciation costs of the car and the operating costs. For the depreciation, 12% per year was used both for ICE vehicles and BEVs. Thus, 48% of the purchase price minus the purchase price was used.
The third analysis was performed on the TCO for an employee using a company owned car exceeding more than 500 km. private in the Netherlands. For an ICE, 22% of the vehicle's catalogue value will be considered part of the driver's income. For a BEV, this benefit in kind (BIK) tax is reduced. This TCO was based between 2014 and 2026. The TCO was compared for a BEV and an ICE vehicle in the car segments A, C, and F which represents a small, middle class and top class segment car. The personal-year income of €35,000, €50,000, and €75,000 were selected because this is of relevance for the income tax scale.

Passenger car models

For the BEV, the Volkswagen (VW) E-Golf was selected from 2014 till 2019. For 2020, the VW ID3 was selected because the VW E-Golf was not sold anymore in all countries in 2020.
The models selected for the comparative study are presented in table 3. The model selection was based on the country entry model and availability in all compared countries. It was not always possible to select the same model in for the 5 comparing countries. This was the reason sometimes a different model needed to be selected that was almost similar to the model in the other comparing countries.

Table 3: Model types used in the comparative total cost of ownership (TCO) study

Year	Type	Model	Norway	Netherlands	Germany	Spain	Poland
2014	ICE	Volkswagen Golf; 1.2 TSI 85HP Trendline	x	x	x		x
2014	ICE	Volkswagen Golf; 1.2 TSI 105HP BMT				x	
2014	BEV	Volkswagen Golf; E-Golf	x	x	x	x	x
2015	ICE	Volkswagen Golf; 1.2 TSI 85HP Trendline	x	x	x		x
2015	ICE	Volkswagen Golf; 1.2 TSI 105HP BMT				x	
2015	BEV	Volkswagen Golf; E-Golf	x	x	x	x	x
2016	ICE	Volkswagen Golf; 1.2 TSI 85HP Trendline	x	x	x		x
2016	ICE	Volkswagen Golf; 1.2 TSI 105HP BMT				x	
2016	BEV	Volkswagen Golf; E-Golf	x	x	x	x	x
2017	ICE	Volkswagen Golf; 1.0 TSI 85HP Trendline	x	x	x		x
2017	ICE	Volkswagen Golf; 1.0 TSI 110HP				x	
2017	BEV	Volkswagen Golf; E-Golf	x	x	x	x	x
2018	ICE	Volkswagen Golf; 1.0 TSI 85HP Trendline		x	x		x
2018	ICE	Volkswagen Golf; 1.0 TSI 110HP				x	
2018	ICE	Volkswagen Golf; 1.0 TSI 115HP COMFORTLINE BUSINESS	x				
2018	BEV	Volkswagen Golf; E-Golf	x	x	x	x	x
2019	ICE	Volkswagen Golf; 1.0 TSI 85HP Trendline		x	x		x
2019	ICE	Volkswagen Golf; 1.0 TSI 115HP				x	
2019	ICE	Volkswagen Golf; 1.5 TSI 130HP HIGHLINE	x				
2019	BEV	Volkswagen Golf; E-Golf	x	x	x	x	x
2020	ICE	Volkswagen Golf; 1.0 TSI 90HP		x	x		
2020	ICE	Volkswagen Golf; Golf Life 1.0 TSI 110HP				x	x
2020	ICE	Volkswagen Golf; Golf 1,0 eTSI 110HP Life aut	x				
2020	BEV	Volkswagen ID3 45 kWh 150HP	x	x			x
2020	BEV	Volkswagen ID3 58 kWh 150HP			x	x	

The one-off passenger car purchase price is divided into the base price, the purchase VAT, the registration tax, and the possible subsidy on the purchase price. For the depreciation costs, 12% per year was used both for ICE vehicles and BEVs.

For the operating costs, the motor vehicle tax and energy consumption costs were included. For the energy consumption costs, the fuel and electricity prices per year per country were used. For fuel or electricity consumption, the WLTP standard was used (ACEA, 2021c).

Toll and parking costs were excluded from this study because it was too difficult to calculate reliable outcomes for these costs, although national and local authorities in Norway and Spain use these as an incentive for BEV adoption.

Insurance and maintenance costs were also excluded from this study because it was too difficult to collect reliable data from the compared countries during 2014 and 2020, and the differences were not that significant between ICE vehicles and BEVs. The difference between the ICE vehicle and BEV purchase prices was also analyzed.

4.2.3.3 Cost benefit analysis

4.2.3.3.1 Introduction

The cost-benefit analysis for this thesis compares a BEV with an ICE vehicle and is based on earlier research of Prud'homme and Koning (2012) and Fontainhas, Cunha, and Ferreira (2016).
For the 5 selected countries, a low, medium and high market segment BEV and ICE were compared with a fifteen years lifespan.
For the low market segment, a criterion was that the purchase price of the ICE vehicle should be between €10,000 and €30,000. The choice for the low market segment was made for the Renault Zoe-E-tech electric as a BEV and the Renault Clio zen TCe as an ICE vehicle from the year 2021.
For the mid-market segment, the criterion was that the purchase price of the ICE vehicle should be between €30,000 and €60,000. The choice was made for the Mercedes EQA 250 as BEV and the Mercedes GLA 250 4MATIC as ICE vehicle from the year 2021.
For the high market segment, the criterion was that the purchase price of the ICE vehicle should be over €60,000 euros. The choice was made for the BMW iX xDrive50 as BEV and the BMW X5 M50i as ICE vehicle from the year 2021.

4.2.3.3.2 Dependent variables

The cost-benefit analysis compares the BEV and the ICE vehicle on consumer costs (CC), the difference in carbon dioxide emissions (G)

4.2.3.3.2.1 Consumer Costs

Consumer costs (CC) are the financial costs paid for the use of a BEV and the ICE vehicle. The consumer costs are calculated as follows:

$$CC = Total\ cost\ BEV - Total\ cost\ ICE$$

A negative value of CC indicates that it is cheaper to drive a BEV than an ICE vehicle.

4.2.3.3.2.2 Carbon Dioxide Emission Gain

Carbon dioxide emissions are also an external effect, but it is difficult to price them. Carbon dioxide emission values are often based on political targets for emission reductions. The capped market prices usually reflect the limited scarcity of resources, not the future and uncertain damage caused by global warming (Tol, 2005). Therefore, in this research, carbon dioxide emissions have been calculated separately.

The difference in carbon dioxide (G) emissions is calculated as follows:

$$G = CO2\ emissions\ ICE - CO2\ emissions\ BEV$$

A positive value of G indicates that carbon dioxide is saved by driving a BEV. When the value of G is negative, more carbon dioxide is emitted by driving a BEV.

4.2.3.3.3 Independent variables

4.2.3.3.3.1 Consumer Costs

To calculate the consumer costs, the total cost for the ICE vehicle and the BEV had to be calculated. The total cost for an ICE vehicle and BEV were calculated as follows:

$$Total\ cost\ ICE = Fuel\ cost + Road\ tax + Consumer\ price\ vehicle$$
$$Total\ cost\ BEV = Electricity\ cost + Road\ tax + Consumer\ price\ vehicle + Home\ charger + Purchase\ subsidy$$

The fuel and electricity cost were calculated year 1 as follows:

$$Fuel\ cost\ =\ Distance\ travelled\ *\ Car\ efficiency\ *\ Fuel\ price$$
$$Electricity\ cost\ =\ Distance\ travelled\ *\ Car\ efficiency\ *\ Electricity\ price$$

Subsequently, the following years were calculated as follows:

$$Fuel\ cost\ (n)\ =\ Fuel\ cost\ year\ (n-1)\ +\ Change\ in\ fuel\ price\ *\ Fuel\ cost\ year\ (n-1)$$
$$Electricity\ cost\ (n)\ =\ Electricity\ cost\ year\ (n-1)\ +\ Change\ in\ electricity\ price\ *\ Electricity\ cost\ year\ (n-1)$$

For the road tax, it was assumed that the value of the road tax in the respective countries would not be changed. Therefore, the road tax is a fixed value. It was also assumed that the purchase price of the ICE vehicle and the BEV would not change and is therefore a fixed value. Furthermore, this model assumes that every BEV driver has to buy a home charger to charge his car. Because charging a BEV with a slow charger takes several hours, BEV drivers will usually have to charge their car at home at night. Also, the home charger is assumed not to change in price and is therefore a fixed value in this model. Finally, this model takes into account the purchase subsidy that is given at the purchase year. It's assumed that this purchase subsidy is a fixed value, because the purchase subsidies of the different countries are known (EAFO,2020) (ACEA,2021a).

4.2.3.3.3.2 Carbon Dioxide Emissions

The carbon dioxide gain achieved by driving a BEV is determined by the total carbon dioxide emitted by an ICE vehicle and BEV. The carbon dioxide emissions are calculated as follows:

$$Carbon\ dioxide\ emissions\ ICE\ =\ Distance\ travelled\ *\ Carbon\ dioxide\ emission$$
$$Carbon\ dioxide\ emissions\ BEV\ =\ Distance\ travelled\ *\ Car\ efficiency\ *\ Carbon\ dioxide\ intensity\ in\ electricity\ production$$

4.2.3.3.3.3 Future Costs

To calculate the costs incurred by the use of the BEV and the ICE vehicle for the future years, the current cost (yt), discount rate (r) and the future years (n) are used.

$$Y\ =\ \Sigma yt(1/(1\ +\ r)^n$$

The annual carbon dioxide emissions of the BEV and the ICE vehicle are not discounted. This is because annual carbon dioxide emissions are calculated in tons per year and are not considered as a direct cost in this model.

4.2.3.3.4 Parameters

To carry out the cost-benefit analysis for the five countries, a selection has been made of the parameters to be included in the model based on the formulas and information. A distinction was made between parameters that are the same for the BEV and ICE vehicle, parameters that are specific to the ICE vehicle and parameters that are specific to the BEV.

4.2.3.3.4.1 Generic Parameters

The generic parameters are the discount rate (r), the number of years (n) and the distance traveled (k).

Companies, governments, and investors are able to make large investments without the worry of needing the money quickly. Therefore, companies, governments and investors can make an investment in a fairly rational way and sit out the payback period. When a cost-benefit analysis is made prior to investment by a company, government or investor, a social discount rate is used.

In the case of individuals making a large investment, such as a house or a car, more factors come into play, because these individuals often cannot easily miss the money. When a cost-benefit analysis is made before an individual invests, the implicit discount rate is used. The implicit discount rate is a higher percentage than the social discount rate. This is because the implicit discount rate takes more factors into account, which an individual experiences during a large investment. The implicit discount rate reflects the buying behavior of consumers with a large investment better than the social discount rate.

In the thesis, a cost-benefit analysis is made from the consumer perspective, who makes a large investment. Namely an ICE or BEV. Therefore, an implicit discount rate is used.

The level of the implicit discount rate differs per technology. Based on literature, an implicit discount rate of 20% is used.

Finally, for the distances per year a choice has been made for 10.000 km, 20.000 km and 30.000 km. The research of Fontaínhas et al.,2016 showed that the BEV becomes more advantageous the more kilometers per year are driven. In addition, it is to be expected that most consumer segments do not drive more than 30,000 km. Therefore, almost every consumer segment falls within the chosen distances.

4.2.3.3.4.2 ICE-specific Parameters

The values for the purchase price, car efficiency and carbon dioxide emissions for the ICE vehicles were obtained from the websites of Renault, Mercedes and BMW. It is important to note that for each country, the website of the specific country was used. The reason for this is that the purchase price for the same car model is different in different countries. This is due to different tax regimes that countries apply on the purchase price.

The fuel price per country was obtained from Statista (Statista, 2022), (Statista, 2021),(Statista, 2021b), (Statista, 2021a), (statistics Norway, 2022).The fuel price was looked at between 2010 and 2020. This made it possible to predict what the fuel price in a certain country would be in 2021. Furthermore, by analyzing the fuel price between 2010 and 2020, a prediction could be made of how fuel prices would change in future years.

The road tax for the ICE vehicle was obtained from websites where the road tax could be calculated (Autoweek, 2022), (Diesel o Gasolina, 2022), (kfz-steuer.wiki, 2022),(Tolls.eu , 2022), (The Norwegian Tax Administration, 2021d). However, the five countries have different road tax schemes. In the Netherlands and Spain, the road tax is different per province. In the case of the Netherlands and Spain, the average value of the road tax of the provinces was taken.

Finally, for the purchase price and fuel price, it was decided to include VAT, registration tax and the tax for fuel. The reason for this is that each country has a different tax regime. The model would become too complex to incorporate the different tax regimes of the various countries. By using the purchase price and fuel price in which the VAT, registration tax and the tax for fuel is incorporated, the different tax schemes are in fact included in the model.

4.2.3.3.4.3 BEV-specific Parameters

The values for the purchase price and car efficiency for the BEV were obtained from the websites of Renault, Mercedes and BMW. It is important to note that for each country, the website of the specific country was used. The reason for this is that the purchase price for the same car model is different in different countries. This is due to different tax regimes that countries apply on the purchase price.

This model assumes that every BEV driver must purchase a home charging station. Since Renault, Mercedes and BMW do not clearly indicate the costs of a charging station on their websites, the choice has been made to obtain the costs of the Home Charger from Volkswagen's website. The cost of the charging station has also been obtained by looking at the Volkswagen website of the particular country, as the cost of the charging station varies from country to country due to the different tax regimes that countries operate. The cost of the home charger includes the charging station and installation costs. In addition, it is assumed that the costs of the charging station are the same for each market segment. The reason for this is that there are no different (slow) charging stations for different BEV models.

The electricity price per country was obtained from Statista (Statista, 2022b), (Statista, 2021b), (Statista, 2021c),(Statista, 2021f), (Statista, 2021d). The electricity price was looked at between 2010 and 2020. This allowed a prediction to be made of what the electricity price in a particular country would be in 2021. Furthermore, by analyzing the electricity price between 2010 and 2020, a prediction could be made of how the electricity price would change in future years.

The road tax for the BEV was obtained from websites where the road tax could be calculated (Autoweek, 2022), (Diesel o Gasolina, 2022), (kfz-steuer.wiki, 2022),(Tolls.eu , 2022), (The Norwegian Tax Administration, 2021d). However, the five countries have different road tax schemes. In the Netherlands and Spain, the road tax is different per province. In the case of the Netherlands and Spain, the average value of the road tax of the provinces was taken.

With the help of the website of the European Environment Agency, the carbon dioxide intensity of electricity generation was obtained (European Environment Agency, 2022). The carbon dioxide intensity of electricity generation was looked at between 2010 and 2020. This made it possible to predict what the carbon dioxide intensity of electricity generation in a particular country would be in 2021. Furthermore, by analyzing the electricity price between 2010 and 2020, a prediction could be made of how the electricity price would change in future years.

For the electricity price, it was decided to include the VAT. It was decided to include VAT in the purchase price and the home charger price. However, VAT was included separately in the BEV model in order to research in the sensitivity analysis whether reducing VAT is an appropriate measure to stimulate BEV adoption in a country.

Finally, this model assumes that when purchasing a BEV, the consumer receives a purchase subsidy from the government. The reason for this assumption is that most countries give a purchase subsidy on the purchase of a BEV. Most countries do this to stimulate BEV adoption.

4.2.3.3.5 Sensitivity analysis

The cost-benefit analysis shows whether it is more cost-effective to drive a BEV than an ICE and whether less carbon dioxide is emitted by driving a BEV than an ICE. However, it is relevant to determine when a BEV becomes cost-effective and how much margin of carbon dioxide is allowed in electricity production so that the BEV is a more sustainable solution than the ICE. With this in mind, a sensitivity analysis of various parameters in the cost-benefit analysis was carried out using the Microsoft Excel function "Goal Seek".

The sensitivity analysis was only carried out when it is more expensive to drive a BEV than an ICE. This is in all countries only the case for the low segment. Furthermore, sensitivity analysis has only been carried out within the low segment for the distance 10,000 km. The reason for this is, that a BEV becomes more cost-effective to drive, as the distance travelled per year increases. 10,000 km is the shortest distance per year in the model and is therefore in fact the "worst case scenario". Finally, the sensitivity analysis was carried out to research which buttons governments can turn to make the BEV cost competitive in the low segment. The BEV is already cost competitive in the medium and high segments in all countries. Therefore, no sensitivity analysis was carried out for the medium and high segments.

4.2.3.4 Charging infrastructure

An adequate charging infrastructure is a pre-condition for the acceleration of BEV adoption.

In this thesis, charging infrastructure is divided into public normal, fast, and private charging points. Analysis of the private charging infrastructure was excluded from this thesis because there is no reliable information on this, although it is known that, in Norway, the private charging infrastructure is very well developed.

The number of normal and high-power charging points in the European countries was collected from the EAFO (EAFO, 2020). The charging terminology used in the analysis is related to power level and adopted from the EAFO. Normal charging points are less than or equal to 22 kW. Fast high-power charging points are greater than 22 kW.

For the public normal charging infrastructure it is important that there are sufficient charging points available for the number of BEVs that must use them. The lower the number of BEVs per charging point, the better the charging infrastructure. Analysis has been performed by comparing the number of BEVs per normal charging points and the total number of normal charging points during the years. In addition the number of BEVs per charging points related to the adoption rate of the comparing countries were compared.

Public fast charging infrastructure is essential to address the range anxiety issue when driving long distances. The average range for most BEVs is between 250 km and 350 km. With a high-power charging point, 80% battery is charged in 20–40 minutes. The more the number of high-power charging points per 100 km highway, the less the range anxiety is among BEV users. The number of high-power charging points per 100km was analyzed in relation with the BEV adoption.

4.2.3.5 Model availability

Model availability is of importance for BEV adoption. Similar to charging infrastructure, it is a pre-condition for the acceleration of BEV adoption. A subdivision was made per passenger car segment, in addition to the absolute numbers of models. For this purpose, the European New Car Assessment Programme (Euro NCAP) vehicle segment class was used. Small or compact, middle- and top-class cars can be based on these segments. The A and B segment represent the small or compact car. The C,D,J,L segments represent the middle class car and the F and M segments represent the top class car.

Table 4: Euro NCAP vehicle segment class

Description	Segment
Mini cars	A
Compact or small cars	B
Compact middle-class cars	C
Middle-class cars	D
Upper-middle-class cars	E
Top class (large cars and luxury models)	F
Sporty models	G or S
Sports cars	H
Top limousines	I
Midi MPVs (Multiple Purpose Vehicle) (based on mid-range)	J
Large MPVs	K
SUVs (Sports Utility Vehicle)	L
Large SUVs	M
Vans	N

The following analysis was performed between the compared countries Norway, the Netherlands, Germany, Spain, and Poland during the previous five years (2016–2020):

1. Number of models divided per segment
2. Number of new BEV registrations per segment
3. Share of new BEV registrations per segment

4.2.3.6 Consumer characteristics

The consumer characteristics of age distribution and income were analyzed if there is a relation with the BEV adoption in Europe. According to Rogers, younger people are more willing to pay for an innovative product than an elderly person. The data for the age distribution were retrieved from Eurostat (Eurostat, 2021c). It was not possible to compare the age distribution between ICE and BEV users, so the outcome of this analysis has limited value.
For the income, the GPD per capita was used of the European countries. The data were retrieved from Eurostat, 2022.

4.2.4 Characteristics of well- and poor-performing European countries

The characteristics of well- and poor performing countries will be based on the results from chapter 5 and will be presented in chapter 5.3.

4.2.5 Ways to accelerate the upscaling of BEV adoption at an European level

The ways to accelerate the upscaling of BEV adoption at an European level will be based on the results and discussion in chapter 5 and will be presented in chapter 5.4.

4.2.6 Interviews

A semi-structured interview was conducted with 12 interviewees. The questionnaire is documented in appendix K1 and the list of interviewees is presented in appendix K2.
The interviewees were selected on their research knowledge of Transport policy, their national authority on transportation and on their knowledge of the automotive sector. Representatives of the Dutch embassies of Poland, Norway, Germany and Spain, who are responsible for the Electric transition were also interviewed. 2 Interviewees have a scientific and research background, 4 interviewees were representatives of the Dutch embassies of Poland, Norway, Germany and Spain, who are responsible for the Electric transition and 4 interviewees are employed for national authorities.
The aim of the interviews was to collect more detailed information of the comparing countries, non-published scientific information, policies and regulations from the different comparing countries and information about certain innovation trends.
The answers of the 12 interviews were categorized and we structured as much as possible.

5 Results

5.1 BEV adoption in Europe

To fulfill the European targets of the European Green deal to reduce the GHG emissions in 2030 by at least 55% and to be in 2050 climate neutral a replacement from ICE to BEV vehicles is needed. This section describes the BEV adoption between 2009 and 2021 from the individual European countries and shows how fast the BEV acceleration of the individual countries is.

The BEV adoption rate in Europe is still quite low, considering the goals of the Green Deal that Europe wants to meet.

In 2021, the overall majority of countries have an adoption rate of new BEV registrations below 10% which indicates that incentives are necessary to accelerate the BEV adoption.

Norway was the only country in Europe, with a BEV fleet of the total passenger car fleet with a share of 15% in 2021. All other European countries had a total BEV fleet share under 4%.

The six countries (Germany, the United Kingdom, France, Italy, Spain, and Poland) contain 74% of the European passenger car fleet. In 2021 Germany, The United Kingdom and France had an adoption rate between 10%-15%. Italy and Spain between 2%-5% and Poland even below 2%.

5.1.1 BEV adoption categories

The BEV adoption rate among new car registrations is divided according to the categories defined by Rogers (2003). These categories are laggards (84%–100%), late majority (50%–84%), early majority (16%–50%), early adaptors (2.5%–16%), and innovators (0%–2.5%). When it is described that a certain country belongs to a Rogers category, then in this thesis it is meant that the new BEV users have reached this category

Figure 5 presents that in 2021 Norway has a BEV adoption share of 62% where the new consumers of a BEV belongs to the late majority. New consumers of BEVs in the Netherlands, Iceland and Sweden belong to now the early majority. From the majority (18 of 32 countries) of European countries the new BEV consumers belong to the early majority category. Ten countries like Poland and Greece had a very low BEV adoption rate and the BEV consumers still belong to the innovators category.

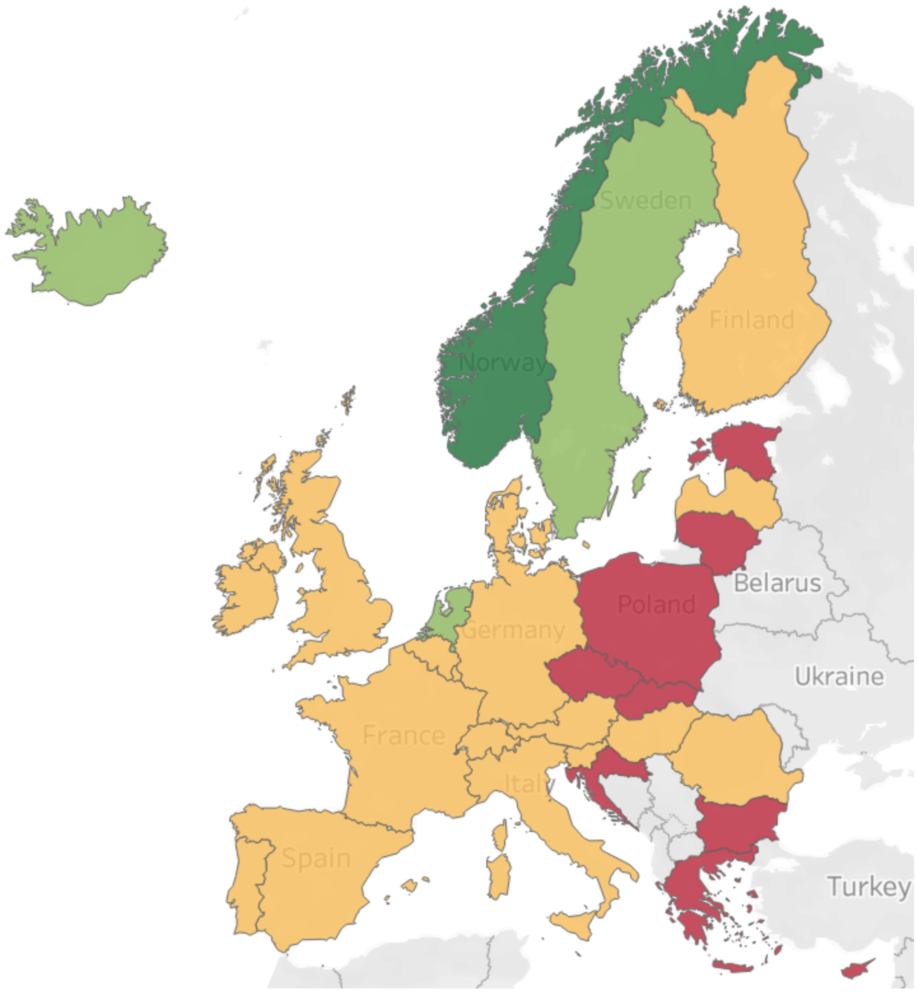


Figure 5: Battery electric vehicle adoption market share new registrations in terms of the Roger categories (2021)

The different Rogers categories indicating that new BEV consumers have reached this category in a certain country.

	Late majority	50%– 84%
	Early majority	16%– 50%
	Early adaptors	2.5%– 16%
	Innovators	0%–2.5%

The laggards (84%–100%)

No country in Europe, or the world, belongs to this category.

The late majority (50%–84%)

Norway is by far the world leader in BEV adoption and have passed the categories innovators, early adaptors, early majority and now reached the category of late majority. Figure 6 presents that Norway already from 2009 except 2016 had an annually acceleration of the BEV adoption and in 2021 63.2% of Norway's new passenger car registrations were BEVs. Since 2019, more BEVs have been sold in Germany than in Norway. Norway still has the largest BEV car fleet, followed by Germany, the United Kingdom, and the Netherlands in Europe. However, Norway has a minor role in the total European passenger car market with a European market share of 1%.

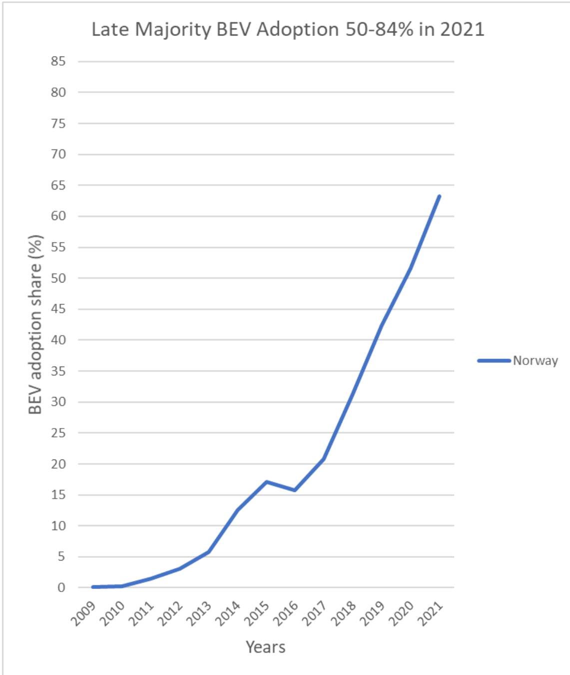


Figure 6: Late majority battery electric vehicle (BEV) category (50%–84%)

The early majority (16%–50%)

Since 2020, the Netherlands and Iceland belong to the early majority category and Sweden since 2021.

According to Rogers (Rogers,2003), the part of the diffusion curve from about 10% to 20% adoption is the heart of the diffusion process. After this point, the further diffusion of the BEV will not stop and no stimulating incentives should need anymore. Figure 7 shows that the claim of the theory of Rogers is not supported by the BEV adoption pattern The Netherlands showed in 2021. The Netherlands did not continue the acceleration of the BEV in 2021. The most likely reason was that the incentive on the Benefit in Kind (BIK) tax was reduced for company owned BEVs used privately.

The Netherlands, Sweden and Iceland represents only 5% of the European passenger car market. For the acceleration of the BEV adoption in Europe, the Netherlands, Sweden and Iceland have only a minor contribution because of their share of the European car market.

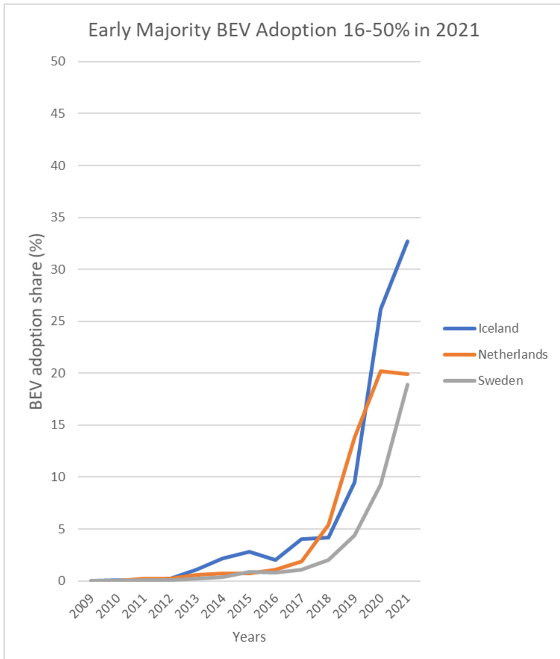


Figure 7: Early majority battery electric vehicle (BEV) category (16%–50%)

The early adaptors (2.5%–16%)
The majority, 18 of the 32 European countries belong now to the Early adoption category. Figure 8 presents that Germany, The United Kingdom and France, countries with an extensive passenger car fleet all have a BEV adoption rate of 10% or higher. If Germany continues the acceleration of the BEV adoption from 2021, it will reach the Rogers category of the early majority in 2022 which is a milestone for the country with the largest passenger car fleet of Europe.
Italy and Spain have performed much less with a BEV adoption rate of below 5%. The acceleration of the BEV adoption of Spain decreased in 2021 compared with the previous countries.

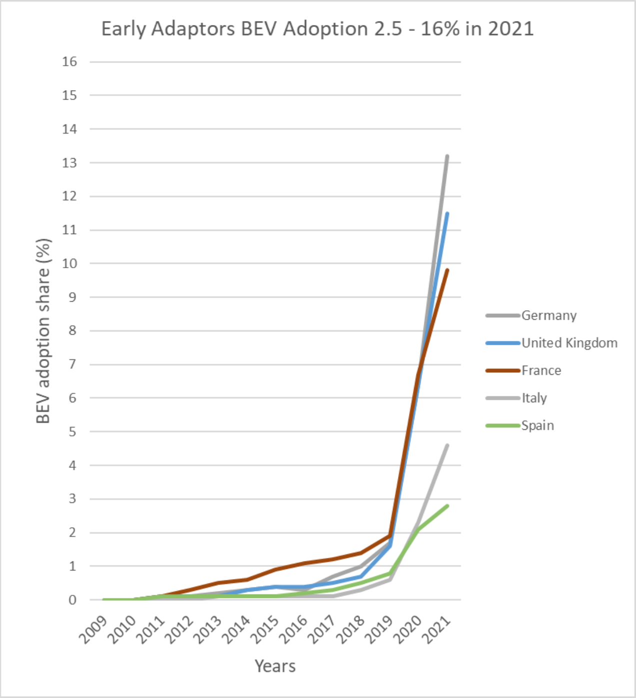


Figure 8: Early adaptors battery electric vehicle (BEV) category (2.5%–16%)

Innovators (0%–2.5%)
In 10 out of the 32 European countries, the BEV adoption rate was still between 0%–2.5%. in 2021, which is disappointing because the EU greenhouse goals must be achieved by 2050. Poland belongs to this category and has the 6th largest passenger car fleet in Europe. Figure 9 presents that the Czech Republic even decreased in the BEV adoption from 1.6% to 1.2% in 2021. Greece will hopefully reach in 2022 the category of Early adoption. For Poland this is not expected.
Within this category, the share of new passenger car registrations of these three countries is 22% of the European new car registrations.

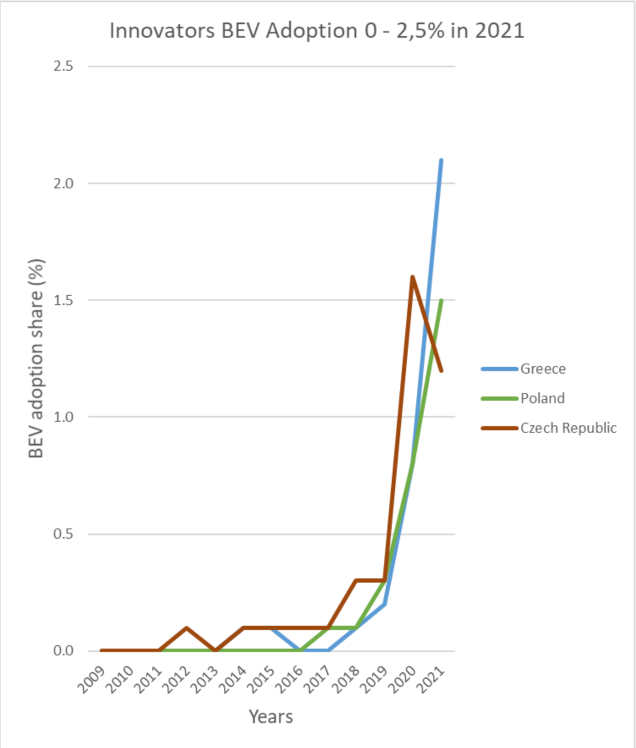


Figure 9: Innovators battery electric vehicle (BEV) category (0%–2.5%)

Norway has had an acceleration in BEV adoption since 2011, and the other European countries have shown an acceleration in one or two years (EAFO, 2021).

Annually, the BEV market share generally is growing faster than the year before and that the acceleration rate for Norway is decreasing compared to the past shows a logarithmic model according to the Rogers's diffusion of innovation theory.

Norway has a BEV market share of new car registration of 62.3%, meaning that Norway is the only country that has reached the late majority consumer segment. In addition, Iceland (32.7%), the Netherlands (19.9%) and Sweden (18.9%) have reached the early majority consumer segment, meaning that Norway, Iceland, the Netherlands and Sweden have reached the mainstream market and have successfully promoted BEV adoption. The majority of the European countries (18 of 32) have reached the early adopters consumer segment, meaning that these countries have reached the next phase in BEV adoption. However, these countries are still in the early market phase, meaning that the governments in these countries should continue to stimulate BEV adoption with financial incentives. Germany shows that the financial incentives really worked with a spectacular acceleration between 2019 and 2021. Finally, 10 countries belong still to the innovators consumer segment like Poland and Greece. Governments in these countries need to continue stimulating BEV adoption or even increasing their financial incentives.

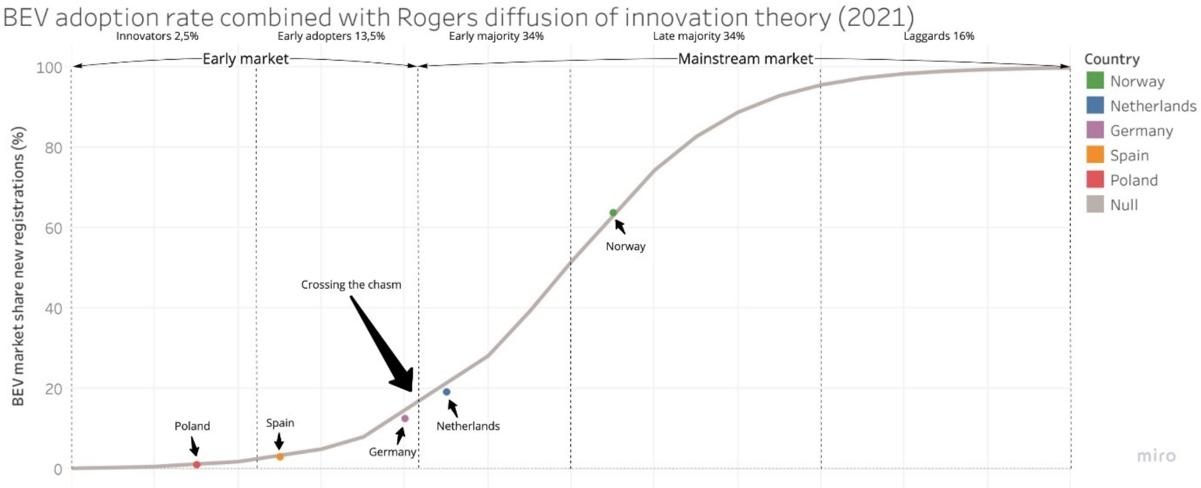


Figure 10: BEV adoption rate combined with Rogers diffusion of innovation theory

5.2 Factors that influence BEV adoption among countries

There are several factors that have influence on the BEV adoption in the individual European countries. The costs driving a passenger car are largely determined by the tax regulations of the individual European country. The base price of a BEV is still higher than an ICE, but national authorities have influence to reduce the purchase price and the operating costs of a BEV compared to an ICE.

The charging infrastructure is a pre-condition for the acceleration of BEV adoption in Europe. Charging infrastructure can be divided into public and private charging points. Public charging points can be divided into normal-power or slow (AC) and high-power or fast (DC) charging points. High-power charging points are used mainly on the highway. Analysis of the private charging infrastructure is out of the scope for this thesis because reliable data about the number of private charging points in European countries were not available, but where possible, literature references have been made. The private charging infrastructure can be divided into home charging and workplace charging.

The number of BEV models available on the market is an important variable influencing BEV adoption. The reason is that the more BEV models there are in the market, the more consumer segments will be appealed to by an interesting BEV model.

5.2.1 National and local incentives and legislation

For the privately owned BEVs the one-time VAT, registration tax and national subsidies were compared. On the operating costs, the motor vehicle tax and the excise duty was compared. For the company owned BEVs privately used, the benefit in kind tax was compared.

5.2.1.1 Purchase value-added tax (VAT)

All compared countries charge purchase tax both on BEV and ICE vehicles except Norway, which has an exemption on the purchase VAT since 2015. This incentive is substantial because the base price of a BEV is higher than that of an ICE vehicle, and the VAT rate in Norway is 25%, which is one of the highest in Europe (European Commission, 2021). In the EU, it is mandatory to charge VAT on the purchase of a BEV. (European Commission, 2021). For the EFTA countries (Norway, Iceland, Switzerland, and Lichtenstein) there exists a possibility that an EFTA member can exempt VAT on the purchase of a BEV (ESA, 2020). Norway and Iceland make use of this incentive.

The purchase VAT in Europe is between 19%-27% which is a major part of the purchase price of a BEV also because the base price of a BEV is higher than an ICE. VAT is deductible if the purchase is made by an industrial or commercial enterprise.

5.2.1.2 Purchase registration tax

At present there is little EU legislation, or harmonization of national fiscal provisions, applied by the Member States in the area of passenger car taxation (European Commission, 2012). Norway and The Netherlands have and Germany and Poland do not have a registration tax on new purchased passenger cars. In Spain an registration tax exists, but not for all passenger cars.

In Norway, the registration is based on the car weight, CO_2 emissions, NO_x emissions, cylinder capacity, and, for some vehicles, engine power (The Norwegian Tax Administration, 2021a). BEVs are exempted from purchase registration tax and is used as an incentive for the acceleration of the BEV adoption.

In The Netherlands the registration tax is based on CO_2 emissions and fuel efficiency. Additionally, there is a fixed surcharge of €372. Diesel ICE vehicles with a CO_2emission of more than 77 g/km pay an additional surcharge.

In Spain, the purchase tax is based on CO_2 emissions. Vehicles with a CO_2 emission rate below 120 g/km are exempted from registration. Between 120 g/km and 200 g/km, a rate between 4.75% and 9.75% of the vehicle price is charged. Above 200g/km, 14.75% of the vehicle price is charged. BEVs are exempted from purchase tax and also many ICE vehicles with an emission rate below 120 g/km.

In Poland, no registration tax is charged, but an excise duty tax is charged on buying passenger cars. For new and second-hand vehicles, the rate depends. In Poland, excise duty is based on the car engine capacity and not on the engine emission. BEVs are exempted for this excise of duty. The excise duty tax is used instead of the registration tax, because the majority of cars bought, are used cars.

Table 5: Registration tax in Norway, Netherlands, Germany, Spain and Poland

	ICE			BEV
Norway	Car weight, CO_2, NOx, Cylinder capacity			Exempted
Netherlands	CO_2, fuel efficiency, type of fuel			Exempted
Germany	Not existing			
Spain	CO_2	< 120	0% vehicle price	Exempted
	CO_2	120-200	4.75%-9.75%	
	CO_2	>200	14.75	
Poland	≤ 2,000 cc		3% vehicle price	Exempted
	> 2,000 cc		18.6%	

5.2.1.3 Purchase subsidy

Purchase subsidy from a national authority can be used as an incentive to reduce the purchase price of a BEV.

Norway has no policy for purchase subsidies, but Norway is able to exempt VAT for BEVs, which is not possible for EU countries. This VAT exemption can be seen as a kind of purchase subsidy of 25% on the base price of a BEV.

In 2020, the Netherlands introduced a purchase subsidy of €4,000 for new and €2,000 for used private BEVs. The list price must be €12,000–€45000. The budget is spread over the period 2020–2025. The total available budget for 2020 was €17.2 million. The budget for new electric cars is €10 million and for used electric cars €7.2 million. The budget available for funding this subsidy turned out to be insufficient. The funds originally earmarked for 2021 were used in 2020, so only slightly more than 1 million of the originally 14.4 million was available in 2021. The subsidy budget for 2021 was emptied within four days.

Since June 2021, the German federal government, together with the car manufacturer, has been providing a purchase subsidy of €9,000 for BEVs with a list price up to €40,000 and a subsidy of €7,500 for BEVs up to €65,000. Table 6 presents the details of the German subsidy on purchasing and leasing a BEV with a list price below and above € 40,000. Previously, the cost of this bonus was equally shared between the government and the manufacturer. Due to the COVID-19 pandemic, the federal government's share has been doubled, and the manufacturers are temporally exempted from contributing 50% of this subsidy.

In 2019, Spain introduced a purchase subsidy of €4,000 on BEVs. Spain has a relatively old passenger car fleet, with 18% of the passenger car fleet older than 20 years. The subsidy was increased with €1,500 if a scrappage car was added. In 2020, the subsidy was increased to €4,500 and for a scrappage car the buyer received an additional subsidy of €2,500. The subsidized BEV must not cost more than €45,000.

In June 2020, Poland, introduced a purchase subsidy of 15% of the purchase price and a maximum amount of €4,400, capped at a gross purchase price of €29,000 for private individuals and companies for BEVs and FCEVs.

Table 6: Purchase subsidy in Germany

	Net list price under €40,000		Net list price over €40,000		
	Federal share	**Manufacturer share**	**Federal share**	**Manufacturer share**	**Minimum holding time**
Purchase	€6,000	€3,000	€5,000	€2,500	six months

5.2.1.4 ***Motor vehicle tax***

Annual Motor vehicle tax on using the road is a tax on passenger car used in many European countries. When the motor vehicle tax is substantial on an ICE it can be used as incentive for BEVs when BEVs are exempted from motor vehicle tax. In Norway, The Netherlands and Germany motor vehicle tax exists. In Spain a low local tax is charged and in Poland no motor vehicle tax exists.

In Norway, the annual motor vehicle tax was replaced by a road traffic insurance tax in 2018. It is a tax on mandatory liability insurance for motor vehicles. The tax is calculated per day that the motor vehicle has been covered by liability insurance. BEVs are exempted from this tax. ICE vehicles are charged 8.12 NOK (€0.81) per day (The Norwegian Tax Administration, 2021c).

In the Netherlands the motor vehicle tax is based on vehicle weight, fuel type, region (province), and CO_2 emissions for ICE vehicles. BEVs are exempted from motor vehicle tax. This exemption will remain in force until 2024. In 2025, electric cars will pay 25% of the motor vehicle tax, and from 2026, 100%.

Germany introduced in 2021 a new motor vehicle tax system as a barrier for an ICE and an incentive for a BEV (Wappelhorst, S., 2020), which is based on the changes in the CO_2 components outlined in figure 11.

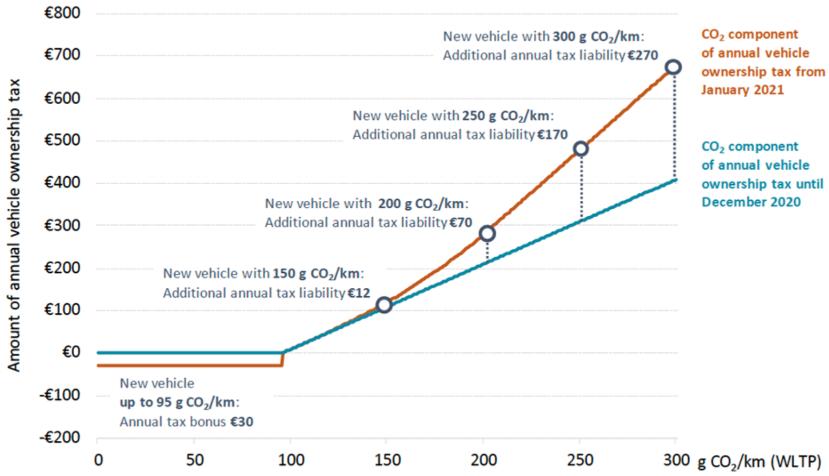


Figure 11:German vehicle ownership tax: Changes to the CO_2 component from 2021.

5.2.1.5 ***Energy consumption price***

Petrol and electricity price differ quite extensively in Europe, which has influence on the operating costs of an ICE and BEV. The differences in price in the individual countries are due to the different excise duty that can be charged above the mandatory minimum price , which is set by the EU. Poland and Spain charge almost the minimum rate of excise duty, and the Netherlands and Germany charge more than double the minimum rate.

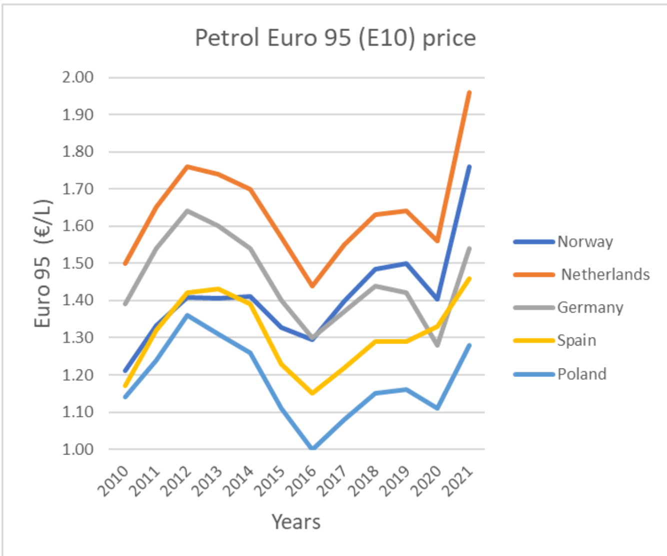


Figure 12: Petrol Euro 95 prices 2010-2021

Figure 12 and 13 presents the differences in energy consumption prices in the comparing countries. In Norway and The Netherlands the petrol price is high and the electricity price is low, what is an incentive for driving a BEV. Germany has a high electricity price and an average petrol price which reduce the incentive in a certain way of the energy consumption price. In Spain the petrol price is low but the electricity price high and in Poland both the petrol and electricity price is low. This does not contribute as an incentive, to drive electric.

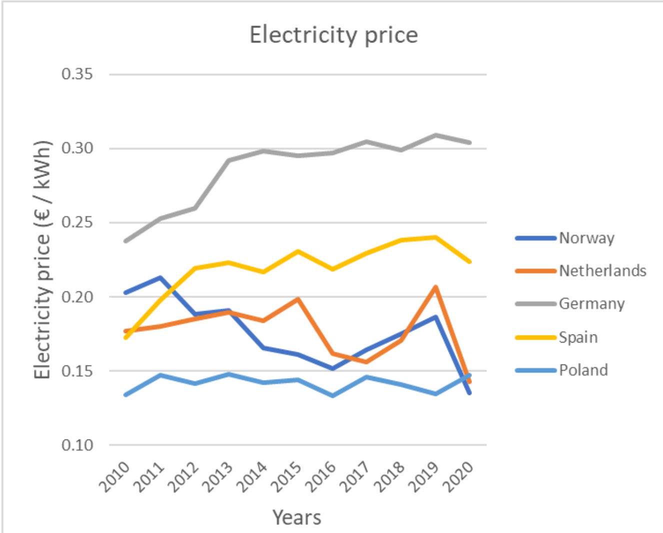


Figure 13: Electricity prices 2010-2021

5.2.1.6 Benefit-in-kind (BIK) tax

Tax to pay on company cars used privately is in most European countries needed. This benefit in kind (BIK) tax can be used as an incentive, to reduce the amount of tax for a BEV compared to an ICE.
In Norway the amount added to the income is 30% of the list price, with a cap till €31,323 and 20% of the remaining list price for cars younger than three years old. If the car is three or more years old, the calculation is set to 75% of the vehicle's list price. If the work-related driving amounts 40,000 km or more, 75% of the calculated list price is calculated. BEVs have a reduction of 40% of the BIK tax (The Norwegian Tax Administration, 2021).
In the Netherlands, using a company car privately for more than 500 km per year requires to pay BIK tax, which is 22% of the vehicle's list price. The BIK tax is used as a major incentive for a BEV from 2011 which is reduced as an incentive during the years and will be in 2026 again equal with an ICE.
In Germany the BIK tax rate is based on the gross catalog price of the company car and the distance between the residence and the office of the employee. The taxable amount is 1% of the gross catalog price, plus 0.03%, per month, of the gross catalog price per kilometer distance between the residence and the office of the employee for an ICE vehicle. The tax on BIK for BEVs with a maximum list price of €60,000 is 0.25% per month of the list price.
In Spain the BIK tax is 20% of the vehicle list price. BEVs have a reduction on the BIK tax 30% compared to an ICE.
In Poland the flat rate BIK tax on private use of a company car is 250 PLN (€55) for cars with engine capacity up to 1,600 cc^3 and 400 PLN (€88) for cars with a capacity of more than 1,600 cc.
The Netherlands is the country that used the BIK tax the most dynamically as an incentive for BEV adoption. Norway, Germany and Spain all have a static policy around the BIK tax for BEVs. In Poland there is hardly any BIK tax.

Table 7: Benefit in kind (BIK) tax in Norway, Netherlands, Germany, Spain and Poland

<table>
<tr><th></th><th colspan="2">ICE</th><th colspan="3">BEV</th></tr>
<tr><td>Norway</td><td colspan="2">< €31,323 30% vehicle price
> €31,323 20% vehicle price</td><td colspan="3">40% reduction compared to ICE</td></tr>
<tr><td rowspan="10">Netherlands</td><td colspan="2" rowspan="10">22% vehicle price</td><td>Years</td><td>BIK</td><td>max vehicle price</td></tr>
<tr><td>2011-2013</td><td>0%</td><td></td></tr>
<tr><td>2014-2018</td><td>4%</td><td></td></tr>
<tr><td>2019</td><td>4%</td><td>€50,000</td></tr>
<tr><td>2020</td><td>8%</td><td>€45,000</td></tr>
<tr><td>2021</td><td>12%</td><td>€40,000</td></tr>
<tr><td>2022</td><td>16%</td><td>€35,000</td></tr>
<tr><td>2023-2024</td><td>16%</td><td>€35,000</td></tr>
<tr><td>2025</td><td>17%</td><td>€30,000</td></tr>
<tr><td>2026 →</td><td>22%</td><td></td></tr>
<tr><td rowspan="2">Germany</td><td>Vehicle price</td><td>Distance home - work</td><td></td><td>BIK</td><td>max vehicle price</td></tr>
<tr><td>1%</td><td>0.36% x km distance</td><td></td><td>3%</td><td>€60,000</td></tr>
<tr><td>Spain</td><td colspan="2">20% vehicle price</td><td colspan="3">30% reduction compared to ICE</td></tr>
<tr><td>Poland</td><td colspan="2">Engine < 1,600 : €55
Engine > 1,600 : €88</td><td colspan="3">Engine < 1,600 : €55
Engine > 1,600 : €88</td></tr>
</table>

5.2.2 *Purchase price and private total cost of ownership (TCO) of a middle class car*

Norway

Norway is already more than 30 years stimulating the adoption of BEVs with several financial incentives. In 2021, 63% of new passenger car registrations were BEVs, and Norway is now the first country in Rogers's late majority category. Figure 14 shows that, the purchase price of a BEV is equal and even in some years lower than the ICE. The increase of the ICE purchase price is also due to the ICE model availability. Low end VW golf ICE models were not available in 2019. Exemption on VAT and registrations tax results in an equal and even lower purchase price of the BEV. Norway is the only country of the 5 comparing countries that have a lower BEV purchase price than the ICE.

Figure 15 shows that with the exemption of the road tax for BEVs and the lower energy consumption price for BEVs, the TCO for a BEV in Norway has been lower than that for an ICE vehicle already for many years.

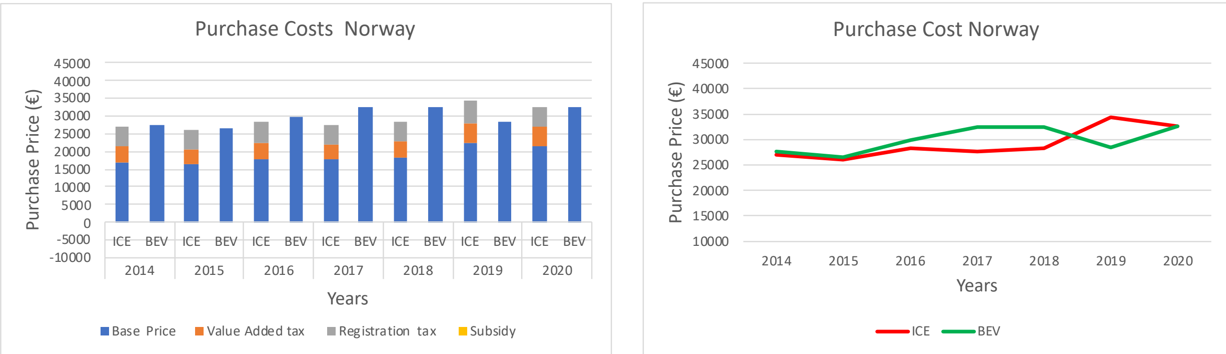


Figure 15: Purchase cost — Norway, VW Golf, and VW E-Golf

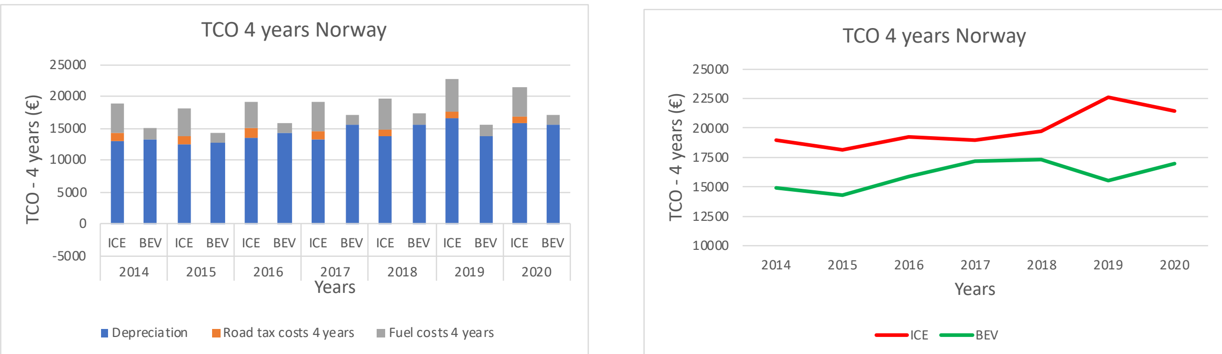


Figure 14: Total cost of ownership – Norway, VW Golf and VW E-Golf for four years and 15,000 km per year

The Netherlands

The Netherlands started the incentives to accelerate BEV adoption in 2011. Figure 16 shows that the purchase price of a BEV in the Netherlands is still higher than that of an ICE due to a higher base price and a higher VAT on the BEV despite an exemption from registration tax for the BEV. In 2020 the difference of the purchase price decreased between the BEV and the ICE because a purchase subsidy of €4,000 was started for a new car and €2,000 for a used car. The condition for this subsidy for a BEV, was a list price between €12,000 and €45,000. The budget is spread over the period 2020–2025. The budget for new electric cars was €10 million and for used electric cars €7.2 million. After four days in 2020, the subsidy budget was exhausted. People could apply for the subsidy budget of 2021.

Figure 17 shows that the TCO of a BEV was for years higher than an ICE despite the exemption of road tax and a lower energy consumption price. Due to the purchase subsidy in 2020 of €4,000 on a BEV, the depreciation on a BEV was reduced, resulted in a lower TCO since 2020 for the BEV.

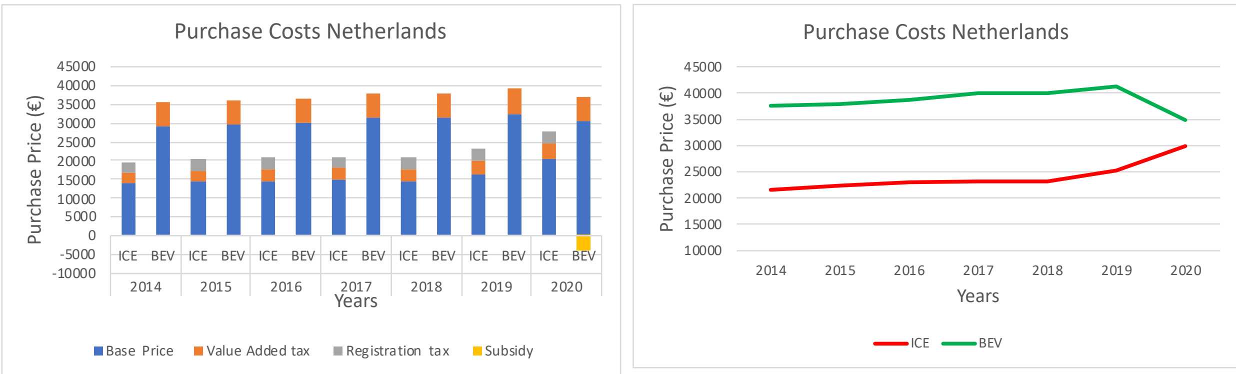


Figure 17: Purchase cost — The Netherlands, VW Golf, and VW E-Golf

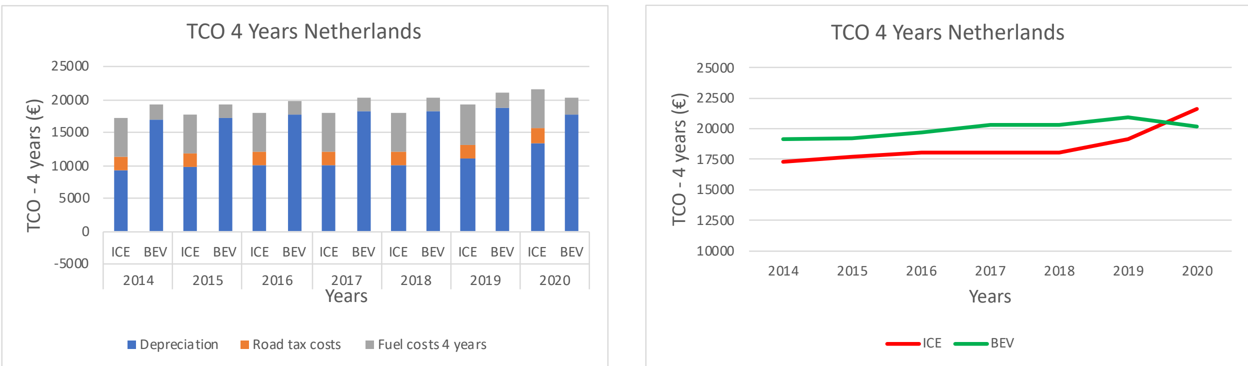


Figure 16: Total cost of ownership – The Netherlands, VW Golf, and VW E-Golf for four years and 15,000 km per year

Germany

Figure 18 shows that the BEV purchase price in Germany is since years substantially higher than an ICE because Germany has no purchase registrations tax that could be used as an incentive for BEV adoption, as in Norway and the Netherlands. Due to EU legislation, 19% VAT is charged both on BEVs and ICE. This is not favorable for BEVs because the base price of a BEV is still higher. In 2020, a major purchase subsidy of €9,000 was introduced for vehicles with a list price up to €40,000. This subsidy made much difference, resulted in a purchase price difference of only a bit more than €2,000.

Figure 19 shows that the TCO for a BEV became lower than an ICE since 2020. This is because of the purchase subsidy resulted in a decrease of the depreciation costs for the BEV and a change in 2020 in the road taxation for passenger cars. Germany started the road tax exemption for 10 years in 2016 as an incentive for BEV adoption, but the road tax for an ICE vehicle was so low that it was hardly a barrier for the ICE. In 2020, the road tax changed, and it now depends on the size of the engine capacity and the CO_2 emissions. The road tax is still not a major part of the operating costs for small engines with a low CO_2 emission, such as the VW Golf 1.0 used in this comparison.

In 2020, the number of BEV sales tripled compared to 2019 and in 2021 almost doubled compared to 2020. Reduction of the purchase costs and the TCO is most likely the reason for this acceleration of BEV adoption in Germany

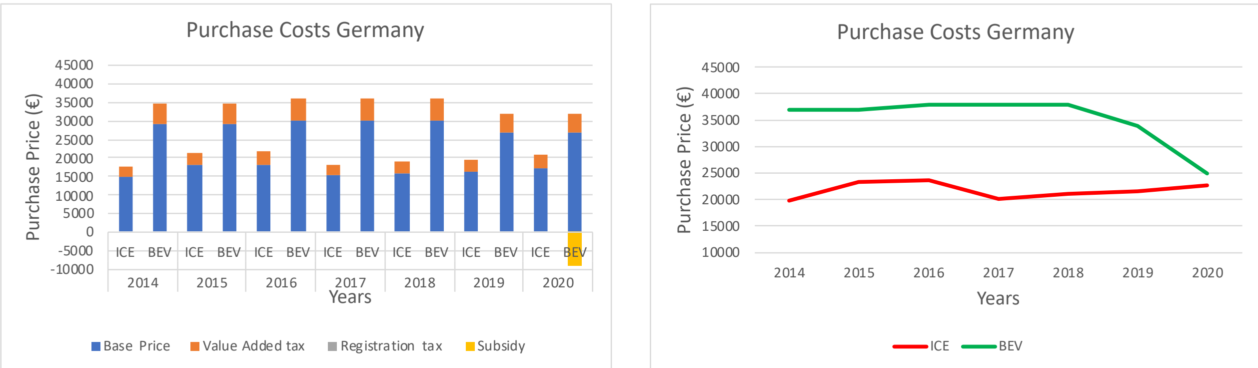


Figure 18: Purchase cost — Germany, VW Golf, and VW E-Golf

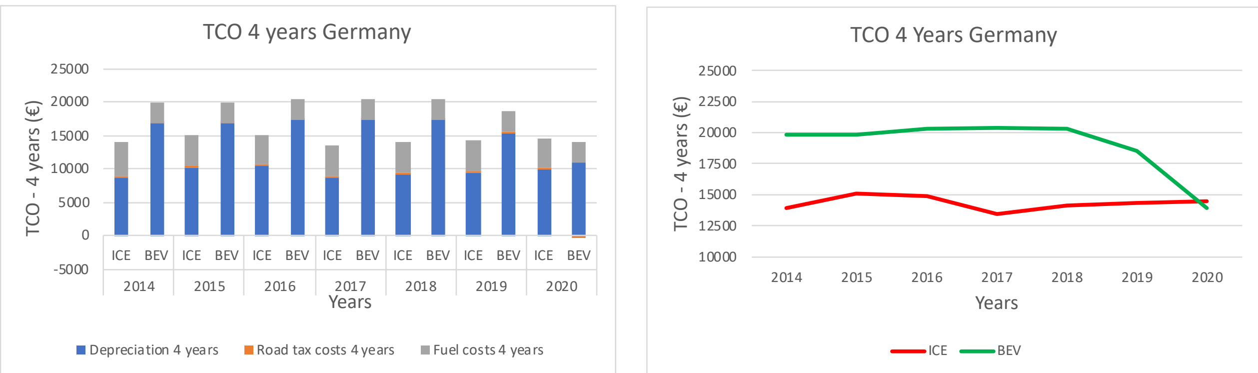


Figure 19: Total cost of ownership — Germany, VW Golf, and VW E-Golf for four years and 15,000 km per year

Spain

Figure 20 shows that in Spain the purchase price of a BEV has always been higher than the comparing ICE. In Spain there is an exemption on registration tax for ICE with emissions of less than 120 g/km CO_2. Modern low- and middle-class ICE like the VW golf do not pay a registration tax and cannot be used as a financial incentive for the BEV. But the difference of the purchase price between the BEV and ICE is decreasing. The reason for this is that in 2020 Spain started with a purchase subsidy for BEVs and that the low-end VW golf ICE model was not available.

Figure 21 shows that the TCO in Spain for a BEV is still higher than an ICE. Taxation on passenger cars in Spain is relatively low, which makes it difficult for financial incentives also on the operational costs. The road tax is locally arranged, and the amount is quite low for an ICE . The energy consumption costs for a BEV are lower than those for an ICE vehicle, but the excise duty on petrol is low compared to other European countries.

A higher purchase price and a higher TCO for a BEV is an indication that Spain performs in the low end of the BEV adoption rate of new registrations in Europe.

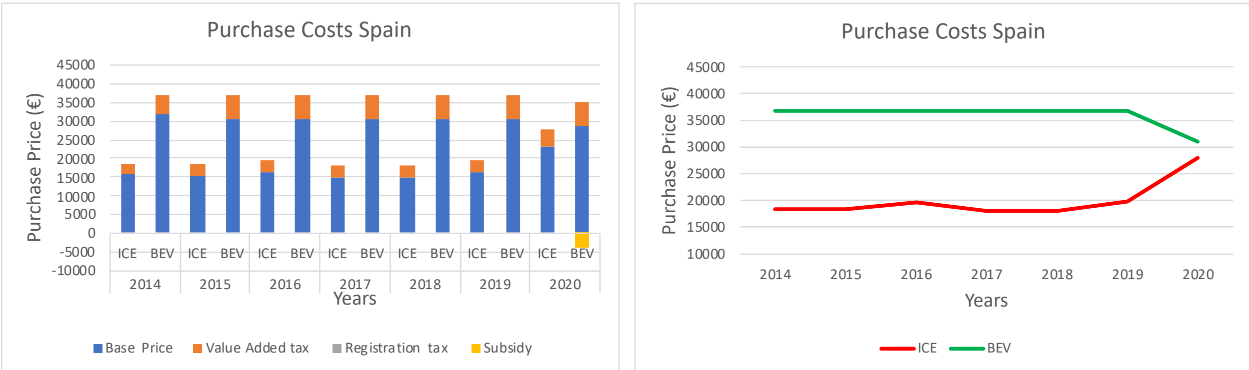


Figure 20: : Purchase cost — Spain, VW Golf, and VW E-Golf

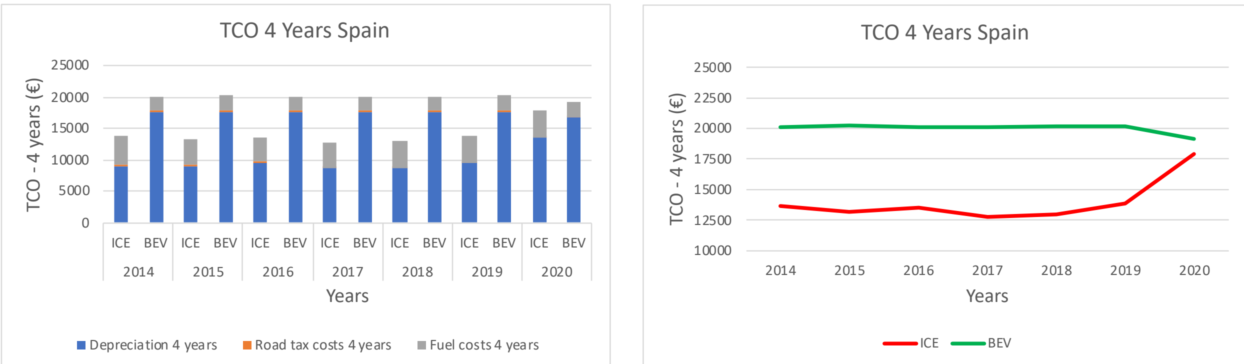


Figure 21: Total cost of ownership — Spain, VW Golf, and VW E-Golf for four years and 15,000 km per year

Poland

Poland belongs to the earliest Rogers category of innovators (0%–2.5%) with a poor BEV adoption of new registrations in 2021 of only 1.5%. Figure 22 shows that the purchase price of a BEV is much higher than an ICE. In 2020 the difference between the comparing models was almost €7,000. Although BEVs are exempted from excise duty, this tax for an ICE vehicle with an engine less than 1,600 cc is only 3% of the vehicle price. Since 2020 a purchase subsidy for BEVs was introduced of 15% of the purchase price with a maximum amount of €4,400, which decreased the purchase price of the BEV in some extent.

Figure 23 shows that the TCO of a BEV is still higher than an ICE. It is difficult to introduce financial incentives on operating costs for BEVs because the taxation on passenger cars is generally so low in Poland. Road tax does not exist. The excise duty for gasoil is €330 per 1,000 liters, which is the minimum due to EU legislation.

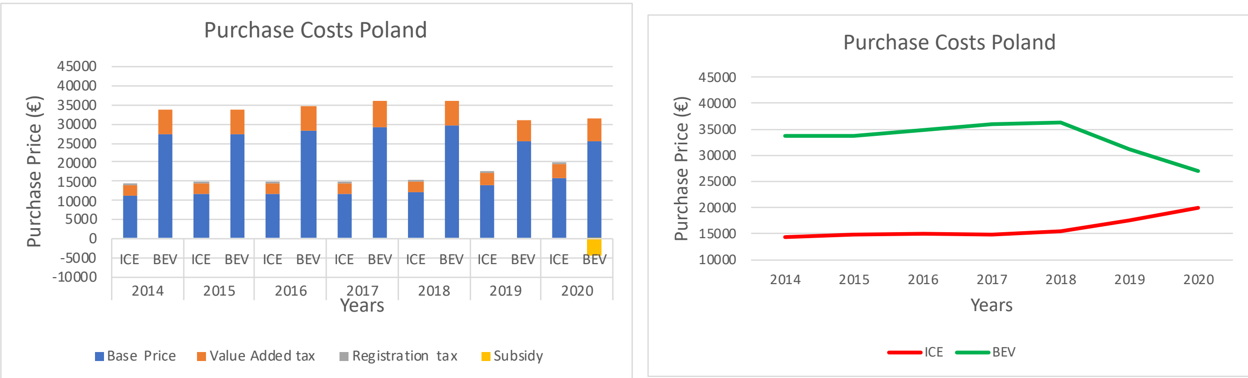


Figure 22: Purchase cost — Poland, VW Golf, and VW E-Golf

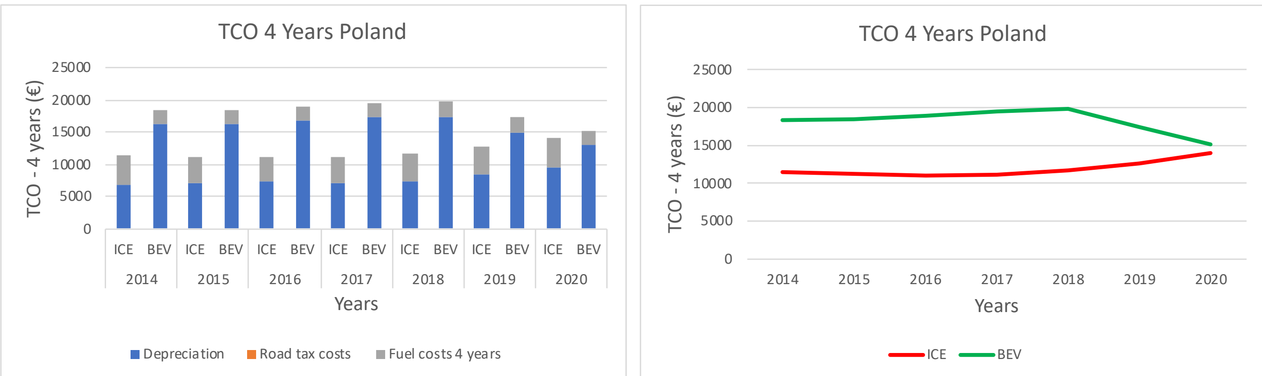


Figure 23: Total cost of ownership — Poland, VW Golf, and VW E-Golf for four years and 15,000 km per year

5.2.3 BIK tax on company cars, privately used in the Netherlands

When a company car is used for private purposes, in many European countries, a Benefit In Kind (BIK) tax is charged. The amount of tax depends on the national income tax system, the income of the individual, and the purchase price of the car. The employee is not the owner of the car and does not pay the purchase price or TCO costs for the car. This is the reason national tax authorities charge a BIK. This paragraph analyzes the differences between BIK tax of an ICE and a BEV in The Netherlands. The reason, The Netherlands is selected to perform the analysis on how the BIK tax can be used as a tool to stimulate the BEV adoption for consumers that drive a company car privately.

The Netherlands, like several other countries has used the BIK tax as an incentive for company BEVs used privately since 2011. The difference is that the amount of incentive decreased gradually during the years, by increasing the percentage of the BIK tax. In 2011 the BIK tax was 0% and in 2026 the BIK tax will be 22%, like the BIK tax for an ICE.

From 2011 to 2013, there was an exemption on BIK tax for BEVs, and from 2013 to 2019, the BIK tax was 4% of the purchase price instead of the 22% for an ICE vehicle. In 2020, the BIK tax increased to 8%, in 2021 to 12%, in 2022 to 16%, in 2025 to 17% and in 2026, the BIK tax will be 22%, both for a BEV and an ICE. A cap on the purchase price for the reduced BIK tax was introduced in 2019 of €50,000 and gradually decreased till €30,000 in 2025.

Figure 24 presents the BIK tax for a top-, middle- and small class vehicle between 2014 and 2026. The BIK tax for a BEV was compared with an ICE.

A yearly income of €35,000, €50,000 and €70,000 was used. In this paragraph the income of €50,000 is presented. The outcome for the other incomes is presented in appendix E.

For the top-class vehicle, a Tesla Model S as a BEV and a BMW 528/530 as an ICE were selected. For the middle-class vehicle, a VW E-Golf and in 2020 a VW ID3 were selected as a BEV. the A VW Golf 1.2/1.0 85HP was selected as an ICE. For the small-class vehicle, a VW E-Up as a BEV and a VW Up as an ICE were selected.

From 2014 till 2018 a consumer paid less BIK tax for a top-class BEV than a middle-class ICE and almost the same as for a small class ICE. From 2019 this change because of the purchase price cap introduced.

Since 2021, the BIK tax for top-class BEV model is higher than an ICE. This because the purchase price of a BEV is higher than an ICE, the cap on the purchase price decreased and the BIK tax for a BEV increased. From 2022, the BIK tax for a middle-class BEV will be higher than a comparing ICE.

For a small-class BEV, the BIK tax will continue to be lower than an ICE, because the purchase of a small class BEV is lower than the purchase price cap till 2025.

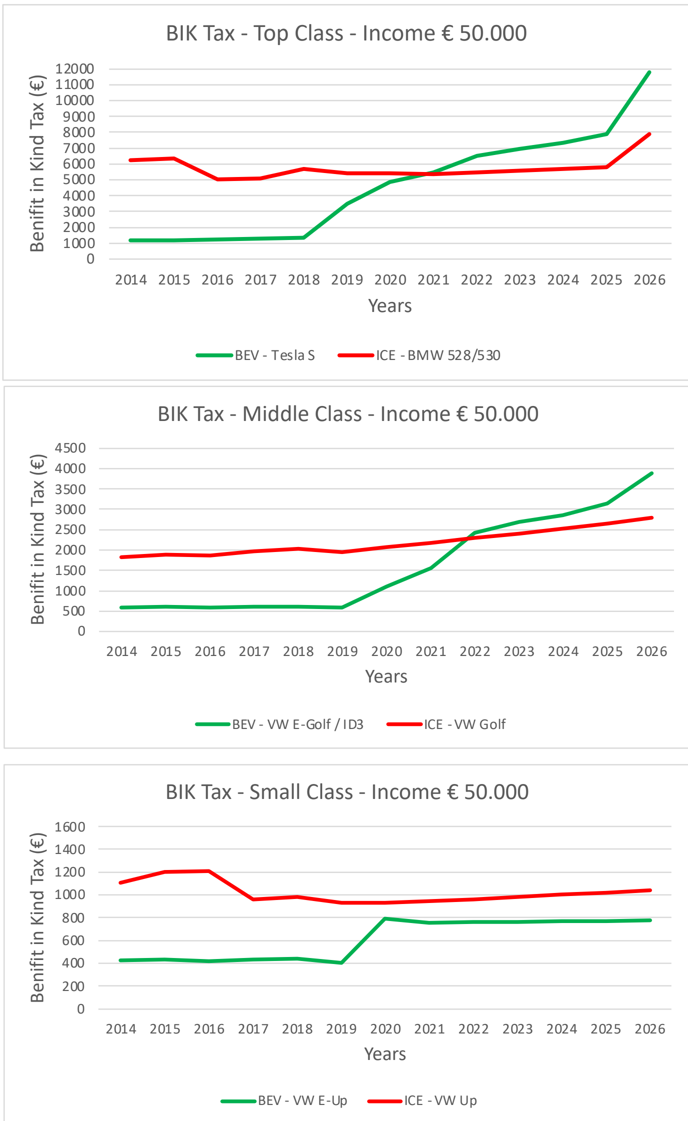


Figure 24: BIK Tax for a Top-, Middle- and Small Class Vehicle

5.2.4 Cost Benefit analysis

Based on the general ICE and BEV parameters, a cost benefit analysis model has been made to analyze when it is cheaper to drive a BEV and also more sustainable in the future, in contrast to the TCO analysis that performs an analysis in the past.

5.2.4.1 Cost to consumer results

Table 8 shows the excess cost to consumers of driving an ICE or a BEV. A positive value means that it is more expensive to drive a BEV than an ICE. A negative value shows that it is cheaper to drive a BEV. The results show that a low segment BEV is still more expensive than an ICE in all comparative countries, with the exception of Norway when 30,000 km are driven.
Furthermore, under the current conditions in 2021, it is more advantageous to drive a medium and high range BEV compared to the ICE in all comparative countries.
Finally, how expensive it is to drive a BEV or ICE varies from country to country. This is because each country has a different policy regarding subsidies and taxes.

Table 8: Excess cost to consumer (ICE vs BEV)

10.000 km	Low segment car	Medium segment car	High segment car
Norway	€ 2,883.15	€ -21,746.86	€ -82,773.76
Netherlands	€ 7,932.39	€ -17,551.91	€ -59,755.62
Germany	€ 8,234.53	€ -2,743.94	€ -6,285.52
Spain	€ 13,224.93	€ -7,166.91	€ -18,544.86
Poland	€ 14,174.53	€ -1,169.55	€ -14,772.64

20.000 km	Low segment car	Medium segment car	High segment car
Norway	€ 285.90	€ -26,234.11	€ -89,906.93
Netherlands	€ 5,578.37	€ -21,748.08	€ -66,502.32
Germany	€ 7,978.81	€ -4,447.47	€ -9,738.70
Spain	€ 12,263.39	€ -9,632.61	€ -22,939.55
Poland	€ 13,026.12	€ -3,455.10	€ -18,583.89

30.000 km	Low segment car	Medium segment car	High segment car
Norway	€ -2,311.35	€ -30,721.37	€ -97,040.09
Netherlands	€ 3,224.34	€ -25,944.25	€ -73,249.02
Germany	€ 7,723.10	€ -6,151.01	€ -13,191.88
Spain	€ 11,301.86	€ -12,098.31	€ -27,334.24
Poland	€ 11,877.70	€ -5,740.65	€ -22,395.13

5.2.4.2 CO_2 gain results

CO_2 gains indicate how the electricity for a BEV is generated in a country and determines how sustainable it is to drive a BEV. Table 11 shows the CO_2 profit per country for a BEV from the low, middle and high segment, driving 10,000, 20,000 or 30,000 km per year. The higher the value, the lower the indirect CO_2 emissions of the BEV.

Furthermore, it can be seen that in every country, for every car segment and for longer distances, it is more sustainable to drive a BEV than an ICE. Another conclusion is that the higher the car segment, the more sustainable a BEV is than an ICE. The more people drive per year, the more sustainable a BEV is compared to an ICE.

By generating electricity, a BEV indirectly emits CO_2. In Norway, electricity is mainly generated by hydroelectric power plants, which is one of the most sustainable methods of energy generation, and therefore driving a BEV in Norway is much more sustainable than in Spain, Germany, the Netherlands and Poland respectively.

Table 9: CO_2 gain results

10.000 km	Low segment car	Medium segment car	High segment car
Norway	17.05	25.89	39.46
Netherlands	6.07	14.79	26.45
Germany	9.08	17.83	30.01
Spain	11.20	19.98	32.53
Poland	0.29	8.94	19.20

20.000 km	Low segment car	Medium segment car	High segment car
Norway	34.10	51.79	78.91
Netherlands	12.15	29.59	52.91
Germany	18.16	35.66	60.03
Spain	22.41	39.96	65.06
Poland	0.58	17.88	39.20

30.000 km	Low segment car	Medium segment car	High segment car
Norway	51.15	77.68	118.37
Netherlands	18.22	44.38	79.36
Germany	27.24	53.50	90.05
Spain	33.61	59.94	97.59
Poland	0.86	26.83	58.80

5.2.4.3 *Sensitivity analysis*

Table 10 shows the original values that were representative in 2021. The values may have changed due to economic and political changes.

Table 10: Original values Cost Benefit Analysis

10.000 km - low segment	Norway	Netherlands	Germany	Spain	Poland
ICE parameters					
Consumer price	€ 24.541,00	€ 20.590,00	€ 17.700,00	€ 14.750,00	€ 13.567,00
Fuel price	€ 1,47	€ 1,57	€ 1,32	€ 1,27	€ 1,03
Road tax	€ 282,88	€ 511,00	€ 64,00	€ 22,20	€ -
BEV parameters					
VAT	0%	21%	19%	21%	23%
Consumer price	€ 29.288,00	€ 35.390,08	€ 33.890,01	€ 31.610,04	€ 31.633,14
Home charger	€ 2.056,00	€ 1.875,50	€ 1.424,43	€ 1.430,22	€ 1.656,81
Electricity price	€ 0,15	€ 0,17	€ 0,32	€ 0,25	€ 0,14
CO2 in electricity production	19	442,82	356,69	249,28	721,27
Purchase subsidy	€ -	€ -4.000,00	€ -9.000,00	€ -4.000,00	€ -4.400,00

Table 11 shows the percentage change from the original values that would be needed for the low-range BEV to become cost effective with the ICE.

Table 11: Sensitivity analysis

10.000 km - low segment	Norway	Netherlands	Germany	Spain	Poland
ICE parameters					
Consumer price	12%	39%	47%	90%	104%
Fuel price	76%	213%	279%	433%	615%
Road tax	218%	332%	2750%	12742%	€ 3.032,00
BEV parameters					
VAT	-	-21%	-23%	-40%	-42%
Consumer price	-10%	-22%	-24%	-42%	-45%
Home charger	-140%	-423%	-593%	-925%	-855%
Electricity price	-240%	-580%	-306%	-632%	-1229%
CO2 in electricity production	3400%	53%	107%	176%	2%
Purchase subsidy	€ -2.883,00	€ -11.932,00	€ -17.234,00	€ -17.225,00	€ -18.574,00

Governments are unlikely to tax the low segment ICE more so that the BEV becomes cost effective. This will cause resistance from citizens and the car industry.
This shows that there is actually one value left that governments can easily influence, because governments do not have to change the value in percentage terms. Governments will have to lower the consumer price of the BEV. It can be seen that the relatively well performing countries have to lower the consumer price less than the poor performing countries. It can also be seen how much governments have to lower the consumer price. This is indicated with the purchase subsidy.
Finally, it can be seen that Norway, Germany and Spain produce their electricity in a relatively sustainable way. On the other hand, the Netherlands and Poland produce their electricity in a less sustainable way. In the case of Poland, when the CO_2 concentration in electricity production increases by 2%, the BEV is not a sustainable replacement.

5.2.5 Charging infrastructure

5.2.5.1 Public normal-charging points (AC)

Normal charging points are mainly used for daily driving with a BEV in limited area from the home of the BEV consumer. The public normal charging is analyzed by calculating the ratio between the number of BEVs in use to the number of charging points available in a certain year. When the ratio is low, the charging infrastructure is adequate to supply the BEVs with electricity. Figure 25 shows the ratio between the number of BEVs in use to the number of charging points of the comparing countries between 2010 and 2021.

Norway, with the highest BEV adoption in the world, has a relatively low number of normal power points. In 2021 the ratio between BEVs to charging points was 33:1, which is high compared with The Netherlands that had a BEV to charging point ratio of 3:1. This high number of BEVs per normal-charging point indicates that the public normal-charging points are not a pre-condition for the acceleration of BEV adoption in Norway. The reason is that, in Norway, the share of home charging is even above 90% (Figenbaum et al., 2016). The public normal charging infrastructure together with the private charging infrastructure is well developed in Norway and is no barrier for the BEV adoption in Norway.

Since 2013, the Netherlands has been the absolute frontrunner in public normal-charging points in Europe, with 79,849 charging points in 2021 (29% of Europe). The main reason is that the availability of private home charging infrastructure is low in the Netherlands, and public slow-charging infrastructure is needed as a substitute. There is no reliable information about the amount of private charging infrastructure in the Netherlands. A derived method is to relate the amount of private charging infrastructure to the share of detached houses of the total housing in a country. This information is available of every European country (Eurostat 2021a). The Netherlands have only 17% detached houses compared with Norway with 57% and thus the (potential) availability of private home charging, is low (Helmus et al., 2018). A dense network of public slow-charging infrastructure was built not only for public charging but also as an important alternative to home charging infrastructure. The public normal charging infrastructure well developed with a ratio of 3:1 and is no barrier for the BEV adoption in The Netherlands.

Germany has a BEV-to-charging-point ratio of 16:1 in 2021. Private home charging is the most important, and the second-best option is charging at work (Gnann et al., 2018). The public normal charging infrastructure together with the private charging infrastructure seems to be at this moment no barrier for the BEV adoption in Germany. Germany is with a BEV adoption share of 13% in the early phase of the BEV adoption and is ambitious to accelerate. Further development either in private or public charging points shall be necessary.

Spain has a BEV-to-charging-point ratio of 13:1 in 2021. The reason that this ratio seems to be better than the ratio in Germany is because of the low amount of BEVs in Spain and not of the high amount of normal charging points. Spain has a poor public normal charging infrastructure, with only 5,607 normal-charging points in 2021 and based on the low percentage of detached houses, the private home charging infrastructure is also not well developed and is likely a barrier for the acceleration of the BEV adoption. The Spanish national authorities initiated the MOVES grants in 2021, covering between 30% and 40% of the purchasing and installation costs associated with publicly accessible charging stations. With these financial incentives Spain tries to solve the poor normal charging infrastructure.

In Poland the normal public charging infrastructure is poor developed with only 2,293 normal charging points in 2021. The ratio between BEVs and AC charging points is 6:1 because of the very low number of BEVs in use. As in Norway, 50% of the people live in a detached house in Poland. Private home charging is an alternative for public normal charging in Poland. Poland is a very poor performer in the BEV adoption with a share of 1.5% of new BEVs in 2021. The normal charging infrastructure in Poland is likely to be a barrier when there is ambition with the acceleration of BEV adoption in Poland.

An alternative outcome measurement is to calculate the ratio between the number of charging points to the number of residents per country. The higher the ratio the better the charging infrastructure. Figure 26 shows that The Netherlands performs the best followed by Norway. The Netherlands represents a well developed normal charging infrastructure with a low amount private charging points and Norway represents a well developed charging infrastructure with a high amount of private charging points.

The Netherlands had in 2021 4.62×10^{-3} normal charging points per resident and Norway 2.45×10^{-3}. If Germany and Poland would have the same normal charging points per resident as in Norway than Germany and Poland should respectively need an additional amount of charging point of about 162,00 and 91,000. If Spain with a low amount of private charging points would have the same normal charging points per residents as the Netherlands, an additional amount of 211,000 normal charging points are needed.

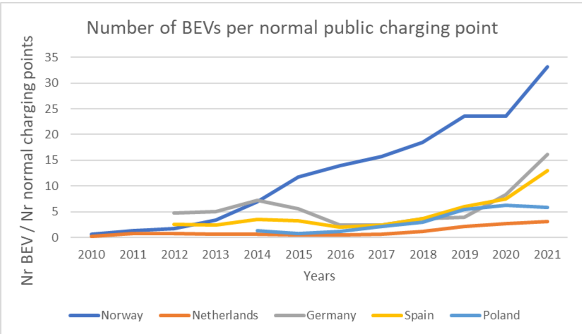


Figure 25: Number of battery electric vehicles (BEVs) per normal-power charging points between 2010 and 2021

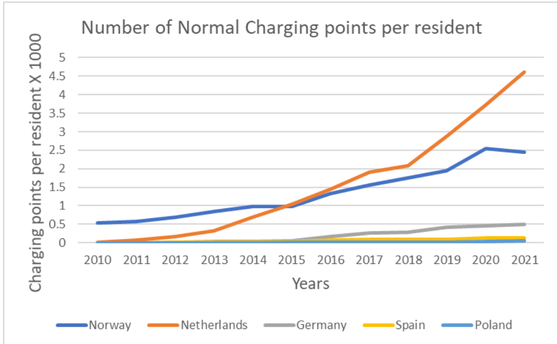


Figure 26: Number of normal-power charging points per resident between 2010 and 2021

5.2.5.2 ***Public fast-charging points (DC)***

Public fast-charging points (DC) are of importance to travel longer distances. An outcome measure how well the fast-charging infrastructure is developed (EAFO, 2020) are the number of charging points per 100 km highway. The more high-power fast charging points per 100 km the better developed charging infrastructure. Figure 27 shows that Norway has by far the best fast-charging infrastructure in Europe. One of the reasons of such a high ratio is that Norway has on 523 km highway. The Netherlands, Germany, Poland and Spain are following. Spain had in 2021 only 17 high-power charging points per km. Spain has highways spanning more than 15,000 km but only 2643 fast charging points in 2021, which is likely a barrier for the BEV adoption.

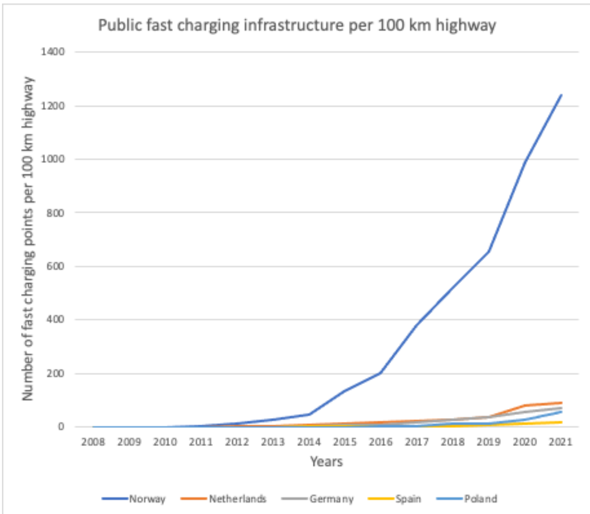


Figure 27: Public fast charging points per 100 km highway

There are no data available how the high-power fast charging points relate to the range anxiety for long distance driving. For this it is necessary to know the distance between the fast-charging locations on a highway and the number of charging points per location. Ideally after every 50-100 km highway a fast-charging location exist, like a petrol station for an ICE.

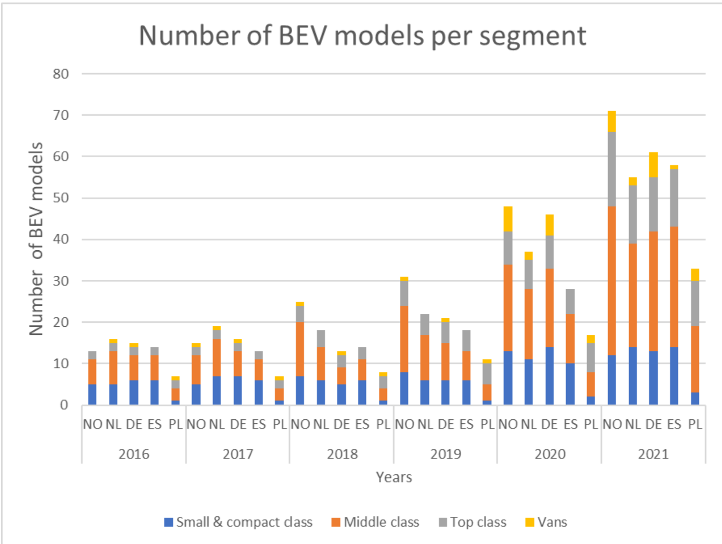
5.2.6 *Model availability*

This section examines how model availability has affected BEV adoption in the five case countries. First, the BEV model development process between 2016 and 2021 is examined. Second, the number of BEV models in the market per country is investigated, and those models are clustered in three classes.

5.2.6.1 Number of models divided per segment

Figure 28 presents the BEV model availability of the comparing countries between 2016 and 2021, divided per passenger class segment.

Model availability has increased during the last five years. In 2016 and 2017, there was no great difference in model availability in the compared countries, except Poland, where it was much lower. Since 2018, the most number of models have been available in Norway, followed by Germany and the Netherlands. There was a remarkable acceleration of models in Germany in 2021 to 61 models, 10 less than Norway. Germany is an important market for BEV car manufacturers because, since 2019, the most annual BEVs have been sold in Europe was in Germany.



Norway = NO, Netherlands = NL, Germany = DE, Spain = ES, Poland = PL

Figure 28: Number of models, divided per car segment, between 2016 and 2021

Analyzing model availability per class, it is shown that, in 2021, for small or compact cars (Segments A and B), the consumer could choose from at least 10 models in all compared countries except Poland with only 3 models. The number of small & compact class sales in Germany is well represented (41%) in the number of sales.

Model availability is the best for the middle-class BEVs in the compared countries. In 2021, for a middle-class car (Segments C, D, J, and L), the consumer could choose from 36 models in Norway, 29 in Germany, and Spain, 25 in the Netherlands and 16 in Poland.

The reason of a high amount of models in Norway is likely of the high BEV adoption share. Another reason is that BEV manufactures introduce often new models first in Norway followed in other countries the next years. The high amount of models in Germany can be explained, that in Germany the most BEVs in numbers are sold now of the European countries. The low amount of BEV models in Poland and especially the small and compact class, can be explained that Poland is really in the very beginning with the BEV adoption with a BEV adoption share of new registrations of only 1,5%.

5.2.6.2 Model availability related to annually BEV adoption share and sales

Until 2019, Norway was the absolute market leader in Europe in terms of BEV sales and BEV adoption share which was also shown in the number of models available in Norway.
Figure 29 shows that Norway with the highest BEV adoption share has the most BEV models, but The Netherlands with the second-best adoption share has less models than Germany and even Spain in 2021. Poland with the lowest BEV adoption share has as expected the least models.
Figure 30 shows that Germany, the country with the most BEV sales in Europe has next to Norway the most BEV models. In Spain less BEVs were sold in 2021 than in The Netherlands, but there were more BEV models available. An explanation for this is difficult to give. Poland with the lowest BEV sales, had also the lowest number of BEV models.

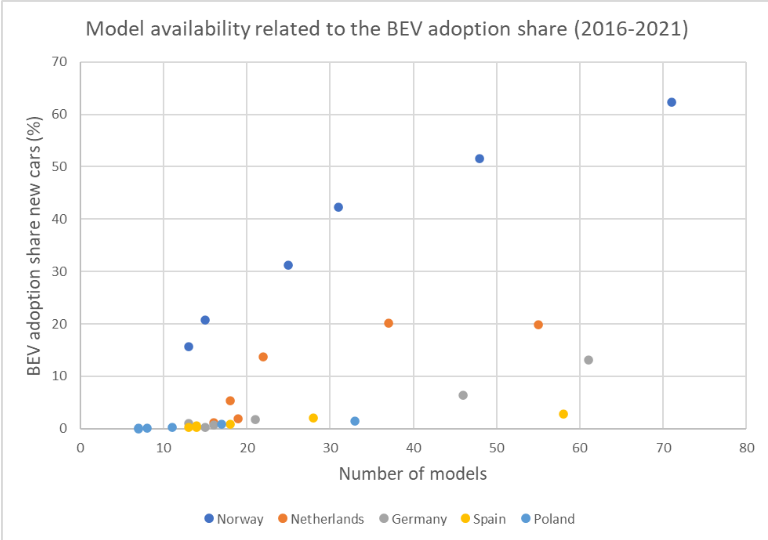


Figure 29: Model availability related to the BEV adoption share

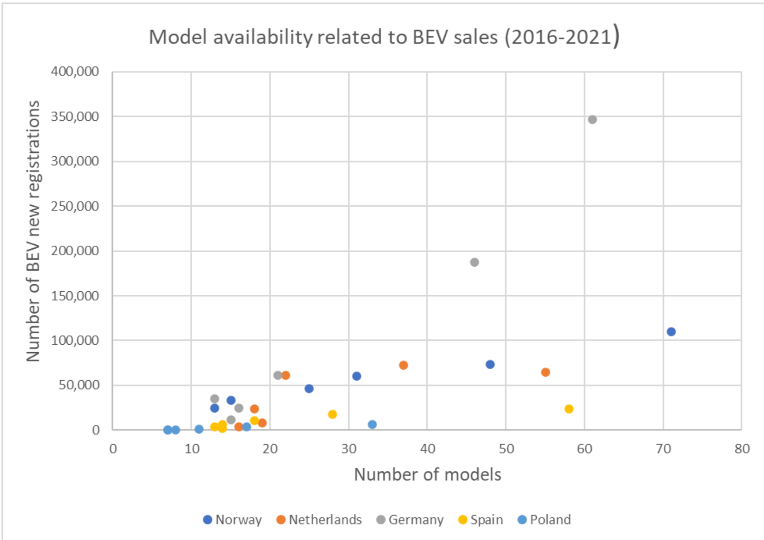


Figure 29: Model availability related to the annually BEV sales

5.2.7 *Consumer characteristics*

5.2.7.1 ***Income***

In 2020, there was a positive medium correlation (R = 0.5; *p* = .001) between BEV adoption of new passenger cars and the GDP per capita in Europe (Eurostat, 2022). Norway, Iceland, and the Netherlands have a better BEV adoption rate than expected. Luxemburg, Ireland, Switzerland, and Denmark have a lower BEV adoption rate than expected. Norway and Iceland, both members of the EFTA, utilized the exemption from the purchase VAT on BEVs. Switzerland, also a member of the EFTA, did not utilize this purchase VAT exemption. In 2011, the Netherlands introduced a significant incentive for driving a business BEV for private purposes with an exemption on the BIK tax. This BIK is 22% of the purchase price for an ICE vehicle. From a GDP per capita aspect, it is not clear why Denmark, Ireland, and Luxemburg performed less than expected.

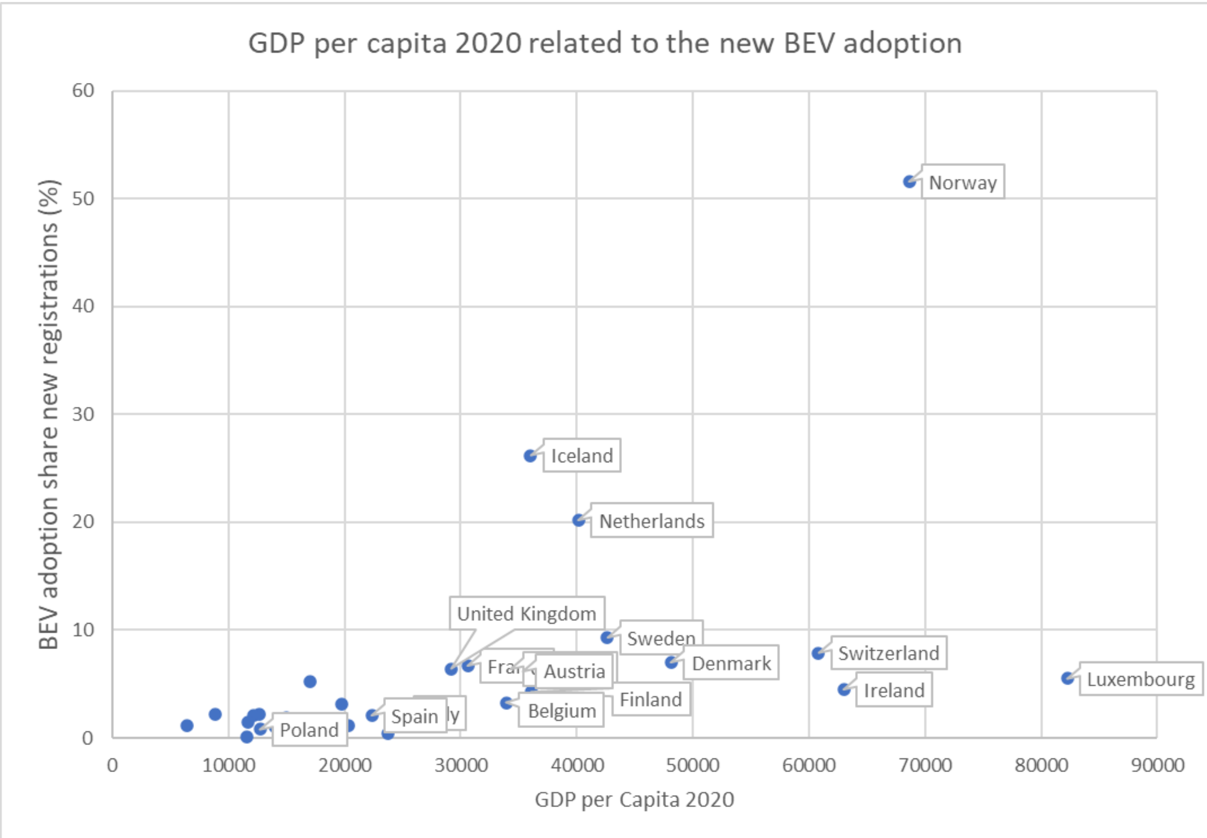


Figure 30: Gross domestic product (GDP) per capita related to BEV adoption share

5.2.7.2 ***Age distribution***

Analysis of the European age distribution (Eurostat, 2021c) of the population between 18 to 40 years old indicated no correlation between the share of young consumers (18–40 years) and BEV adoption in a European country. This result, however, does not mean that there is no correlation because no analysis could be performed between the ICE and BEV consumers in the 18–40 age range.

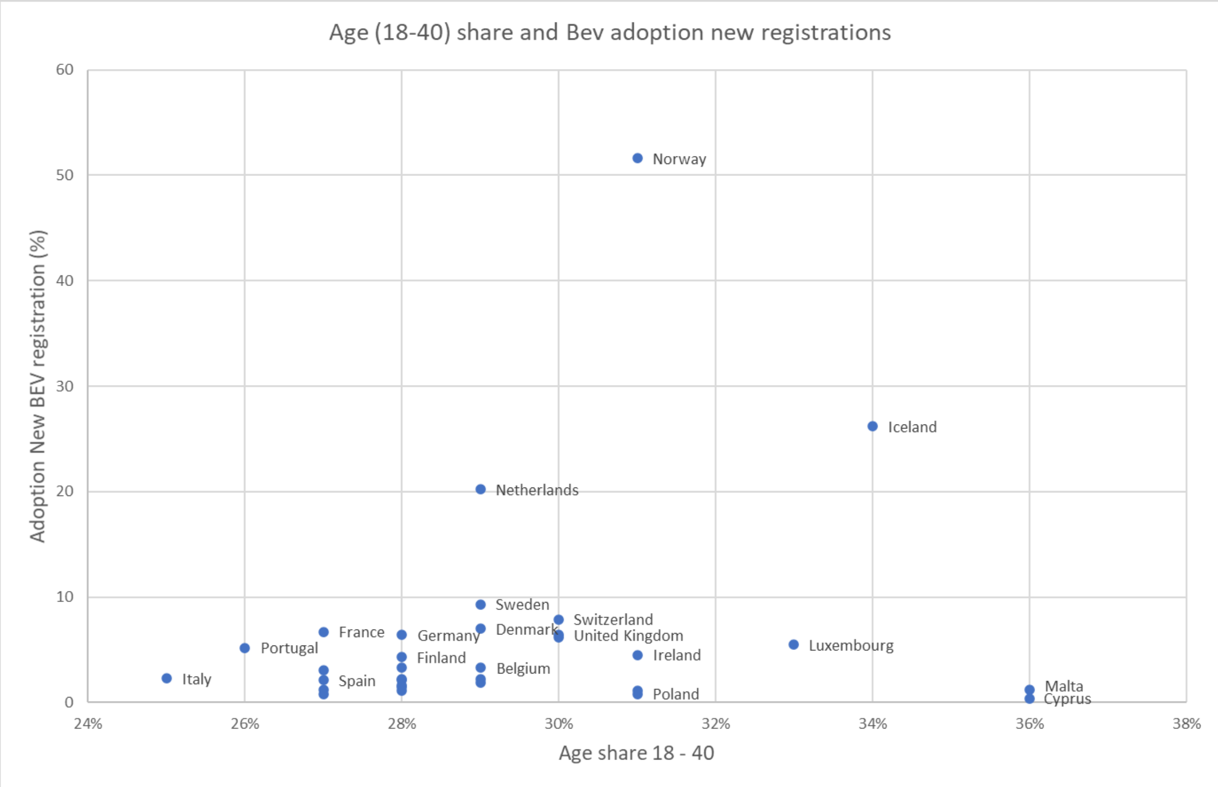


Figure 31: Age distribution and battery electric vehicle (BEV) adoption

5.3 Interview outcome summary

A semi-structured interview was conducted with 12 interviewees. The questionnaire is documented in appendix K1 and the list of interviewees is presented in appendix K2 and were categorized per question and are presented in this section. If possible, the differentiation of the background of the interviewee is mentioned.

5.3.1 The most important factors that are influencing the adoption of EVs

All interviewees were unanimous that the additional costs for a BEV and the charging infrastructure are the two most important factors influencing the BEV adoption. From the Research sector and the automotive sector, the differentiation between purchase costs and total cost of ownership (TCO) was also mentioned as important. The majority of consumers select primary a car on the purchase price and less on the TCO. Some individual remarks were: BEV station wagon model used by many families are not yet available, driving a caravan with a BEV during holiday is not possible in practice, the lack of awareness in Poland about sustainability of passenger cars and the unfamiliarity with electric driving. In Spain and Poland, the BEV is for the “elite” as the second car is for driving in the city. For the weekends an ICE is necessary for driving longer distances.

5.3.2 Different policy strategies between European countries

Norway has the policy that the consumer drives a BEV and in Germany and the Netherlands, the BEV is promoted but there is still a choice to drive an ICE. The Netherlands has focused primarily on the business BEV consumer market, Norway on the private consumer market and Germany on both. The Netherlands has the best public normal charging infrastructure. Norway relies on private charging at home. Spain and Poland have not yet a well-developed charging infrastructure. Goals to meet the European Green Deal and that all new passenger cars are 100% BEV is for Norway 2025, The Netherlands 2030, Germany 2035, Spain 2040 and Poland has not set a year. Norway and The Netherlands have a high taxation policy on passenger cars which give these countries the possibility to introduce financial incentives on the BEV with exemptions on taxation for the BEV. Norway is the only country where the purchase price of a BEV is lower than an ICE.

5.3.3 Is there a policy on different types of people on BEV adoption in Europe?

The majority of the interviewees answered that the private and business BEV consumer market receives different kind of financial benefits. From the automotive sector the answer came that private car consumers buy primarily a used car and the business market drives a new lease car for 4 years.
The research sector explained that in areas with non-detached houses and flats public charging infrastructure is needed. People living in detached houses charge their BEV privately at home.

5.3.4 Are there lobby activities to national authorities and to the EU

There are some indications but not scientifically documented. The research sector mentioned that the German Car manufactures needed time to launch their BEV models and have used pressure to postpone the financial incentives for BEV adoption and development of the charging infrastructure In Spain, a big part of the employment is dependent on the car manufacturer industry. This sector is providing 11% of the Gross National Product and there was a resistance to the BEV innovation.

5.3.5 Which incentives in the past were without effect.

In The Netherlands buying a PHEV in the past received the same financial incentives as a BEV. The Mitsubishi Outlander was very popular. Consumers drove these vehicles mainly on petrol and not on electricity. Arranging free parking for BEVs was in many cases too difficult.

5.3.6 What are future incentive plans to stimulate BEV adoption

In Norway the incentives are at their peak and will sooner be phased out. Only for the northern region of Norway additional subsidies will used for the development of the charging infrastructure. The Netherlands will continue with the purchase subsidy on BEVs for private consumers. In Germany a masterplan of billions of Euros will be launched to develop the charging infrastructure in the country. Spain will receive from the EU Covid recovery fund billons of Euros. This will be used mainly in the electrification of mobility and the transition to E mobility. In Poland it is not clear what the future incentive plans are to stimulate the BEV adoption.

5.3.7 What are the barriers for consumers buying a BEV?

According to the majority of the interviewees, the most important barrier is that the purchase price is still higher than an ICE except in Norway. The automotive and authority sector mentions the model availability of the low segment BEVs. There is not yet a market of used BEVs affordable for the majority of the private consumer of around € 10,000. There is not yet a BEV family station wagon available and driving a BEV with a caravan during holiday is in practice not possible due to range limitations. There is an uncertainty buying an used BEV about the lifespan of a battery of a BEV.

5.3.8 How can these barriers be tackled?

The BEV purchase price will reduce because battery price will continue to reduce and due to more model availability, more competitions exist between BEV manufactures. The battery price reduced 85% between 2011 and 2019. It is expected that the purchase price of a BEV in 2024 – 2025 equals with an ICE. Efforts must be made developing a mature charging infrastructure. BEV consumers need to be better informed about the electricity price and free charging points to use the charging points more efficiently. In Poland it is important to put afford in the awareness of sustainability and motivate the Polish consumer in cleaner cities.

5.3.9 How is the electricity price for BEV compared to petrol and diesel for the ICE

The price of electricity for a BEV is in general lower than the petrol and diesel. Charging at home is by far the cheapest and with solar panels even for free. High power fast charging on the highway can be more expensive than petrol for an ICE. The research and automotive sector mentioned that unlike petrol the price of electricity of public charging points can differ till 300%. People with lower incomes are less likely to have their own driveway and charger to charge their car, which means that they have to pay 50% more with a public charging point to charge their BEV.

5.3.10 Charging infrastructure compared to the increase adoption of BEVs?

From the research sector is explained that a double of BEVs does not mean that the charging infrastructure needs to double. In Norway many commercial charging point operators exists. They use Norway as a pilot country, and it is expected that these companies will settle also in other European countries. In Poland the charging infrastructure is still so under developed that it is lagging the BEV adoption. From the research sector was mentioned that countries with a low BEV adoption rate need 1 BEV to 1 public charging point. Countries with a higher BEV adoption rate need 2-3 BEV to 1 charging point.

5.3.11 Model availability in relation to the BEV adoption

Model availability is a positive factor, the more BEVs you can buy, the more likely the EV adoption will increase. The offer must be wider in the lower segments, to reach the mainstream market. From the research sector was mentioned that it is not that the number of models is driving BEV adoption, it's a trade-off between where the car manufacturers launch the BEVs and they launch models in a country with good policies and incentives and favorable BEV conditions in the next 5 years. Many car consumers stick to the same car manufacturer. These consumers wait till the manufacturer also launch a BEV model. For example, “always drive a VW”. The model availability is maturing but station wagons are still not available while that is a popular family car.

5.3.12 Relation GDP per capita and age difference:

In literature is mentioned that age, income and education level are correlated to BEV adoption but young people have lower incomes and thus less BEVs and younger people seem to be less concerned with a car ownership, but more with carsharing. When the young age group is normalized for income there is a correlation between age and BEV adoption.

5.3.13 Willingness to pay:

People prefer the cheapest option when they buy a car. Most people will never buy a new car, but only a used car. The market for used BEVs is still too expensive. Passenger car consumers focus primarily on the purchase price and less to the total cost of ownership (TCO). Even when the purchase price of a BEV is equal to an ICE, many car consumers prefer an ICE because of the range anxiety with a BEV. For the low-class segment BEV, it is difficult to compete a comparing ICE. VAT, registration tax and motor vehicle tax is relatively low for these ICE. For Poland the willingness to pay is low but in contrast, 33 of the 50 most polluting cities in the whole world are in Poland. There is a strong drive in some cities to try and get that smog down. The willingness to pay might increase to contribute to this air pollution problem.

5.3.14 The role of range anxiety

Range anxiety is a serious factor that many passenger car consumers prefer an ICE to an BEV. Range anxiety is exaggerated due to unfamiliarity with the possibilities. A driving range for a BEV of 300 km is more than sufficient in general. The average daily driving distance is 80 km and people travel 1-2 times per year a long-distance trip for holidays. Even in Norway, the country with the best charging infrastructure, range anxiety plays a role. When people leave for the weekend to the mountains there are traffic jams near public charging points on the highways.

5.3.15 How can the scaling up of EV adoption at a European level be accelerated?

The most effective policy is that a national authority announces that new car registrations must have zero emissions. The purchase price of a BEV must be equal and better lower than an ICE. Base price of BEVs is decreasing but when there is still a difference between an ICE in a country, the price difference must equalize through financial incentives on the national car taxation policy.

The total cost of ownership (TCO) of a BEV needs to be lower than an ICE. Operating cost incentives for BEVs like reduced fares for parking and tolls need to be used.

Non-financial benefits for a BEV or barriers for an ICE are also important for the BEV adoption accelerations in Europe. Examples are emission free zones in cities and parking privileges for BEVs.

Charging points at home, at work and public charging point for BEV consumers not living in a detached house must be well developed. High power fast charging points on highways needs to exist every 50 – 100 km. On roads with few cars driving, charging point operators need to get subsidies.

The EU has the power to car manufactures to reduce the number of new cars that are not emission free.

The acceleration of the BEV adoption in Europe cannot be the case that the North and the West will pay for the South and the East. It must be feasible. It should become a stimulus in the economy of the European countries and that the BEV adoption will become self-supporting.

The BEV adoption started out as a sustainable replacement for the ICE, but it is also needed to be a critical on this policy from a sustainability point of view. Consumers can share the opinion that they don't want a BEV at all and are banning a car. People want to be better for the world and a better public transport system and car share opportunities is part of the discussion to reduce the CO_2 emissions in the transport sector.

5.4 Characteristics of well- and poor-performing European countries

The characteristics of well- and poor performing European countries are presented in Table 12 and summarized in table 13. In figure 33 an overview is given of the governmental incentives between 2008 and 2021 to stimulate battery electric vehicle (BEV) adoption.

Norway and the Netherlands represents the well performing countries, where Norway is the champion of Europe with 62% of annually new BEV registrations. In Norway both the purchase price and the total cost of ownership of a middle-class BEV is cheaper than an ICE. Spain and Poland represent the poor performing countries where Poland is one of the worst performing countries in Europe. In both Spain and Poland, the purchase price and the TCO are for a BEV higher than an ICE. Germany represents the category where the new BEV consumers belong to the early adoption phase, but is very ambitious to accelerate in the BEV adoption.

There is an indication that the well performing countries have a history of an extensive program of financial incentives on BEVs both on the one-time costs as on the operating costs. Substantial financial incentives for BEV are possible when the taxation on ICE is high. Exemption or reduction of the taxation of BEV results in a lower total cost of ownership of the BEV compared to the ICE. These financial incentives on BEV exists already for many years in these well performing countries. The next characteristic of the well performing countries are a well-developed charging infrastructure which is a precondition for a well-developed BEV adoption. Factors that have no influence on the well or poor performing countries from this thesis are the consumer characteristics like age distribution and the income of the BEV consumer. The poor performing countries have a low taxation on the ICE. Reducing this tax for the BEV has little effect because the financial incentive for the BEV is relatively low. Poor developing countries have a poor developed charging infrastructure.

Table 12: Characteristics of well- and poor performing European countries

	Norway	Netherlands	Germany	Spain	Poland
BEV adoption (2021)					
New BEVs (%)	62.3	19.9	13.2	2.8	1.5
New BEVs (numbers)	109,872	64,372	346,748	24,039	6,769
BEVs in use (%)	15.1	2.83	1.36	0.30	0.06
BEVs in use (numbers)	433,153	243,664	658,972	72,738	13,614
Purchase price BEV < ICE	+	-	-	-	-
TCO BEV < ICE	+	+	+	-	-
Demographics					
Population (million)	5.3	17.3	83.0	46.9	38.0
Total land area (km2)	323,802	41,543	357,121	505,992	312,685
Passenger cars	2,700,000	8,373,244	47,095,784	24,074,216	23,429,016
Highway (km)	523	3,055	13,009	15,523	2,549
GDP per Capita 2020	68,590	40,160	34,310	22,350	12,700
GDP (2020)	318,051	800,095	3,367,560	1,121,948	523,668
Passenger car taxation					
VAT (%)	25	21	19	21	23
Registration tax	++	+++	-	+	+
Motor vehicle tax	++	++	+	±	-
Excise duty petrol	++	+++	+	+	±
Excise duty electricity	+	+	+++	++	+
Benefit in kind tax (BIK)	++	++	+	++	-

Incentives and legislation					
BEV - VAT exemption	Yes	No	No	No	No
BEV - Purchase subsidy	-	+	++	+	+
BEV – Registration tax	++	++	+	±	-
BEV - Motor vehicle tax	++	+++	++	+	-
BEV - BIK tax reduction	++	++	+	+	-
Public charging infrastructure (2021)					
Normal charging points	13,048	79,849	40,924	5,607	2,293
Normal charging point * 10^3 per resident (2021)	2.45	4.62	0.49	0.12	0.06
BEV / normal charging point	33	3	16	13	6
Fast charging points	6,491	2,766	9,159	2,643	1,381
Fast charging point * 10^3 per resident (2021)	1.22	0.16	0,11	0.06	0.04
BEV / fast charging point	67	88	72	28	10
Fast charging points / 100 km highway	1241	91	70	17	54
Model availability					
Small class	12	14	13	14	3
Middle class	36	25	29	29	16
Top class	18	14	13	14	11
Van	5	2	6	1	3
Total	71	55	61	58	33

Table 13: BEV upscaling climate in Norway, Netherlands, Germany, Spain and Poland

	Norway	Netherlands	Germany	Spain	Poland
BEV adoption	+++	++	+	-	- -
Purchase price: BEV < ICE	++	-	-	- -	- -
TCO: BEV < ICE	+++	++	++	-	-
Public Fast charging	+++	+	+	- -	- -
Public normal charging	+	+++	-	-	-
Private charging	++	-	++	?	?
Model availability	++	+	++	+	-

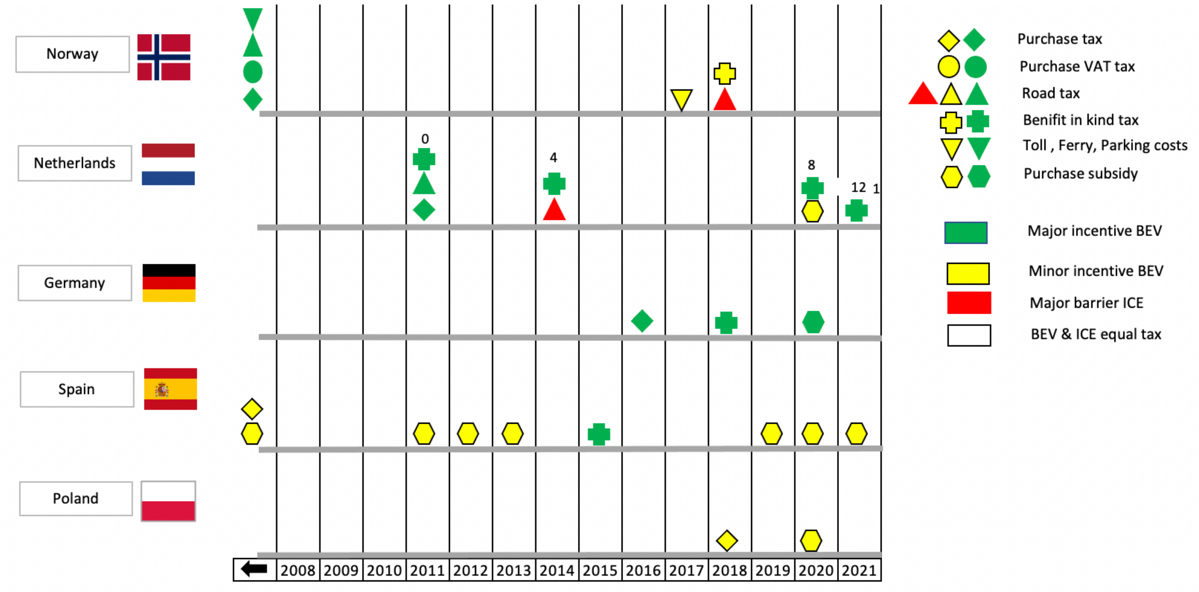


Figure 32: Governmental incentives to stimulate battery electric vehicle (BEV) adoption

Note: Numbers in figure above Benefit in kind tax (The Netherlands) is the percentage of purchase price

5.5 Ways to accelerate the upscaling of BEV adoption at a European level

Based on the results of this thesis there is an indication that there are four conditions needed for the upscaling of the BEV adoption. These are that the purchase price and the total cost of ownership (TCO) of a BEV is lower than an ICE. There is a well-developed charging infrastructure and that there are enough BEV models available to choose from. How to optimize these four conditions is described in this paragraph.

There is no one fits all solution to reduce the purchase price and the TCO cost of a BEV compared to an ICE.

The base price of a BEV is still higher than a comparing ICE but the difference in the base price is decreasing because the price of the battery is decreasing and the competition between the BEV manufactures is increasing. Reduction of the purchase of a BEV is possible with financial incentives on the car taxation or by introduction of a purchase subsidy. Countries with a high taxation policy, like Norway and The Netherlands on passenger cars can reduce or exempt the registration tax on BEVs. Countries that are not a member of the EU can reduce or exempt the VAT on BEVs. EU members are obliged to charge VAT on a BEV by the EU. Countries with a low taxation policy on cars can best use a purchase subsidy to upscale the BEV adoption.

The TCO of a passenger car can be divided in the depreciation and operating costs of a car. The operating cost of a passenger car are heavily dependent on the taxation policy of the country. National authorities can use the road tax, excise duty on energy consumption and toll costs to reduce the TCO costs of a BEV resulting in an upscaling of the BEV adoption. Another option is to increase the operational cost taxation for an ICE like in Germany. A new road tax system was introduced in 2021 where the road tax now depends on the amount of CO_2 emission of a car and BEV receive a small yearly subsidy.

The Netherlands have shown that a reduction of the benefit of kind tax and even an exemption in the past is a strong tool to upscale the BEV adoption of BEVs owned by the company but used privately by the employees.

A well-developed charging infrastructure is likely to increase the consumer adoption of BEVs by reducing the uncertainty regarding range anxiety. The charging infrastructure is divided into a private and public charging infrastructure. The public infrastructure is divided into high power fast charging and normal charging points. Charging points at home and at workplaces belong to the private charging infrastructure.

For daily driving of limited distances, a well-developed private charging infrastructure at home and or at workplaces is necessary. Subsidies installing a charging point by an individual at or by a company is a tool to improve the upscaling of the BEV adoption. Countries where a large amount of people do not live in detached houses, like The Netherlands and Spain, need a well-developed public normal charging infrastructure. The Netherlands have shown that this is possible. For Charging point operators (CPO), in most cases public normal charging points are not financial beneficial. National or local authorities need to subsidies CPOs for the installations of public normal charging point. The reason for this is that the electricity price between home charging and public normal charging cannot differ too much. If did would be the case, the high social class who live in detached houses pay less for electricity than the people who live in a flat.

High power charging points are necessary for driving long distances with a BEV. In general, high-power fast charging points are for CPOs financial beneficial because a much higher electricity price is charged. Countries with already a high BEV adoption, like Norway and The Netherlands have a well-developed high-power fast charging infrastructure managed by different commercial CPOs. Countries with a low BEV adoption rate and especially those with an extensive highway infrastructure, like Spain have a problem. CPOs are not interested to install high-power fast charging points as long as they are not driving enough BEVs in a certain country. In this case national authorities need to subsidies a minimum of fast charging points on highways, so that is it possible to drive long distances in a country with a BEV. For example, driving from Madrid to Sevilla in Spain which is about 550 km is hardly to manage now with a BEV.

BEV model availability, especially in the in the small and middle-class segment is necessary for the upscaling the BEV adoption in a country.
The amount of BEV models in a country depends on how financially attractive it is to launch a new BEV model by a BEV manufacturer. Norway is used often as pilot country to introduce a new model. When the model is a success, the BEV manufacturer will launch the model also in other countries.
National authorities do not have much power to BEV manufactures to introduce as many as available BEV models. If the potential BEV market is interesting with a low purchase and TCO for a BEV and there is there is a well-developed charging infrastructure, the increase of models will automatically follow.
Non-financial BEV adoption incentives were out of the scope of the analysis of this thesis. From the interviews done for this thesis, emission free zones in cities and parking privileges for BEVs are tools mentioned to upscale the BEV adoption.
The most effective way to upscale the BEV adoption in Europe is the legislation in an European country, that only emission free passenger cars can be sold. In Norway this will be in 2025 and in the Netherlands in 2030. The earlier emission passenger cars are only aloud to be sold, the earlier the upscaling of BEV adoption at a European level will be accomplished.

6 Discussion

From this thesis several topics are highlighted in the discussion. The passenger car distribution in Europe related to the BEV adoption categories is of importance and several factors are of influence in relation to the BEV adoption in the different European countries. Finally, the limitations of the several outcomes are mentioned and in the conclusion, recommendations are given for further research.

6.1 Passenger car fleet

Six countries dominate the European passenger car fleet with a 73% share: Germany, Italy, France, the United Kingdom, Spain, and Poland. The average BEV adoption rate in terms of new BEV registrations is below 10% in 2021, which is quite low considering the European Green Deal. Only four countries in Europe, new BEV consumers belong to the mainstream BEV market but only represent 5% of the European passenger car market. National authorities in Germany, United Kingdom and France have serious programs to accelerate the BEV adoption and hopefully these countries will reach the level of Norway and The Netherlands in a few years. The situation in Italy, Spain and Poland is concerning. The stimulation programs in these countries are not strong enough and the taxation policy on passenger cars is too low, so it is not very effective to introduce financial incentives for a BEV except a purchase subsidy.

6.2 Purchase price

The base price of a BEV is still higher than an ICE. Norway is the country where both the purchase price and the TCO of a BEV is lower than an ICE and Norway has the best BEV adoption share in Europe. The reason that Norway could reduce the purchase price of a BEV so much is that Norway is not a member of the EU, has a high VAT rate of 25% and has a high taxation policy on passenger cars. Norway started already for years with an exemption on VAT and registration tax for BEVs. It is allowed for EFTA members to exempt VAT on the purchase price of a BEV. This is not the case in the EU. A temporary reduction of the VAT on the purchase price of a BEV for EU members should be a topic to be discussed at an European commission level. Reduction or exemption of registration tax for BEVs is only useful if there is a high registration tax on passenger cars. Countries that have low or no registration tax need to decide to increase this tax for the ICE. If a reduction of the VAT and or registration tax for a BEV is not possible or attractive in a certain country, a purchase subsidy can be launched for a BEV. The discussion is if this subsidy should be limited to only the small and compact classes.

Objectively, only a lower TCO for a BEV should be enough as an incentive for the BEV adoption. But passenger car consumers select primary on the direct costs of a car and less on the operating costs (Gomez Vilchez et al.,2019). Norway showed that a lower purchase price for a BEV is a factor for the BEV adoption. Base prices of a BEV are decreasing and hopefully it will be comparing to an ICE in the coming years.

6.3 Total cost of ownership

Norway, The Netherlands and Germany managed that the TCO of a BEV is lower than an ICE. It is most likely that a TCO comparable or lower than an ICE is an important factor for the BEV adoption.

From the cost benefit analysis performed in this thesis it is shown that the TCO of middle and Top class BEVs is already lower than a comparing ICE. For upscaling the BEV share in Europe, the TCO of small and compact class BEV needs to be reduced. Small and compact ICE are cheap, have a low weight and produce low amounts of CO_2 emissions. This is the reason that taxation on a small class BEV is relatively low and the base price is certainly lower than a BEV. Especially driving a small class BEV less than 10,000 km a year will be a challenge to compete the ICE.

In the EU the passenger car tax regulations are not homogeneous which makes it very difficult to organize financial incentives in a uniform way (Costa et al.,2021). Countries like Norway and the Netherlands have an history of high tax regulations on cars. Germany, Spain and Poland have an

history of low taxes on passenger cars. In Norway these high taxes are already exempted for BEVs for many years. It has been shown that this was effective and is one of reasons Norway has the highest BEV adoption in the world. When certain taxes like registration tax and motor vehicle tax do not exist, it is also not possible to use them as an incentive with an exemption for BEVs.
In most countries incentives for BEVs are generalized incentives for all BEVs. BEV incentives are needed most for small & compact class BEVs. For middle class and top class BEVs, the incentives are less necessary because the TCO of a middle- and top-class BEV is already lower than an ICE. An option is reducing the BEV incentives on middle and top class BEVs and increase the BEV incentives for the small and compact BEVs using the money from the reduction of the incentives on the middle- and top-class cars. This policy can be started when there are enough middle- and top-class BEV models sold in a certain country.

6.4 Charging infrastructure

A well-developed charging infrastructure is likely to increase the consumer adoption of BEVs by reducing the uncertainty regarding range anxiety, confirmed by the interviewees. In the charging station placement process three important factors play a role. Namely where, how many and of which type of charging stations should be placed (Motoaki, 2019).
It is estimated that, between now and 2030, the number of charge points for EV charging in the public infrastructure will increase in Europe from around 200,000 to 1.8 million. Most chargers today are slow but fast and high-power chargers are estimated to grow from a 15% market share today to 27% by 2030 (BCG, 2021).
The decision to place a charging station is based on the potential business case. Charging for limited distances will mainly be covered by private charging points at home when this is possible. For people living in a flat or a non-detached house, it is difficult to have a charging point at home. BEV consumers that cannot charge at home or at work are dependent on a public slow charging points. Although the electricity price is higher at a public slow charging point compared with a home charging point, public slow charging stations hardly ever become profitable (Gnann et al., 2018). In general, the research confirms the need for private home and workplace charging points (Wolbertus, 2021). Reliable data about the private charging infrastructure are not available. It is difficult to draw conclusions how well the charging infrastructure is developed in a certain country when only data on public charging infrastructure is available. Information on private charging infrastructure is also important to know for further development of the charging infrastructure. For some areas where home charging is not possible and a shortage of public slow charging points exists, national or local authorities need to subsidies charging point operators, for placing these charging points.
If the private charging infrastructure is well developed like in Norway, the amount of normal public charging points can be lower than for countries where not many private charging points are available. More demographic information is needed about the private charging infrastructure in the European countries.
For driving longer distances it is needed that there is a well-developed high power fast charging infrastructure where a BEV can be recharged. For long distances mainly highways are used. The EU is trying to set new goals, promoting a basic charging infrastructure through Europe ensuring the existence of fast charging points every 50-100 kilometer (European Commission, 2021a). For some countries this target is more challenging than for others. The reason is that there are huge differences in the length of the highway. Norway with a bit more than 500 km highway cannot be compared with Spain with more than 15,000 km highway. The decision to place a charging station is made by the Charge Point Operator (CPO). The CPO optimizes its business case and accordingly only places a new charging station if there is sufficient demand. In general, high-power fast charging points are profitable, because the electricity price charged is high and the energy costs are comparable with the fuel costs of an ICE.

Discussion is necessary if the EU needs to support a high-power fast charging infrastructure for the nine corridors covering the Trans-European transport network like the European Commission has done to develop this Trans-European transport network (ECA, 2019).
Since the batteries are getting better and charging is getting faster, the number of BEVs needed per charging pole is also changing in the time.

6.5 Passenger car age

In the European nations differences exist in the average age of passenger cars. Generally, can be seen that the poorer east and south European countries have an older passenger car fleet. An example is Poland with 37% of the cars are older than 20 years old (ACEA, 2021b). These poor countries also have a low BEV adoption rate. Scrappage subsidies when buying a BEV for an old ICE can be used in countries with an old passenger car fleet.

6.6 Model availability

The model availability of BEV in the different car segments is increasing quite spectacular in the last year and the forecast is promising for the next years. Car manufactures are free to launch the models they want to launch in the individual European countries. National authorities have little influence on the number of BEVs which are available in a country. When the conditions are good, like a competing purchase price and TCO with an ICE and a well-developed charging infrastructure, the BEV manufacturers will launch their BEV models in that country.

6.7 Electricity production

The electricity production of the individual countries is out of the scope of this thesis. But of importance is, that the electricity used by the BEV is produced with a minimum amount of GHG-emissions. The results from this thesis, presents that the CO_2 gain driving a BEV instead of an ICE differs a lot between the comparing countries because of the electricity production. When in Poland the CO_2 emission of the electricity production increases with 2%, a BEV is not more sustainable compared with an ICE from the low segment car. The reason is that in Poland, the electricity is mainly produced with coal. The discussion is if a sustainable way of electricity production is a pre-condition for upscaling the BEV adoption.

6.8 Consumer characteristics

Results from the consumer characteristics like age distribution and income in a certain country did not show any remarkable differences. One of the reasons is that no reliable data are available comparing these consumer characteristics between ICE and BEV users.

6.9 Limitations

This thesis is subject to several limitations.
This thesis analyzed the purchase price and TCO between 2014 and 2021 of a middle-class BEV and ICE vehicle in 5 comparing countries. The results of this analysis are hopefully representative for the other European countries. Date necessary to analyze the TCO from Norway, The Netherlands and Germany were collected from well-known organizations. Data collected from Spain and Poland from less robust data sources like automotive magazines. Ideally a database would be available with objective data about all passenger cars with the base price, purchase price, taxation and depreciation off all passenger car models in all European countries of the previous years. With this dataset a TCO calculator could be developed for every model, in every European country with different yearly kilometer usage. Such TCO calculator can be used, to analyze which incentives are necessary and till when for the acceleration of the BEV adoption in every European country.
Only data about the public charging infrastructure were presented. It is known that private charging points at home and at workplaces have an important role in the charging infrastructure.
An indirect indicator that is used for the amount of private charging points is the share of detached houses in a country. The hypothesis is that people living in a detached house, more likely have a private

charging point than people living in a flat. It was not possible to present data about the private charging infrastructure due to a lack of reliable data. The absence of data about private charging infrastructure, certainly affects the results of this thesis. Reliable data on the amount of private charging points and the amount of electricity used from these charging points, would be useful information in future research.

An indicator about how well the fast high-power charging infrastructure is developed, is the number of charging points per 100 km highway. From the results of this thesis, it is shown that this ratio has certain limitations. Norway certainly has a large amount of fast charging points but the reason that this ratio is so high is also due that Norway has only 523 km highway. A better indicator about the high-power charging infrastructure is information about the distance between high-power locations on a highway and how many charging points are at one charging point location. The lack of information about the distance between charging locations, certainly had influence about the outcome of the fast charging infrastructure related to the BEV adoption.

A selection was made of 5 countries representing the European countries. The selection was based on the different Rogers categories where the BEV consumers belong to, and several demographic parameters but these 5 countries certainly do not represent all European countries. Analyzing more than 5 European countries would have shown possible different outcomes.

The model availability was divided according to the Euro NCAP vehicle segment classes. These segments are more related to the type and purchase price of the vehicle. BEV models are not yet divided in battery capacity segments. If there would exist a battery capacity classification and how many BEV of each classification has been sold, an analysis could have been performed about the range of these BEVs after being charged.

Analyzing the consumer characteristics in this thesis had limitations. The GDP per capita could be an indicator for the BEV adoption in a country but it was not possible to compare the incomes from BEV or ICE consumers and the model type related to the income. The age distribution can only be analyzed per European country, but no comparison could be made between ICE and BEV users.

7 Conclusion

The results from this thesis show that national authorities have influence on the BEV adoption primarily with two mechanisms. The first is by financial incentives through subsidies and taxation benefits that results, driving a BEV is cheaper than driving an ICE. The second is to stimulate the development of the charging infrastructure.

For the BEV consumer, the financial part can be divided in the one-off purchase price and the total cost of ownership (TCO) during the ownership of the passenger car. For the car consumer driving a company car privately, it is the amount of Benefit In Kind (BIK) tax, that influences the BEV adoption.

The conclusion can be made that a lower purchase price, TCO or BIK tax for a BEV compared to an ICE, stimulates the BEV adoption.

According to the theory of Rogers, the financial incentives can be reduced when the new BEV consumers belong to the early majority category and have a BEV adoption share between 10%-20%. The Netherlands that belongs to that category reduced the benefit in kind tax incentive for company owned BEVs used also private. In 2021 the BEV adoption share decreased compared with 2020. Even Norway has not yet started to reduce the financial incentives for BEVs. It is likely that financial incentives to accelerate the BEV adoption are needed longer then from the Rogers theory would be expected.

A well-developed slow charging infrastructure has the most effect in the early phase of the BEV adoption in a country. It differs per country how the slow charging infrastructure is organized. When there is a large opportunity of home charging in a country, private charging points at home are preferred because it is cheaper and easier than public charging. The percentage of “detached houses” in a country indicates whether it is more favorable to focus on private charging or public charging when setting up the slow charging infrastructure. A high percentage of “detached houses” indicates that it is more favorable to focus on private charging and a low percentage indicates that it is more favorable to focus on public charging in a country.

Fast chargers have a stimulating effect on BEV adoption when BEV adoption is already at a further stage. In addition, it is expected that fast chargers will have a greater effect on countries with a larger surface area than countries with a smaller surface area. However, this could not be established in this thesis, because most of the comparing countries analyzed are still developing their slow charging infrastructure.

The conclusion is that the slow charging infrastructure determines the BEV adoption mainly in the initial BEV adoption phase but will certainly also have to grow in a further phase. Additionally, the fast-charging infrastructure stimulates the BEV adoption mainly when the BEV adoption moves into a further phase.

The economic perspective and the charging infrastructure influences the BEV model availability in a country. It differs how many BEV models are available per country. This is because car manufacturers are sending more models to countries that have favorable policies for driving a BEV. In general, it can be concluded that when more BEV models are for sale in a country, it has a stimulating effect on the BEV adoption, because consumers then have more choice. However, it was not expected that Spain had more BEV models in 2021 than the Netherlands with a lower BEV share and less BEVs sold than The Netherlands.

No relation was found between consumer characteristics like the age distribution and the GDP per capita related to the BEV adoption. The reason was that the variables could not be compared between BEV and ICE consumers.

Recommendations for further research are:

Objective and reliable data about purchase and operating costs of a passenger car from all European countries should be available and collected by an independent organization like the EAFO and or Eurostat. With this dataset the research performed in this thesis could be extended to all European countries and a statistical comparative case study analysis could be performed to explore how robust the analytical model is, used in this thesis.
Financial incentives are of importance for the acceleration of the BEV adoption to reduce the total cost of ownership. Today the BEV TCO for the small and compact class is higher than for a comparative ICE but for middle and top class models the TCO of a BEV is already cheaper than an ICE. Further research how more differentiation in financial incentives can be organized between the different BEV models is a recommendation based on the results of this thesis.
Reliable data about the private charging infrastructure do not exist from the different European countries. Research should be started to collect reliable objective data about of the amount of private charging points at home and at workplaces per European country.
The amount of electric energy consumption per public and private charging point per BEV is information that is not available yet. Further research of this data is recommended, to investigate how efficient charging per charging point is taken place.
The distance between fast charging stations on a highway is of importance for traveling long distances. The European Commission recommends every 50-100 kilometer a fast-charging point on the highway. The EAFO uses the amount fast charging points per 100 km highway. Research should start to investigate the density and distances between fast charging points on cross border highways for example on the nine Trans-European transport network corridors.
Transparently on the TCO of a BEV is of importance for the BEV adoption share in Europe. Useful should be that a uniform TCO calculator for every model in every European country will be developed under control of the independent EAFO organization. The EAFO started developing a TCO calculator, but this tool is in a premature stadium.
Most incentives to accelerate BEV adoption in Europe have so far focused on the traditional business model of private car ownership. New and innovative business models for mobility such as mobility as a service can play an important role in the future in a sustainable green economy through an economically efficient and socially progressive approach without compromising the mobility needs of current and future generations. Decision makers will have to strike a balance between the undesirable growth of vehicle fleets and optimal mobility of the individual. Therefore, incentives for electric mobility should be implemented as part of an integrated approach to urban and regional mobility and an improvement in public transport.

8 References

ACEA. (2010). VEHICLES IN USE. (2005–2010). Retrieved November 6, 2021, from https://www.acea.auto/uploads/statistic_documents/ANFAC_Report_2010_(2012).pdf

ACEA. (2020, June). *CO2-based motor vehicle taxes in the european union*. Retrieved from https://www.acea.auto/fact/overview-co2-based-motor-vehicle-taxes-in-the-european-union/

ACEA. (2021a, April). *ACEA tax guide 2021*. Retrieved from https://www.acea.auto/publication/acea-tax-guide-2021/

ACEA. (2021b, January). *Vehicles in use Europe*. Retrieved from https://www.acea.auto/files/report-vehicles-in-use-europe-january-2021-1.pdf

ACEA. (2021c). WLTP facts. Retrieved January 6, 2022, from https://www.wltpfacts.eu/

ADAC. (2021). Autokatalog VW. Retrieved November 19, 2021, from https://www.adac.de/rund-ums-fahrzeug/autokatalog/marken-modelle/vw/?filter=ONLY_RECENT&sort=SORTING_DESC

Ahmed, M., Zheng, Y., Amine, A., Fathiannasab, H., & Chen, Z. (2021). The role of artificial intelligence in the mass adoption of electric vehicles. *Joule*, *5*(9), 2296–2322. https://doi.org/10.1016/j.joule.2021.07.012

ANWB. (2021). Fuel prices Europe. Retrieved October 8, 2021, from https://www.anwb.nl/vakantie/reisvoorbereiding/brandstofprijzen-europa

Autoweek. (2022). WEGENBELASTING AUTO. Retrieved January 10, 2022, from https://www.autoweek.nl/wegenbelasting/?id=102022&jaar=2021&cache=no

Balali, Y., & Stegen, S. (2021). Review of energy storage systems for vehicles based on technology, environmental impacts, and costs. *Renewable and Sustainable Energy Reviews*, *135*, 110185. https://doi.org/10.1016/j.rser.2020.110185

Bas, J., Cirillo, C., & Cherchi, E. (2021). Classification of potential electric vehicle purchasers: A machine learning approach. *Technological Forecasting and Social Change*, *168*, 120759. https://doi.org/10.1016/j.techfore.2021.120759

BCG, Hagenmaier, M., Wagener, C., Bert, J., & Ohngemach, M. (2021, April). *Winning the Battle in the EV Charging Ecosystem*. Stockholm, Sweden: BCG.

Bento, N., & Wilson, C. (2016). Measuring the duration of formative phases for energy technologies. *Environmental Innovation and Societal Transitions*, *21*, 95–112. https://doi.org/10.1016/j.eist.2016.04.004

BEUC (The European Consumer Organisation). (2021, April). *Electric cars: Calculating the total cost of ownership for Consumers.* Element Energy Limited, Cambridge, UK. Retrieved from https://www.beuc.eu/publications/beuc-x-2021-039_electric_cars_calculating_the_total_cost_of_ownership_for_consumers.pdf

Bhutada, G. (2021, May 19). Visualizing the Freefall in Electric Vehicle Battery Prices. Retrieved October 17, 2021, from https://elements.visualcapitalist.com/electric-vehicle-battery-prices-fall/

Biresselioglu, M. E., Demirbag Kaplan, M., & Yilmaz, B. K. (2018). Electric mobility in Europe: A comprehensive review of motivators and barriers in decision making processes. *Transportation Research Part A: Policy and Practice*, *109*, 1–13. https://doi.org/10.1016/j.tra.2018.01.017

Broadbent, G. H., Drozdzewski, D., & Metternicht, G. (2017). Electric vehicle adoption: An analysis of best practice and pitfalls for policy making from experiences of Europe and the US. *Geography Compass*, *12*(2), e12358. https://doi.org/10.1111/gec3.12358

Calearo, L., Marinelli, M., & Ziras, C. (2021). A review of data sources for electric vehicle integration studies. *Renewable and Sustainable Energy Reviews*, *151*, 111518. https://doi.org/10.1016/j.rser.2021.111518

Chakraborty, M., & al Rashdi, S. (2018). Venkatesh et al.'s Unified Theory of Acceptance and Use of Technology (UTAUT) (2003). *Technology Adoption and Social Issues*, 1657–1674. https://doi.org/10.4018/978-1-5225-5201-7.ch077

Chen, C. F., Zarazua De Rubens, G., Noel, L., Kester, J., & Sovacool, B. K. (2020). Assessing the socio-demographic, technical, economic and behavioral factors of Nordic electric vehicle adoption and the influence of vehicle-to-grid preferences. *Renewable and Sustainable Energy Reviews*, *121*, 109692. https://doi.org/10.1016/j.rser.2019.109692

Costa, C., Barbosa, J., Castro, H., Gonçalves, R., & Lanceros-Méndez, S. (2021). Electric vehicles: To what extent are environmentally friendly and cost effective? – Comparative study by european countries. *Renewable and Sustainable Energy Reviews*, *151*, 111548. https://doi.org/10.1016/j.rser.2021.111548

Cronbach, L. J., & Meehl, P. E. (1955). Construct validity in psychological tests. *Psychological Bulletin*, *52*(4), 281–302. https://doi.org/10.1037/h0040957

Deloitte Insights. (2020). Electric vehicles Setting a course for 2030. *Electric vehicles Setting a course for 2030*. Retrieved from https://www2.deloitte.com/uk/en/insights/focus/future-of-mobility/electric-vehicle-trends-2030.html

Diesel o Gasolina. (2022). Calcular el precio del impuesto de circulación. IVTM. Retrieved January 10, 2022, from https://www.dieselogasolina.com/calcular-precio-impuesto-circulacion-ivtm.html

EAFO. (2021). TCO Calculator. Retrieved January 10, 2022, from https://www.eafo.eu/knowledge-center/tco-calculator

EAFO (European Alternative Fuels Observatory). (2020). Alternative Fuel market share Passenger cars. Retrieved September 24, 2021, from https://www.eafo.eu/vehicles-and-fleet/m1

ECA. (2019, May). *Roads connecting European regions*. Retrieved from https://www.eca.europa.eu/lists/ecadocuments/ap19_08/ap_connecting_roads_en.pdf

ESA (EFTA Surveillance Authority). (2020, December 16). ESA gives green light for Norway to continue tax reduction on electric vehicles for two more years. Retrieved January 2, 2022, from https://www.eftasurv.int/newsroom/updates/esa-gives-green-light-norway-continue-tax-reduction-electric-vehicles-two-more

EU. (2019). National energy and climate plans (NECPs). Retrieved September 24, 2021, from https://ec.europa.eu/energy/topics/energy-strategy/national-energy-climate-plans_en

European Commision. (2012). Passenger car taxation. Retrieved December 12, 2021, from https://ec.europa.eu/taxation_customs/personal-car-taxation_en

European Commission. (2014, December). *Guide to Cost-Benefit Analysis of Investment Projects*. Retrieved from https://ec.europa.eu/regional_policy/sources/docgener/studies/pdf/cba_guide.pdf

European Commission. (2020). CO_2 emission performance standards for cars and vans. Retrieved October 17, 2021, from https://ec.europa.eu/clima/eu-action/transport-emissions/road-transport-reducing-co2-emissions-vehicles/co2-emission_en

European Commission. (2021a, July). *Deployment of alternative fuels infrastructure in the EU*. Retrieved from https://ec.europa.eu/info/sites/default/files/revision_of_the_directive_on_deployment_of_the_alternative_fuels_infrastructure_with_annex_0.pdf

European Commission. (2021b). NextGenerationEU. Retrieved January 10, 2022, from https://ec.europa.eu/info/strategy/recovery-plan-europe_en

European Commission. (2021c). Taxation and customs union. Retrieved November 7, 2021, from https://ec.europa.eu/taxation_customs/vat-rates_en

European Commission. (2021d, July 1). Excise Duty on Energy. Retrieved January 8, 2022, from https://ec.europa.eu/taxation_customs/taxation-1/excise-duties/excise-duty-energy_nl

European Environment Agency. (2022). Greenhouse gas emission intensity of electricity generation in Europe. Retrieved January 10, 2022, from https://www.eea.europa.eu/ims/greenhouse-gas-emission-intensity-of-1

Eurostat. (2021a). Distribution of population by degree of urbanisation, dwelling type and income group - EU-SILC survey. Retrieved January 10, 2021, from https://ec.europa.eu/eurostat/databrowser/view/ILC_LVHO01__custom_2127888/default/table?lang=en

Eurostat. (2021b, March 30). Passenger cars, by type of motor energy and size of engine. Retrieved November 6, 2021, from https://ec.europa.eu/eurostat/databrowser/view/road_eqs_carmot/default/table?lang=en

Eurostat. (2021c, April 1). Passenger cars, by age. Retrieved December 31, 2021, from http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=road_eqs_carage&lang=en;

Eurostat. (2021d, July 5). Population by age group and sex. Retrieved December 22, 2021, from https://ec.europa.eu/eurostat/databrowser/view/demo_pjangroup/default/table?lang=en

Eurostat. (2021e, October 14). New registrations of passenger cars by type of motor energy and engine size. Retrieved November 6, 2021, from https://ec.europa.eu/eurostat/databrowser/view/road_eqr_carmot/settings_1/table?lang=en

Eurostat. (2022, February 3). Real GDP per capita. Retrieved October 10, 2022, from https://ec.europa.eu/eurostat/databrowser/view/SDG_08_10/default/table

Figenbaum, E., Kolbenstved, M., & TOI(Institute of Transport Economic). (2016). *Learning from Norwegian Battery Electric and Plug-in Hybrid Vehicle users – Results from a survey of vehicle owners*. Retrieved from https://www.toi.no/getfile.php/1343167-1467632310/Publikasjoner/T%C3%98I%20rapporter/2016/1492-2016/Summary.pdf

Fontaínhas, J., Cunha, J., & Ferreira, P. (2016). Is investing in an electric car worthwhile from a consumers' perspective? *Energy*, *115*, 1459–1477. https://doi.org/10.1016/j.energy.2016.05.075

Gersdorf, T., Hertzke, P., Schaufuss, P., & Schenk, S. (2020). McKinsey Electric Vehicle Index: Europe cushions a global plunge in EV sales. *McKinsey & Company*. Retrieved from https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/mckinsey-electric-vehicle-index-europe-cushions-a-global-plunge-in-ev-sales

Ghadikolaei, M. A., Wong, P. K., Cheung, C. S., Zhao, J., Ning, Z., Yung, K. F., . . . Gali, N. K. (2021). Why is the world not yet ready to use alternative fuel vehicles? *Heliyon*, *7*(7), e07527. https://doi.org/10.1016/j.heliyon.2021.e07527

Gnann, T., Plötz, P., & Wietschel, M. (2015). *How to address the chicken-egg-problem of electric vehicles? Introducing an interaction market diffusion model for EVs and charging infrastructure*. Presented at the eceee Summer Study, Hyères, France: ECEEE.

Gnann, T., Stephens, T. S., Lin, Z., Plötz, P., Liu, C., & Brokate, J. (2018). What drives the market for plug-in electric vehicles? - A review of international PEV market diffusion models. *Renewable and Sustainable Energy Reviews*, *93*, 158–164. https://doi.org/10.1016/j.rser.2018.03.055

Gómez Vilchez, Smyth, Kelleher, Lu, Rohr, Harrison, & Thiel. (2019). Electric Car Purchase Price as a Factor Determining Consumers' Choice and their Views on Incentives in Europe. *Sustainability*, *11*(22), 6357. https://doi.org/10.3390/su11226357

Government , The Netherlands. (2020). Klimaatwet. Retrieved September 26, 2021, from https://wetten.overheid.nl/BWBR0042394/2020-01-01

GREAT. (2021). Green Region for Electrification and Alternative fuels for Transport. Retrieved January 10, 2022, from https://great-region.org/

Gross, R., Hanna, R., Gambhir, A., Heptonstall, P., & Speirs, J. (2018). How long does innovation and commercialisation in the energy sectors take? Historical case studies of the timescale from invention to widespread commercialisation in energy supply and end use technology. *Energy Policy*, *123*, 682–699. https://doi.org/10.1016/j.enpol.2018.08.061

Habla, W., Huwe, V., & Kesternich, M. (2021). Electric and conventional vehicle usage in private and car sharing fleets in Germany. *Transportation Research Part D: Transport and Environment*, *93*, 102729. https://doi.org/10.1016/j.trd.2021.102729

Hardman, S., Jenn, A., Tal, G., Axsen, J., Beard, G., Daina, N., . . . Witkamp, B. (2018). A review of consumer preferences of and interactions with electric vehicle charging infrastructure. *Transportation Research Part D: Transport and Environment*, *62*, 508–523. https://doi.org/10.1016/j.trd.2018.04.002

Helmus, J., Spoelstra, J., Refa, N., Lees, M., & van den Hoed, R. (2018). Assessment of public charging infrastructure push and pull rollout strategies: The case of the Netherlands. *Energy Policy*, *121*, 35–47. https://doi.org/10.1016/j.enpol.2018.06.011

Hoeft, F. (2021). Internal combustion engine to electric vehicle retrofitting: Potential customer's needs, public perception and business model implications. *Transportation Research Interdisciplinary Perspectives*, *9*, 100330. https://doi.org/10.1016/j.trip.2021.100330

Huang, Y., Qian, L., Soopramanien, D., & Tyfield, D. (2021). Buy, lease, or share? Consumer preferences for innovative business models in the market for electric vehicles. *Technological Forecasting and Social Change*, *166*, 120639. https://doi.org/10.1016/j.techfore.2021.120639

ICCT. (2020, September 28). Germany's vehicle tax system: Small steps towards future-proof incentives for low-emission vehicles. Retrieved January 2, 2022, from https://theicct.org/blog/staff/germany-vehicle-tax-system-sept2020

ICCT. (2021, April 9). Transport could burn up the EU's entire carbon budget. Retrieved November 14, 2021, from https://theicct.org/blog/staff/eu-carbon-budget-apr2021

Ilieva, I., & Bremdal, B. (2021). Flexibility-Enhancing Charging Station to Support the Integration of Electric Vehicles. *World Electric Vehicle Journal*, *12*(2), 53. https://doi.org/10.3390/wevj12020053

Jansson, J., Nordlund, A., & Westin, K. (2017). Examining drivers of sustainable consumption: The influence of norms and opinion leadership on electric vehicle adoption in Sweden. *Journal of Cleaner Production*, *154*, 176–187. https://doi.org/10.1016/j.jclepro.2017.03.186

Johnson, R. B., Onwuegbuzie, A. J., & Turner, L. A. (2007). Toward a Definition of Mixed Methods Research. *Journal of Mixed Methods Research*, *1*(2), 112–133. https://doi.org/10.1177/1558689806298224

Kester, J., Sovacool, B. K., Noel, L., & Zarazua De Rubens, G. (2020). Rethinking the spatiality of Nordic electric vehicles and their popularity in urban environments: Moving beyond the city? *Journal of Transport Geography*, *82*, 102557. https://doi.org/10.1016/j.jtrangeo.2019.102557

kfz-steuer.wiki. (2022). German Electric Car Tax 2021. Retrieved January 10, 2022, from https://kfz-steuer.wiki/en/electric-vehicle-tax-germany/

Krishna, G. (2021). Understanding and identifying barriers to electric vehicle adoption through thematic analysis. *Transportation Research Interdisciplinary Perspectives*, *10*, 100364. https://doi.org/10.1016/j.trip.2021.100364

Kumar, R. R., & Alok, K. (2020). Adoption of electric vehicle: A literature review and prospects for sustainability. *Journal of Cleaner Production*, *253*, 119911. https://doi.org/10.1016/j.jclepro.2019.119911

Kumar, R. R., Chakraborty, A., & Mandal, P. (2021). Promoting electric vehicle adoption: Who should invest in charging infrastructure? *Transportation Research Part E: Logistics and Transportation Review*, *149*, 102295. https://doi.org/10.1016/j.tre.2021.102295

Künle, E., & Minke, C. (2020). Macro-environmental comparative analysis of e-mobility adoption pathways in France, Germany and Norway. *Transport Policy*. https://doi.org/10.1016/j.tranpol.2020.08.019

Manca, F., Sivakumar, A., Daina, N., Axsen, J., & Polak, J. W. (2020). Modelling the influence of peers' attitudes on choice behaviour: Theory and empirical application on electric vehicle

preferences. *Transportation Research Part A: Policy and Practice*, *140*, 278–298. https://doi.org/10.1016/j.tra.2020.08.016
Mandys, F. (2021). Electric vehicles and consumer choices. *Renewable and Sustainable Energy Reviews*, *142*, 110874. https://doi.org/10.1016/j.rser.2021.110874
McKinsey & Company. (2021). Why the automotive future is electric. *Why the automotive future is electric*. Retrieved from https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/why-the-automotive-future-is-electric
Motoaki, Y. (2019). Location-Allocation of Electric Vehicle Fast Chargers—Research and Practice. *World Electric Vehicle Journal*, *10*(1), 12. https://doi.org/10.3390/wevj10010012
Nazari, F., Rahimi, E., & Mohammadian, A. K. (2019). Simultaneous estimation of battery electric vehicle adoption with endogenous willingness to pay. *eTransportation*, *1*, 100008. https://doi.org/10.1016/j.etran.2019.100008
Noel, L., Papu Carrone, A., Jensen, A. F., Zarazua De Rubens, G., Kester, J., & Sovacool, B. K. (2019). Willingness to pay for electric vehicles and vehicle-to-grid applications: A Nordic choice experiment. *Energy Economics*, *78*, 525–534. https://doi.org/10.1016/j.eneco.2018.12.014
Peterson, S. B., & Michalek, J. J. (2013). Cost-effectiveness of plug-in hybrid electric vehicle battery capacity and charging infrastructure investment for reducing US gasoline consumption. *Energy Policy*, *52*, 429–438. https://doi.org/10.1016/j.enpol.2012.09.059
Pevec, D., Babic, J., Carvalho, A., Ghiassi-Farrokhfal, Y., Ketter, W., & Podobnik, V. (2019). Electric Vehicle Range Anxiety: An Obstacle for the Personal Transportation (R)evolution? *2019 4th International Conference on Smart and Sustainable Technologies (SpliTech)*. https://doi.org/10.23919/splitech.2019.8783178
Philipsen, R., Schmidt, T., van Heek, J., & Ziefle, M. (2016). Fast-charging station here, please! User criteria for electric vehicle fast-charging locations. *Transportation Research Part F: Traffic Psychology and Behaviour*, *40*, 119–129. https://doi.org/10.1016/j.trf.2016.04.013
Prud'homme, R., & Koning, M. (2012). Electric vehicles: A tentative economic and environmental evaluation. *Transport Policy*, *23*, 60–69. https://doi.org/10.1016/j.tranpol.2012.06.001
PwC. (2019). *Doing business in Poland 2019*. Retrieved from https://www.pwc.pl/pl/pdf/doing-bussiness-in-poland-2019.pdf
Redelbach, M., Propfe, B., & Friedrich, H. E. (2012). COMPETITIVE COST ANALYSIS OF ALTERNATIVE POWERTRAIN TECHNOLOGIES. *IAMF*. Retrieved from https://elib.dlr.de/75204/1/2012_Redelbach_(IAMF_2012)_-_Competitive_Cost_Analysis_of_Alternative_Powertrain_Technologies.pdf
Reuters, & Faus, J. (2021, May 6). Spain pours billions into fight for slice of European electric vehicle sector. Retrieved May 21, 2021, from https://www.reuters.com/business/autos-transportation/spain-pours-billions-into-fight-slice-european-electric-vehicle-sector-2021-05-06/
Rivers, N., & Jaccard, M. (2006). Useful models for simulating policies to induce technological change. *Energy Policy*, *34*(15), 2038–2047. https://doi.org/10.1016/j.enpol.2005.02.003
Rogers, E. M. (2003). *Diffusion of Innovations* (5th Edition). New York, United States of America: Free Press.
Schleich, J., Gassmann, X., Faure, C., & Meissner, T. (2016). Making the implicit explicit: A look inside the implicit discount rate. *Energy Policy*, *97*, 321–331. https://doi.org/10.1016/j.enpol.2016.07.044
Sierzchula, W., Bakker, S., Maat, K., & van Wee, B. (2014). The influence of financial incentives and other socio-economic factors on electric vehicle adoption. *Energy Policy*, *68*, 183–194. https://doi.org/10.1016/j.enpol.2014.01.043
Slowik, P., Hall, D., Lutsey, N., Nicholas, M., & Wappelhorst, S. (2019). Funding the transition to all zero-emission vehicles. *ICCT*. Retrieved from https://theicct.org/publications/funding-ZEV-transition

Sovacool, B. K., Kester, J., Noel, L., & de Rubens, G. Z. (2019). Income, political affiliation, urbanism and geography in stated preferences for electric vehicles (EVs) and vehicle-to-grid (V2G) technologies in Northern Europe. *Journal of Transport Geography*, *78*, 214–229. https://doi.org/10.1016/j.jtrangeo.2019.06.006

Statista. (2021a, April 14). Average prices of unleaded gasoline (95 RON) in Poland from 2004 to 2020. Retrieved January 10, 2022, from https://www.statista.com/statistics/598097/unleaded-gasoline-prices-poland/

Statista. (2021b, April 27). Electricity prices for households in Spain from 2010 to 2020, semi-annually. Retrieved January 10, 2022, from https://www.statista.com/statistics/418085/electricity-prices-for-households-in-spain/

Statista. (2021c, April 28). Electricity prices for households in Germany from 2010 to 2020, semi-annually. Retrieved January 10, 2022, from https://www.statista.com/statistics/418078/electricity-prices-for-households-in-germany/

Statista. (2021d, April 28). Electricity prices for households in Norway from 2010 to 2020, semi-annually. Retrieved January 10, 2022, from https://www.statista.com/statistics/643369/electricity-prices-for-households-in-norway/

Statista. (2021e, May 6). Average prices of unleaded gasoline (95 RON) in Germany from 2000 to 2021. Retrieved January 10, 2022, from https://www.statista.com/statistics/598020/unleaded-gasoline-prices-germany/

Statista. (2021f, July 14). Average prices of unleaded gasoline (95 RON) in Spain from 2000 to 2021. Retrieved January 10, 2022, from https://www.statista.com/statistics/598078/unleaded-gasoline-prices-spain/

Statista. (2021g, November 5). Electricity prices for households in Poland from 2010 to 2021, semi-annually. Retrieved January 10, 2022, from https://www.statista.com/statistics/418110/electricity-prices-for-households-in-poland/#:~:text=Electricity%20prices%20for%20households%20in%20Poland%202010%2D2020%2C%20semi%2Dannually&text=Since%202010%2C%20the%20household%20price,the%20first%20semester%20of%202020

Statista. (2022a). Average prices of unleaded gasoline (95 RON) in the Netherlands from 2000 to 2021. Retrieved January 10, 2022, from https://www.statista.com/statistics/598055/unleaded-gasoline-prices-netherlands/

Statista. (2022b, February 8). Electricity prices for households in the Netherlands from 2010 to 2021, semi-annually. Retrieved February 10, 2022, from https://www.statista.com/statistics/418106/electricity-prices-for-households-in-netherlands/

Statistics Norway. (2022, January 21). Prices on engine fuel (NOK per litres) 1986M08 - 2021M12. Retrieved January 10, 2022, from https://www.ssb.no/en/statbank/table/09654/

The Dutch Tax Administration. (2021). Registration tax passenger cars , The Netherlands. Retrieved November 18, 2021, from https://www.belastingdienst.nl/wps/wcm/connect/bldcontentnl/belastingdienst/prive/auto_en_vervoer/belastingen_op_auto_en_motor/bpm/bpm_berekenen_en_betalen/bpm_tarief/bpm-tarief-personenauto

The Norwegian Tax Administration. (2017). Special taxes - Annual motor vehicle tax - The Norwegian Tax Administration. Retrieved October 29, 2021, from https://www.skatteetaten.no/en/rates/special-taxes---annual-motor-vehicle-tax/?year=2017#rateShowYear

The Norwegian Tax Administration. (2021a). Electrical power tax. Retrieved January 9, 2022, from https://www.skatteetaten.no/en/business-and-organisation/vat-and-duties/excise-duties/about-the-excise-duties/electrical-power-tax/

The Norwegian Tax Administration. (2021b). One-off registration tax. Retrieved November 7, 2021, from https://www.skatteetaten.no/en/business-and-organisation/vat-and-duties/car/one-off-registration-tax/

The Norwegian Tax Administration. (2021c). Private use of a company car. Retrieved October 17, 2021, from https://www.skatteetaten.no/en/person/taxes/get-the-taxes-right/property-and-belongings/cars-boats-and-other-vehicles/company-car/private-use-of-a-company-car/

The Norwegian Tax Administration. (2021d). Road traffic insurance tax. Retrieved November 7, 2021, from https://www.skatteetaten.no/en/business-and-organisation/vat-and-duties/excise-duties/about-the-excise-duties/road-traffic-insurance/

Tolls.eu. (2022). Motorway toll Poland. Retrieved January 10, 2022, from https://www.tolls.eu/poland

Ustawa z dnia 6 grudnia 2008 r. o podatku akcyzowym (Act of 6 December 2008 on excise duty). (n.d.). In *Kancelaria Sejmu*. Retrieved October 13, 2021, from http://isap.sejm.gov.pl/isap.nsf/download.xsp/WDU20090030011/U/

van Velzen, A., Annema, J. A., van de Kaa, G., & van Wee, B. (2019). Proposing a more comprehensive future total cost of ownership estimation framework for electric vehicles. *Energy Policy*, *129*, 1034–1046. https://doi.org/10.1016/j.enpol.2019.02.071

Wang, S., Wang, J., Li, J., Wang, J., & Liang, L. (2018). Policy implications for promoting the adoption of electric vehicles: Do consumer’s knowledge, perceived risk and financial incentive policy matter? *Transportation Research Part A: Policy and Practice*, *117*, 58–69. https://doi.org/10.1016/j.tra.2018.08.014

Wappelhorst, S. (2020). Germany’s vehicle tax system: Small steps towards future-proof incentives for low-emission vehicles. *ICCT*. Retrieved from https://theicct.org/blog/staff/germany-vehicle-tax-system-sept2020

Wappelhorst, S. (2021a). Beyond major cities: Analysis of electric passenger car uptake in European rural regions. *ICCT*. Retrieved from http://www.indiaenvironmentportal.org.in/files/file/Ev%20europe%20rural.pdf

Wappelhorst, S. (2021b, March). *On the electrification path: Europe’s progress towards clean transportation*. EAFO. Retrieved from https://www.eafo.eu/sites/default/files/2021-03/EAFO%20Europe%20on%20the%20electrification%20path%20March%202021.pdf

Wappelhorst, S. & ICCT. (2020, September 8). Emerging electric passenger car markets in Europe: Can Poland lead the way? Retrieved May 21, 2021, from https://theicct.org/publication/emerging-electric-passenger-car-markets-in-europe-can-poland-lead-the-way/

Wenig, J., Sodenkamp, M., & Staake, T. (2019). Battery versus infrastructure: Tradeoffs between battery capacity and charging infrastructure for plug-in hybrid electric vehicles. *Applied Energy*, *255*, 113787. https://doi.org/10.1016/j.apenergy.2019.113787

White, L. V., & Sintov, N. D. (2017). You are what you drive: Environmentalist and social innovator symbolism drives electric vehicle adoption intentions. *Transportation Research Part A: Policy and Practice*, *99*, 94–113. https://doi.org/10.1016/j.tra.2017.03.008

Williams, E., Carvalho, R., Hittinger, E., & Ronnenberg, M. (2020). Empirical development of parsimonious model for international diffusion of residential solar. *Renewable Energy*, *150*, 570–577. https://doi.org/10.1016/j.renene.2019.12.101

Wolbertus, R., van den Hoed, R., Kroesen, M., & Chorus, C. (2021). Charging infrastructure roll-out strategies for large scale introduction of electric vehicles in urban areas: An agent-based simulation study. *Transportation Research Part A: Policy and Practice*, *148*, 262–285. https://doi.org/10.1016/j.tra.2021.04.010

Wu, G., Inderbitzin, A., & Bening, C. (2015). Total cost of ownership of electric vehicles compared to conventional vehicles: A probabilistic analysis and projection across market segments. *Energy Policy*, *80*, 196–214. https://doi.org/10.1016/j.enpol.2015.02.004

Zarazua De Rubens, G. (2019). Who will buy electric vehicles after early adopters? Using machine learning to identify the electric vehicle mainstream market. *Energy*, *172*, 243–254. https://doi.org/10.1016/j.energy.2019.01.114

Appendix

A. Demographics

Normal	Population	Total land area (km2)	Passenger cars	Highway (km)	Pop / cars	Pop / Area	cars / km2 area	area km2 / highway
Spain	46934632	505992	24074216	15523	1.9	93	48	33
Germany	83019213	357121	47095784	13009	1.8	232	132	27
France	67028048	551500	33020132	11618	2.0	122	60	47
Italy	60359546	301339	39018170	6943	1.5	200	129	43
United Kingdom	66647112	244820	34887915	3803	1.9	272	143	64
Portugal	10276617	91568	5015057	3065	2.0	112	55	30
Netherlands	17282163	41543	8373244	3055	2.1	416	202	14
Turkey	84078320	783562	12398190	2657	6.8	107	16	295
Poland	37972812	312685	23429016	2549	1.6	121	75	123
Greece	10722287	131957	5164183	2309	2.1	81	39	57
Sweden	10230185	449964	4870783	2132	2.1	23	11	211
Hungary	9772756	93030	3638374	1936	2.7	105	39	48
Belgium	11467923	30510	5782685	1763	2.0	376	190	17
Austria	8858775	83858	4978852	1743	1.8	106	59	48
Latvia	1919968	64589	636671	1651	3.0	30	10	39
Switzerland	8570000	41290	4665390	1458	1.8	208	113	28
Croatia	4076246	56594	1665391	1310	2.4	72	29	43
Denmark	5806081	43094	2593568	1308	2.2	135	60	33
Czech Republic	10649800	78866	8502520	1240	1.3	135	108	64
Ireland	4904226	70273	2104060	916	2.3	70	30	77
Finland	5517919	338155	2696334	893	2.0	16	8	379
Slovenia	208090	20273	1203774	783	0.2	10	59	26
Romania	19401658	238392	6450750	763	3.0	81	27	312
Bulgaria	7000039	110910	2770615	734	2.5	63	25	151
Norway	5328212	323802	2700000	523	2.0	16	8	619
Slovakia	5450421	49036	2326787	482	2.3	111	47	102
Lithuania	2794184	65300	1430520	324	2.0	43	22	202
Cyprus	875898	9251	526617	257	1.7	95	57	36
Luxembourg	613894	2586	415128	165	1.5	237	161	16
Estonia	1324820	45339	754464	154	1.8	29	17	294
Iceland	356991	102775	250000	37	1.4	3	2	2778
Liechtenstein	38378	160	29241	0	1.3	240	183	na
Malta	493559	316	291664	0	1.7	1562	923	na

B. European passenger car fleet and BEV adoption

B.1. Number of passenger car in use

Country	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Germany	41.321.171	41.737.627	42.301.563	42.927.647	43.431.124	43.851.230	44.403.124	45.071.209	45.803.560	46.474.594	47.095.784	47.715.977
France	30.850.000	31.050.000	31.300.000	31.550.000	31.550.000	31.600.000	31.650.000	37.458.000	37.934.000	38.371.000	38.336.000	38.215.000
Italy	36.105.183	36.371.790	36.751.311	37.113.300	37.078.274	36.962.934	37.080.753	37.351.233	37.876.138	38.520.321	39.018.170	39.545.232
United Kingdom	30.309.171	30.073.138	30.314.587	30.371.615	30.485.550	30.908.239	31.637.328	33.542.448	34.378.386	34.686.328	34.887.915	35.168.259
Spain	22.145.364	21.983.485	22.147.455	22.277.244	222.475.281	22.024.538	22.029.512	22.793.348	23.320.290	23.942.022	24.520.287	25.008.216
Poland	16.079.533	16.494.650	17.239.800	17.871.810	18.744.412	19.389.446	20.003.863	20.123.423	21.675.388	22.503.579	23.429.016	24.360.166
Netherlands	7.757.000	7.775.718	8.002.579	8.126.000	8.142.000	8.154.000	8.193.000	8.336.414	8.439.318	8.594.600	8.787.283	8.938.572
Belgium	5.086.756	5.160.257	5.279.110	5.359.014	5.392.908	5.439.295	5.511.080	5.587.735	5.569.766	5.735.280	5.782.684	5.813.771
Romania		4.230.635	4.307.290	4.322.951	4.485.148	4.693.651	4.905.630	5.153.182	5.470.578	5.996.377	6.450.750	6.901.236
Czech Republic	4.423.370	4.435.052	4.496.232	4.582.903	4.698.800	4.787.849	4.893.562	5.158.516	5.368.660	5.592.733	5.802.520	5.989.538
Greece	5.101.354	5.157.092	5.267.835	5.092.912	5.156.789	5.221.053	5.110.873	5.104.908	5.126.024	5.169.026	5.164.183	5.247.295
Austria	4.284.919	4.359.944	4.441.027	4.513.421	4.584.202	4.641.308	4.694.921	4.748.048	4.821.557	4.898.578	4.918.852	5.039.548
Sweden	4.278.995	4.300.752	4.335.182	4.401.352	44.471.651	4.495.473	4.585.519	4.669.063	4.768.060	4.845.609	4.870.783	4.887.904
Switzerland								4.503.865	4.731.994	4.620.530	4.665.390	4.572.188
Portugal	4.408.000	4.457.000	4.480.000	4.522.000	4.497.000	4.480.000	4.496.000	4.538.000	4.600.000	4.800.000	5.015.000	5.205.000
Hungary				2.961.951	2.978.745	3.035.764	3.101.752	3.192.132	3.308.495	3.467.861	3.638.374	3.809.670
Norway								2.592.324	2.639.246	2.693.021	2.120.013	2.768.990
Finland	2.700.492	2.776.664	2.858.244	2.532.496	2.560.190	2.575.951	2.595.867	2.612.922	2.629.432	2.668.930	2.696.334	2.720.307
Denmark	2.105.049	2.126.048	2.169.325	2.203.191	2.240.119	2.279.731	2.334.531	2.392.180	2.465.946	2.529.973	2.593.585	2.650.225
Slovakia	1.544.888	1.591.073	1.671.368					2.037.772	2.124.972	2.228.118	2.326.787	2.391.355
Ireland	1.924.281	1.902.429	1.872.715	1.887.810	1.882.550	1.910.165	1.943.868	2.031.455	2.089.419	7.064.020	2.104.060	2.172.098
Croatia								1.416.229	1.528.119	1.567.883	1.665.391	1.728.911
Lithuania	1.704.063	1.726.462	1.718.397	1.747.557	1.797.721	1.829.997	1.212.886	1.153.859	1.190.146	1.212.154	1.238.119	1.264.084
Slovenia								1.116.006	1.143.218	1.192.358	1.220.814	1.245.012
Estonia	551.830	545.692	552.684	574.007	602.133	628.563	552.022	676.592	703.151	725.944	746.464	794.926
Latvia	932.828	904.308	636.664	392.886				575.685	594.295	617.791	636.671	656.815
Luxembourg								381.105	300.933	403.258	415.128	426.324
Iceland												250.000

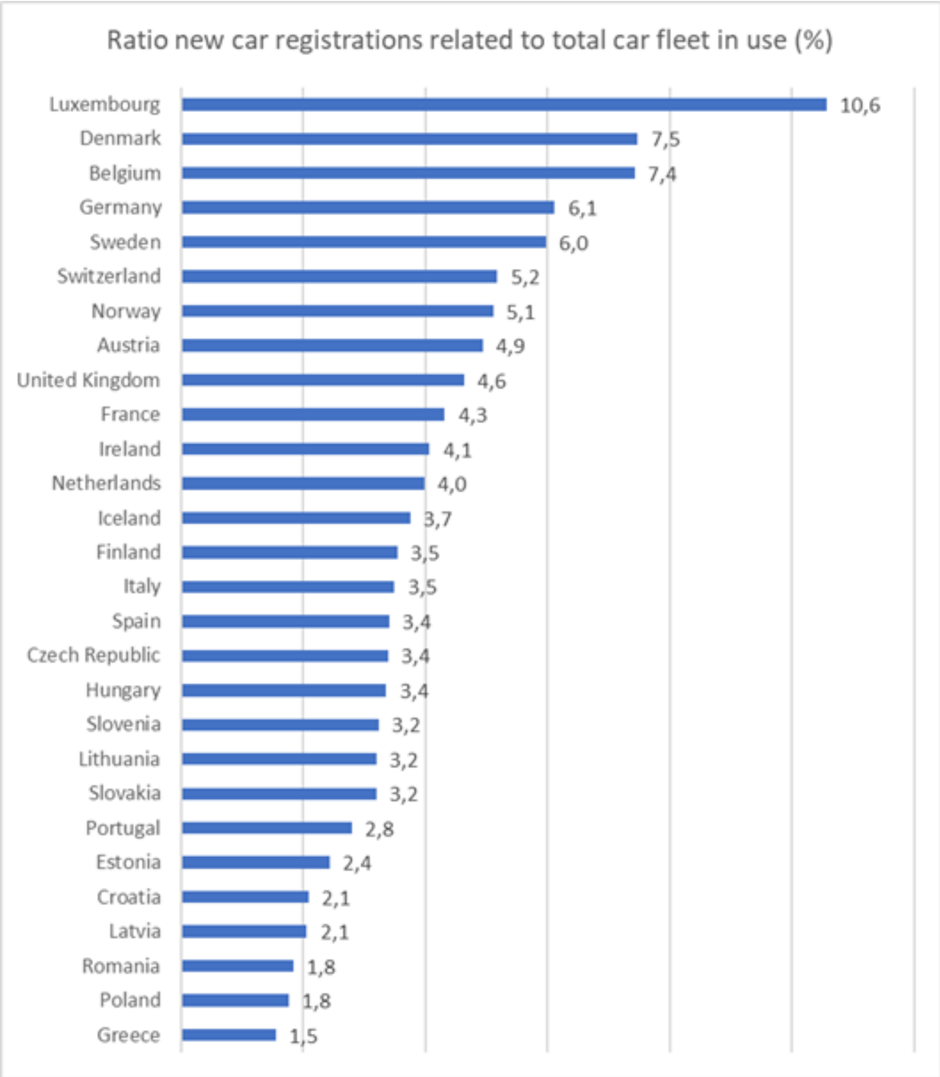
Data of Bulgaria, Lichtenstein, Malta, Cyprus not available
Source: ACEA (2010,2021b)

B.2. Number of new passenger car registrations

Country	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Germany	3.090.040	3.807.175	2.916.259	3.173.634	3.082.504	2.952.431	3.036.773	3.206.042	3.351.607	3.441.261	3.435.778	3.607.258	2.917.678
France	2.050.282	2.302.398	2.251.669	2.204.229	1.898.760	1.790.456	1.795.885	1.917.226	2.015.177	2.110.748	2.173.481	2.214.279	1.650.118
United Kingdom	2.131.795	1.994.999	2.030.846	1.941.253	2.044.609	2.264.737	2.476.435	2.633.503	2.692.786	2.540.617	2.367.147	2.311.140	1.631.064
Italy	2.161.682	2.159.463	1.961.579	1.749.739	1.403.010	1.304.648	1.360.578	1.569.085	1.825.892	1.971.345	1.910.701	1.916.951	1.381.646
Spain	1.161.176	952.772	982.015	808.051	699.589	722.689	855.308	1.034.232	1.147.009	1.234.932	1.321.437	1.258.251	851.210
Belgium	535.947	476.194	547.340	572.211	486.737	486.065	482.939	501.066	539.519	546.558	549.632	550.003	431.491
Poland	320.040	320.206	333.490	297.937	270.895	288.998	325.371	352.378	418.033	487.593	531.335	553.942	428.527
Netherlands	499.918	387.152	482.567	555.844	502.496	416.674	387.572	448.925	382.514	414.306	443.530	445.217	355.595
Sweden	253.982	213.408	289.684	304.984	279.899	269.558	303.948	345.108	372.318	379.393	353.729	356.036	292.024
Austria	293.697	319.403	328.563	356.145	336.010	319.035	303.318	308.555	329.604	353.320	341.068	329.363	248.740
Switzerland	288.557	266.049	292.453	316.846	325.948	*305.928*	*300.110*	*321.669*	315.295	311.996	299.135	311.256	236.703
Czech Republic	182.554	167.708	169.580	173.595	173.988	164.746	192.314	230.857	259.693	271.595	261.437	249.915	202.971
Denmark	150.145	112.201	153.587	169.744	170.600	181.896	188.612	206.999	222.895	221.592	218.358	225.410	198.162
Portugal	213.389	161.013	223.464	153.404	95.309	105.921	142.826	178.503	207.330	222.129	228.327	223.799	145.136
Norway	110.617	98.675	127.754	138.345	137.967	142.151	144.202	150.686	154.603	158.650	147.929	142.381	141.405
Hungary	153.278	60.189	43.476	45.094	53.059	56.139	67.476	77.171	96.555	116.265	136.601	157.906	128.031
Romania	270.995	130.195	106.328	94.619	72.143	57.710	70.172	81.162	94.919	105.083	130.919	161.562	126.351
Finland	139.611	88.344	107.346	121.171	111.147	103.314	106.259	108.844	118.912	118.529	120.480	114.188	96.430
Ireland	151.607	57.453	88.446	89.878	79.574	74.367	96.284	124.804	146.649	131.332	125.671	117.109	88.324
Greece	267.295	219.730	141.501	97.680	58.479	58.696	71.222	75.804	78.873	88.083	103.431	114.226	80.977
Slovakia	70.040	74.717	64.033	68.254	69.268	66.000	72.252	77.979	88.165	96.105	98.195	101.568	76.305
Luxembourg	52.359	47.265	49.726	49.881	50.398	46.624	49.793	46.473	50.561	52.775	52.786	54.923	45.104
Lithuania	22.217	7.515	7.970	13.234	12.165	12.163	14.461	17.071	20.284	25.836	32.382	46.388	40.338
Slovenia	71.575	57.967	61.142	60.193	50.091	51.585	53.959	59.664	58.963	62.522	65.115	59.862	40.200
Croatia						27.802	33.962	35.715	44.106	50.769	60.041	62.938	36.084
Bulgaria	43.758	24.972	15.646	19.252	20.986	20.718	21.186	24.256	28.216	33.265	37.506	39.419	27.214
Estonia	24.579	9.946	10.295	17.070	19.424	19.694	21.135	21.033	22.997	25.618	26.297	27.585	19.278
Latvia	19.831	5.367	6.365	10.980	10.665	10.636	12.452	13.766	16.357	16.698	16.878	18.233	13.516
Iceland	9.033	2.113	3.106	5.038	7.930	7.274	9.520	14.008	18.473	21.324	17.976	11.719	9.369

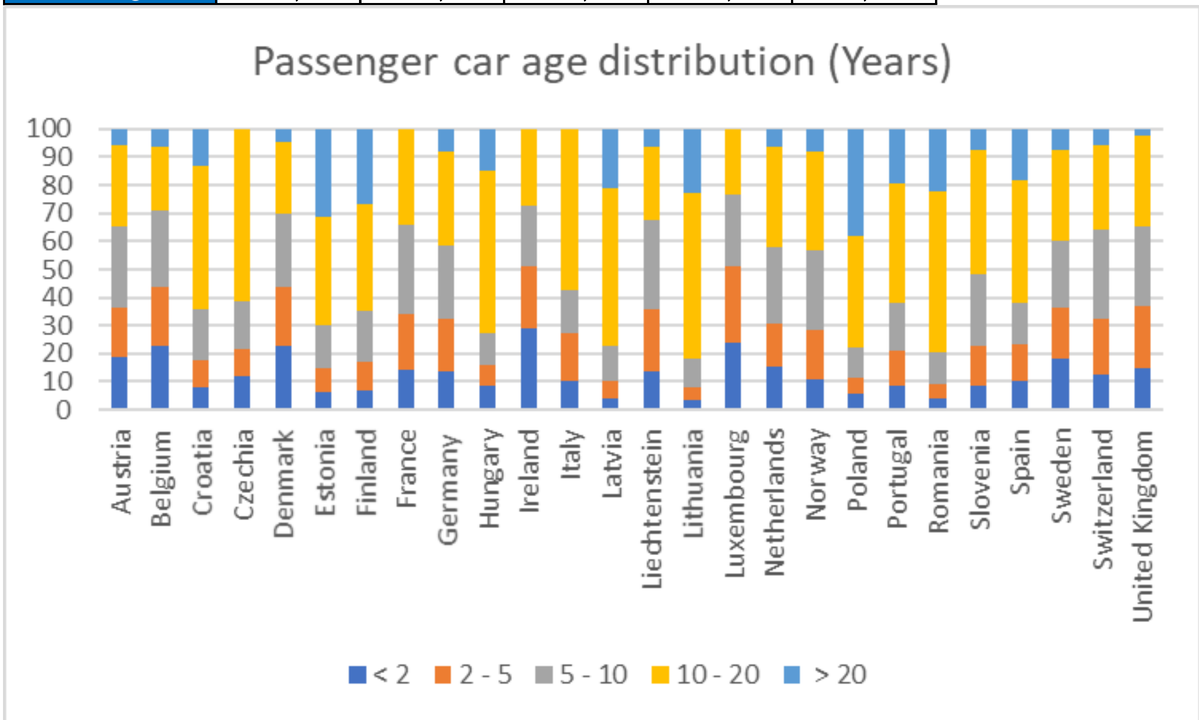
Data of Lichtenstein, Malta, Cyprus not available
Source: ACEA (2010,2021b)

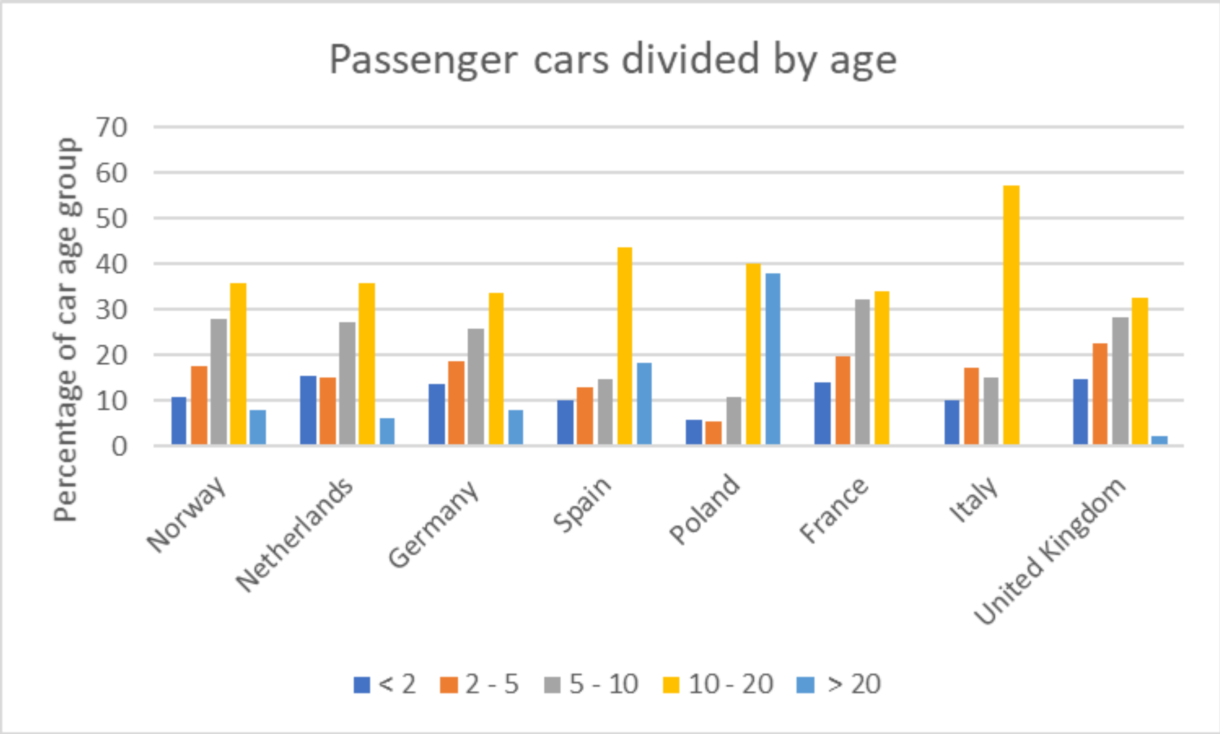
B.3. Ratio new car registrations related to total car fleet in use (%) 2020



B.4. Passenger car age percentage

Country / Years	< 2	2 - 5	5 - 10	10 - 20	> 20
Austria	18,7	17,6	29,2	28,6	6,0
Belgium	22,9	21,0	27,0	22,8	6,3
Croatia	8,0	9,6	18,0	51,3	13,1
Czechia	11,8	10,0	16,8	61,4	
Denmark	22,6	21,2	26,1	25,7	4,5
Estonia	6,1	9,0	14,8	38,7	31,5
Finland	6,6	10,6	17,7	38,2	26,9
France	14,1	19,9	32,1	33,9	
Germany	13,6	18,8	25,8	33,7	8,1
Hungary	8,6	7,2	11,6	57,7	15,0
Ireland	28,8	22,3	21,9	27,1	
Italy	10,2	17,4	15,2	57,2	0,0
Latvia	4,3	6,1	12,1	56,5	21,0
Liechtenstein	13,4	22,2	32,0	25,8	6,6
Lithuania	3,2	4,8	10,3	59,1	22,6
Luxembourg	23,7	27,2	26,0	23,1	
Netherlands	15,6	15,1	27,3	35,7	6,3
Norway	10,8	17,7	28,0	35,7	7,8
Poland	5,8	5,4	10,8	40,1	37,9
Portugal	8,4	12,6	17,0	42,5	19,5
Romania	4,2	5,1	11,5	57,3	22,1
Slovenia	8,5	14,4	25,1	44,7	7,3
Spain	10,1	13,0	14,9	43,6	18,4
Sweden	18,1	18,6	23,8	32,0	7,7
Switzerland	12,4	20,2	31,2	30,1	6,0
United Kingdom	14,6	22,5	28,2	32,5	2,2




Passenger cars divided by age
Percentage of car age group
70
60
50
40
30
20
10
0
Norway
Netherlands
Germany
Spain
Poland
France
Italy
United Kingdom
< 2
2 - 5
5 - 10
10 - 20
> 20

B.5. *Number of BEVs in use*

Country	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Norway	1.243	1.388	1.782	3.982	6.543	15.462	36.345	61.393	97.615	130.532	172.525	242.796	319.540
Germany	1.300	1.588	2.307	4.541	7.114	12.156	18.948	25.502	34.022	53.861	83.175	133.886	308.139
France	2.602	2.599	2.604	5.293	9.318	17.376	28.655	48.288	64.786	89.631	123.171	166.092	277.001
United Kingdom	189	354	394	1.478	2.810	5.312	9.875	20.017	30.129	42.829	61.375	99.437	206.998
Netherlands	0	0	0	0	2.100	4.161	6.825	9.368	12.802	20.798	43.500	105.008	172.524
Sweden	129	157	190	366	603	1.010	2.172	4.765	7.532	11.034	16.664	30.343	58.240
Italy	0	0	0	117	623	1.531	2.430	3.971	5.446	7.460	12.337	22.728	55.307
Switzerland	0	0	123	456	1.023	2.186	3.413	6.631	9.697	13.897	19.602	32.697	52.008
Spain	0	0	0	568	1.023	2.021	2.832	4.480	6.484	10.145	16.407	26.799	45.057
Austria	0	328	353	989	1.389	2.070	3.386	5.032	9.073	14.618	20.831	29.523	41.646
Portugal	28	29	86	282	347	437	484	970	2.357	7.405	16.774	29.033	36.882
Belgium	9	13	61	323	825	1.204	2.237	3.316	5.206	7.548	10.885	18.707	33.703
Denmark	0	31	51	466	937	1.434	2.967	7.491	8.686	9.432	10.898	16.331	30.516
Ireland	0	0	18	64	193	246	560	1.020	1.426	1.946	3.641	7.267	11.278
Finland	7	13	23	56	109	169	360	614	844	1.449	2.404	4.661	9.697
Czech Republic	80	83	92	169	301	448	855	1.326	1.762	2.309	3.047	3.897	7.109
Poland	0	0	0	35	54	81	153	219	348	896	1.487	2.902	6.556
Hungary	0	0	0	9	90	110	145	204	405	1.153	2.460	3.696	6.101
Romania	0	0	0	5	5	42	59	97	164	399	854	2.718	5.563
Iceland	12	12	14	14	31	111	305	691	1.066	1.910	2.684	3.749	5.499
Luxembourg	0	0	0	31	100	263	564	635	771	1.091	1.567	2.574	4.032
Slovenia	0	0	0	0	12	29	87	209	372	722	1.179	1.998	3.665
Lithuania	0	0	0	0	0	2	63	154	330	612	941	1.360	1.945
Malta	0	0	0	0	38	49	87	114	131	178	314	1.128	1.934
Slovakia	0	0	0	25	26	0	113	137	198	398	795	956	1.863
Estonia	0	0	0	56	600	708	1.067	1.099	1.130	1.154	1.258	1.466	1.769
Bulgaria	0	0	0	0	72	91	147	183	289	384	710	1.062	1.404
Croatia	0	0	0	0	0	0	39	114	183	191	299	552	1.353
Greece	0	0	0	0	1	3	45	84	114	148	215	426	1.104
Latvia	0	0	0	0	10	15	188	211	241	295	442	557	846
Cyprus	0	0	0	0	1	6	11	15	35	90	143	208	251
Liechtenstein	0	0	0	0	0	0	0	0	0	0	140	166	222

Source: EAFO 2021

B.6. BEV fleet percentage of total passenger car fleet

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Norway	0,00	0,00	0,00	0,00	0,27	0,62	1,42	2,35	3,67	4,80	6,27	8,62	11,14
Netherlands	0,00	0,00	0,00	0,00	0,03	0,05	0,09	0,12	0,16	0,25	0,51	1,23	2,01
Iceland	0,00	0,00	0,00	0,00	0,01	0,05	0,14	0,31	0,44	0,74	1,00	1,39	1,99
Sweden	0,00	0,00	0,00	0,00	0,01	0,02	0,05	0,10	0,16	0,23	0,34	0,61	1,14
Denmark	0,00	0,00	0,00	0,00	0,04	0,06	0,13	0,31	0,35	0,37	0,42	0,61	1,12
Switzerland	0,00	0,00	0,00	0,00	0,02	0,05	0,08	0,15	0,21	0,30	0,43	0,70	1,10
Luxembourg	0,00	0,00	0,00	0,00	0,03	0,07	0,15	0,17	0,20	0,27	0,38	0,61	0,94
France	0,00	0,00	0,00	0,00	0,03	0,05	0,09	0,15	0,20	0,28	0,38	0,52	0,87
Austria	0,00	0,00	0,00	0,00	0,03	0,04	0,07	0,11	0,19	0,30	0,42	0,59	0,82
Liechtenstein	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,47	0,55	0,72
Portugal	0,00	0,00	0,00	0,00	0,01	0,01	0,01	0,02	0,05	0,15	0,32	0,54	0,67
United Kingdom	0,00	0,00	0,00	0,00	0,01	0,02	0,03	0,07	0,10	0,14	0,19	0,31	0,64
Germany	0,00	0,00	0,00	0,00	0,02	0,03	0,04	0,06	0,07	0,12	0,18	0,28	0,64
Malta	0,00	0,00	0,00	0,00	0,02	0,02	0,03	0,04	0,05	0,06	0,10	0,37	0,61
Belgium	0,00	0,00	0,00	0,00	0,02	0,02	0,04	0,06	0,09	0,13	0,19	0,32	0,56
Ireland	0,00	0,00	0,00	0,00	0,01	0,01	0,03	0,05	0,07	0,09	0,17	0,33	0,50
Slovenia	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,02	0,03	0,06	0,10	0,18	0,32
Finland	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,02	0,03	0,04	0,07	0,13	0,27
Estonia	0,00	0,00	0,00	0,00	0,10	0,11	0,16	0,16	0,16	0,16	0,17	0,19	0,22
Lithuania	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,03	0,05	0,07	0,14	0,22
Spain	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,02	0,03	0,04	0,07	0,11	0,18
Hungary	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,03	0,07	0,10	0,16
Italy	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,01	0,02	0,03	0,06	0,14
Latvia	0,00	0,00	0,00	0,00	0,00	0,00	0,03	0,03	0,04	0,04	0,06	0,08	0,12
Czech Republic	0,00	0,00	0,00	0,00	0,01	0,01	0,02	0,03	0,03	0,04	0,05	0,07	0,12
Romania	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,05	0,09
Slovakia	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,01	0,02	0,03	0,04	0,08
Croatia	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,01	0,02	0,03	0,08
Cyprus	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,02	0,03	0,04	0,05
Bulgaria	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,01	0,03	0,04	0,05
Poland	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,03
Greece	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,02

B.7. *Number of annually new BEV registrations*

Country	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Germany	0	15	144	1.828	2.555	5.464	8.378	12.097	11.243	24.438	35.238	61.007	187.536
France	0	10	184	2.630	5.663	8.779	10.560	17.268	21.751	25.271	30.989	42.836	110.405
United Kingdom	0	164	90	1.073	1.416	2.552	6.688	9.936	10.246	13.678	17.513	37.993	104.634
Norway	243	145	394	2.010	4.273	8.232	18.098	25.792	24.222	33.025	46.112	60.221	73.036
Netherlands	0	28	86	849	828	2.441	2.853	3.168	4.029	8.007	23.938	61.544	72.298
Italy	0	0	40	117	507	836	1.075	1.451	1.376	1.957	4.983	10.698	32.227
Sweden	0	18	56	183	267	444	1.206	2.978	2.945	4.217	7.109	15.556	27.122
Switzerland	0	21	123	398	463	1.127	1.292	3.065	3.272	4.751	5.090	12.934	18.750
Spain	0	1	73	568	443	921	1.035	1.422	2.021	3.920	6.003	10.380	17.774
Austria	0	25	112	631	427	654	1.271	1.677	3.826	5.433	6.760	9.231	15.533
Belgium	0	0	34	288	585	494	1.169	1.358	2.052	2.709	3.728	8.858	14.453
Denmark	0	31	20	415	471	497	1.533	4.524	1.223	706	1.470	5.536	13.895
Portugal	0	0	18	201	64	166	196	639	784	1.793	4.474	6.875	7.629
Finland	0	0	13	29	51	50	185	242	225	502	776	1.886	4.135
Ireland	5	2	18	46	139	47	222	460	392	622	1.237	3.646	4.000
Poland	0	0	0	35	19	27	68	86	138	475	639	1.446	3.449
Czech Republic	0	0	4	56	92	39	187	331	233	389	699	780	3.218
Hungary	0	0	0	9	8	11	28	166	201	753	1.267	1.821	2.856
Romania	0	0	0	5	2	37	17	28	69	232	472	1.605	2.777
Luxembourg	0	0	0	31	61	143	301	71	136	354	470	1.013	2.474
Iceland	0	0	2	0	17	80	206	387	376	854	759	1.110	2.457
Slovenia	0	0	0	12	17	5	39	122	178	336	470	578	1.666
Slovakia	0	0	0	25	3	16	69	123	55	209	302	156	867
Greece	0	0	0	0	1	2	42	39	33	34	64	185	656
Croatia	0	0	0	0	0	0	39	75	48	8	129	240	532
Lithuania	0	0	0	0	0	2	4	25	65	49	141	173	441
Estonia	0	0	0	56	506	146	334	39	49	26	103	80	355
Latvia	0	0	0	0	6	3	172	20	28	71	128	118	291
Bulgaria	0	0	0	0	0	0	2	10	11	66	125	190	276
Malta	0	0	0	0	1	7	28	34	17	48	180	282	137
Liechtenstein	0	0	0	0	0	0	0	8	43	55	34	84	56
Cyprus	0	0	0	0	0	0	0	4	19	44	45	68	42

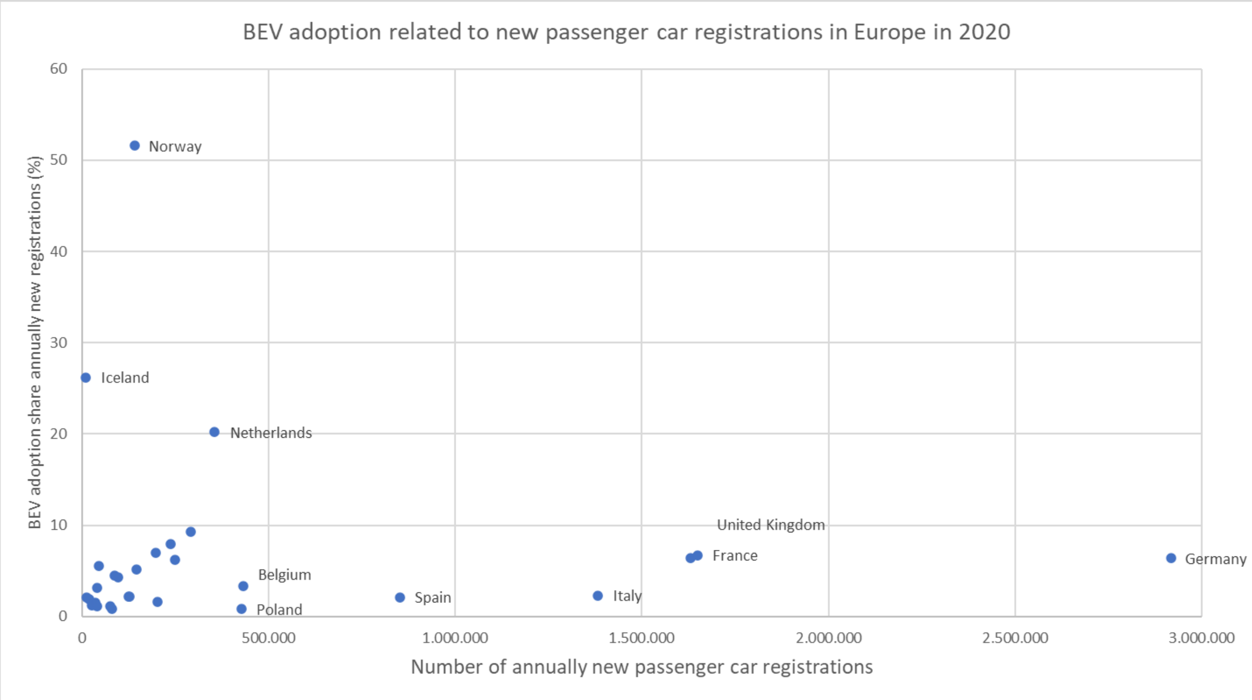
B.8. *Newly registered BEVs relative to total newly registered passenger cars (in %)*

Country	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Norway	0,1	0,3	1,5	3,1	5,8	12,6	17,1	15,7	20,8	31,2	42,3	51,6	63,2
Iceland	0,0	0,1	0,0	0,2	1,1	2,2	2,8	2,0	4,0	4,2	9,5	26,2	32,7
Netherlands	0,0	0,0	0,2	0,2	0,6	0,7	0,7	1,1	1,9	5,4	13,8	20,2	19,9
Sweden	0,0	0,0	0,1	0,1	0,2	0,4	0,9	0,8	1,1	2,0	4,4	9,3	18,9
Austria	0,0	0,0	0,2	0,1	0,2	0,4	0,5	1,2	1,5	2,0	2,8	6,2	13,7
Denmark	0,0	0,0	0,2	0,3	0,3	0,8	2,2	0,5	0,3	0,7	2,5	7,0	13,2
Germany	0,0	0,0	0,1	0,1	0,2	0,3	0,4	0,3	0,7	1,0	1,7	6,4	13,2
Switzerland	0,0	0,0	0,1	0,1	0,4	0,4	0,9	1,0	1,5	1,7	4,2	7,9	13,1
United Kingdom	0,0	0,0	0,1	0,1	0,1	0,3	0,4	0,4	0,5	0,7	1,6	6,4	11,5
Luxembourg	0,0	0,0	0,1	0,1	0,3	0,6	0,2	0,3	0,7	0,9	1,8	5,5	10,3
Finland	0,0	0,0	0,0	0,0	0,0	0,2	0,2	0,2	0,4	0,6	1,7	4,3	10,2
France	0,0	0,0	0,1	0,3	0,5	0,6	0,9	1,1	1,2	1,4	1,9	6,7	9,8
Portugal	0,0	0,0	0,1	0,1	0,2	0,1	0,4	0,4	0,8	2,0	3,1	5,2	8,9
Ireland	0,0	0,0	0,1	0,2	0,1	0,2	0,4	0,3	0,5	1,0	3,1	4,5	8,3
Belgium	0,0	0,0	0,1	0,1	0,1	0,2	0,3	0,4	0,5	0,7	1,6	3,3	5,6
Romania	0,0	0,0	0,0	0,0	0,1	0,0	0,0	0,1	0,2	0,4	1,0	2,2	5,2
Italy	0,0	0,0	0,0	0,0	0,1	0,1	0,1	0,1	0,1	0,3	0,6	2,3	4,6
Liechtenstein	0,0	0,0	0,0	0,0	0,0	0,0	0,4	2,2	2,7	1,8	4,3	3,3	3,3
Hungary	0,0	0,0	0,0	0,0	0,0	0,0	0,2	0,2	0,6	0,9	1,2	2,2	3,2
Latvia	0,0	0,0	0,0	0,1	0,0	1,4	0,1	0,2	0,4	0,8	0,6	2,1	3,2
Slovenia	0,0	0,0	0,0	0,0	0,0	0,1	0,2	0,3	0,5	0,6	0,8	3,1	3,1
Spain	0,0	0,0	0,1	0,1	0,1	0,1	0,1	0,2	0,3	0,5	0,8	2,1	2,8
Lithuania	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,3	0,2	0,4	0,4	1,1	2,5
Bulgaria	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,2	0,4	0,5	1,2	2,2
Croatia		0,0	0,0	0,0	0,0	0,1	0,2	0,1	0,0	0,2	0,4	1,5	2,2
Estonia	0,0	0,0	0,3	2,6	0,7	1,6	0,2	0,2	0,1	0,4	0,3	1,9	2,1
Greece	0,0	0,0	0,0	0,0	0,0	0,1	0,1	0,0	0,0	0,1	0,2	0,8	2,1
Poland	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,1	0,3	0,8	1,5
Slovakia	0,0	0,0	0,0	0,0	0,0	0,1	0,2	0,1	0,2	0,3	0,2	1,1	1,4
Czech Republic	0,0	0,0	0,0	0,1	0,0	0,1	0,1	0,1	0,1	0,3	0,3	1,6	1,2
Malta							0,3	0,1	0,4	1,4	2,3	1,2	1,1
Cyprus			0,0	0,0	0,0	0,0	0,0	0,2	0,3	0,3	0,6	0,4	0,8

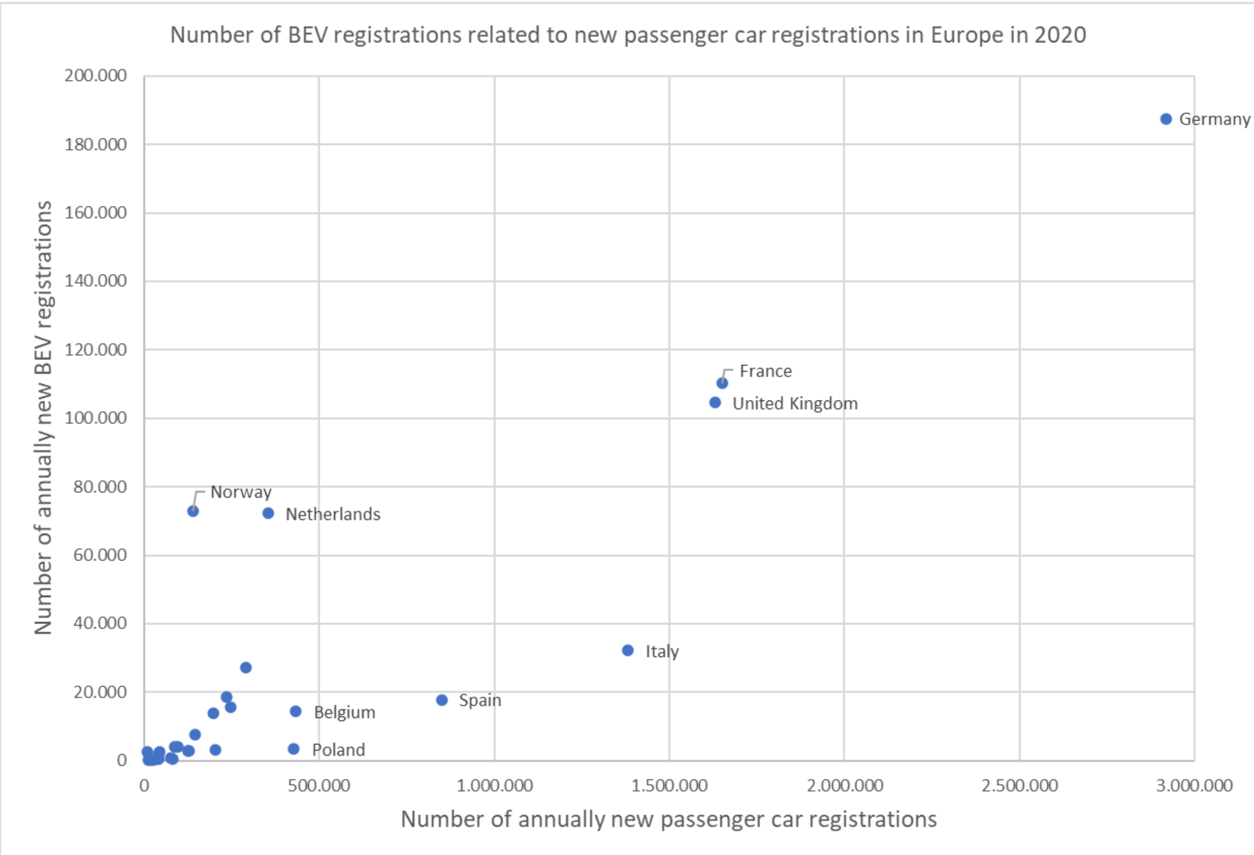
B.9. *European Car and BEV market relative to Rogers categories*

		European passenger car market in 2020				European BEV market in 2020			
	Countries	Passenger car fleet (%)		New car registrations (%)		BEV fleet in use		New BEV registrations	
Laggards 84-100%		0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Late Majority 50 - 84%	Norway	1,0	1,0	1,2	1,2	18,7	18,7	10,0	10,0
Early Majority 16-50%	Netherlands	3,1	3,2	3,0	3,1	10,1	10,4	10,0	10,3
	Iceland	0,1		0,1		0,3		0,3	
Early Adaptors 2,5 - 16%	Germany	16,7	42,4	24,4	51,9	18,0	46,3	25,8	55,5
	France	13,4		13,8		16,2		15,2	
	UK	12,3		13,7		12,1		14,4	
	Other	12,2		15,2		16,6		15,3	
Innovators 0 - 2,5%	Italy	13,9	31,2	11,6	22,3	3,2	6,2	4,4	7,4
	Spain	8,8		7,1		2,6		2,4	
	Poland	8,5		3,6		0,4		0,5	
	Other	10,0		6,3		1,8		1,7	

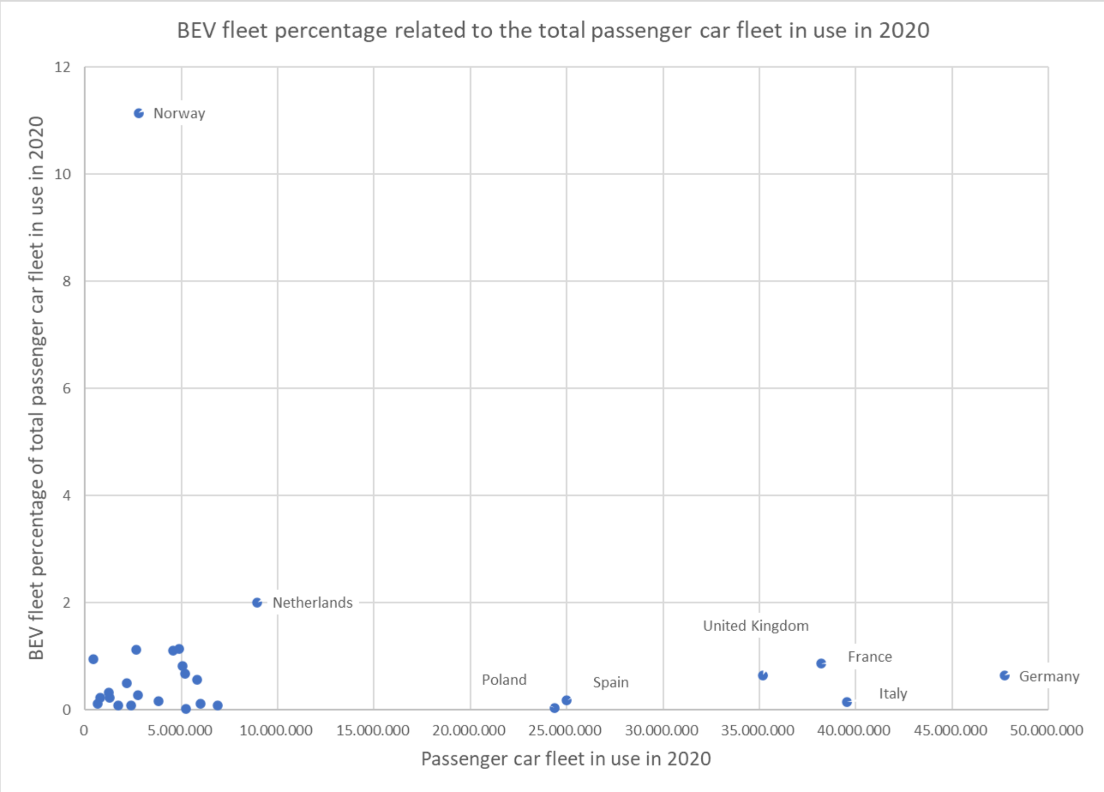
B.10. BEV adoption related to new passenger car registrations in 2020



B.11. Number of BEV registrations related to new passenger car registrations



B.12. BEV fleet percentage in use related to the total passenger car fleet



C. National and local incentives to increase BEV adoption

C.1. Norway

Year	Description
1990	Exemption import / purchase tax for EV's
1996-2021	Exemption road tax for EV's
1997-2017	Exemption for toll and ferry costs
1999	Special "EL" license plates were introduced, so free municipal parking was possible.
1999-	Possibility for local authorities of free municipal parking
2000-2018	50 % reduced company car tax
2001-2022	Exemption from 25% purchase VAT for BEVs
2003	Access to bus lanes in the Oslo region and in 2005 extended nationwide
2015	Exemption from 25% VAT on leasing
2016	Local authorities are able to limit access to only EV's
2018	Local authorities can charge a maximum fee of 50% of the regular parking fee for EV's
2018	Company car tax reduction to 40%
2018	Annual road tax was replaced for road traffic insurance tax but still exemption for EV's
2019	Maximum 50% of the total amount on toll roads
2020	Reduced annual road tax for EV's (was exemption since 1996)
2021	Traffic insurance tax for ICE of 8,40 NOK / day and EV 's 5,85 NOK / day

C.1.1. Purchase tax

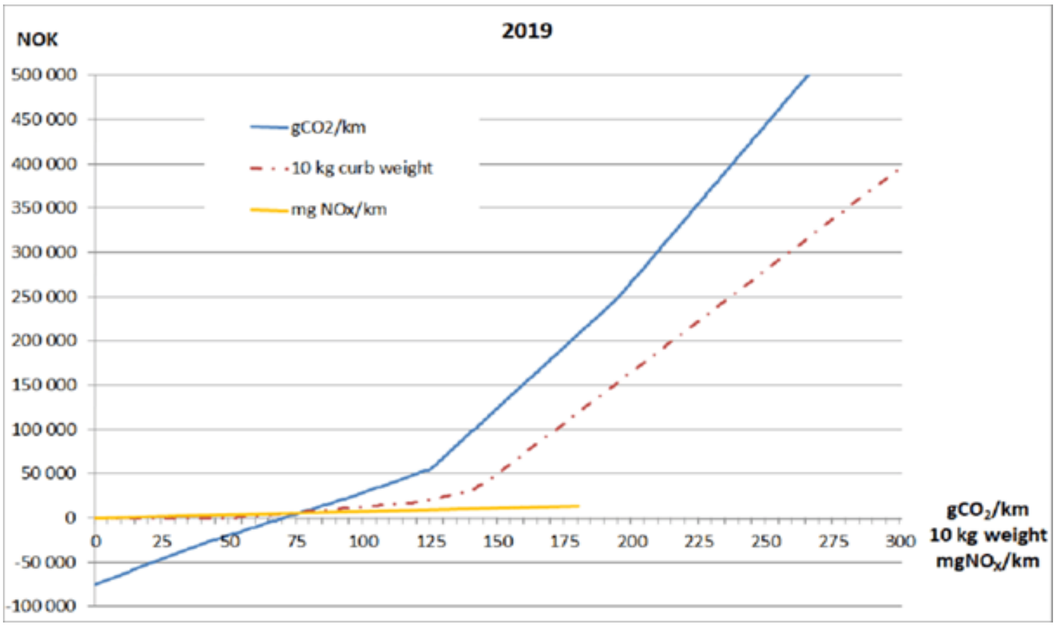


Figure C.1.1. Norwegian vehicle registration tax based on curb weight, CO_2 and NOx emissions rates

C.2. The Netherlands

National and local Incentives driving the EV adoption in The Netherlands

Year	Description
2011	Exemption purchase tax for EV's
2011	Exemption road tax for EV's
2011	Exemption Motor vehicle tax for EV's
2013	0% BIK tax for BEVs
2014	4% BIK tax for BEVs
2019	4% BIK tax for BEV 's with a list price < €50.000)
2020	8% BiK for (<45.000)
2020	Purchase subsidy €4000 for new & 2000 for used cars
2021	12% BiK for BEV (<40.000)
2022	16% BiK for BEV (<35.000)
2023-2024	16% BiK for BEV (<30.000)
2025	17% BiK for BEV (<30.000)
2026	22% BIK for BEV

C.3. Germany

Year	Description
2016	purchase tax exemption of 10 years for BEV
2018	Tax BIK BEV 0,25% listprice (till 2030) (ICE 1,% list price)
2020	€9000 purchase subsidy (BEV < 40.000)

C.4. Spain

Spain is the fifth largest passenger car market in Europe by stock behind Germany, Italy, France, and the United Kingdom with over 24 million passenger cars on the road at the end of 2019. Yet, there were only 45057 BEVs in Spain by the end of 2020, representing 0.2% of passenger car stock (EAFO,2021).

The aim of the support program is to get at least 250,000 electric vehicles on Spain's roads and 100,000 charging points by the end of 2023.

National and local Incentives driving the EV adoption in Spain

National	Regional	Region	Description
	2001	Castile and Leon	Maximum aid of 4800 EURO
2003			National decree regulating that cities can provide a reduction on ownership tax for HEV up to 75%
	2004	Andalusia	Maximum aid of €3000
	2005	Andalusia	Information about aid program
2007			Registration tax exemption for vehicles up to 120 g CO_2/km
	2007	Valencia	Maximum aid of2000E (Program CO_2 TXE 2008)
	2008	Extremadura	Extremadura Maximum aid of E 2.300
2008			National/regional aid plan: Minimum aid of €1.500 (Plan 2000 E)
2008			National/regional scrapping program: Reduced loans (VIVE Plan 2008-2010)
	2010	Catalonia	Internet platform to raise awareness (LIVE Platform)
	2010	Barcelona	Plan for Energy, Climate Change and Air Quality 2011-2020
	2010	Catalonia	30% reduction on road tolls
2011			National scrapping program: Aid of E 2.000 (PIVE 1)
2012			National scrapping program Aid of E 1.000 or E 2.000 (PIMA Aire 1,2,3)
	2012	Madrid	Aid of E 2.000 (Piam Plan)
2013			National scrapping program: Aid of E 1.000 or E 2.000 (PIMA Aire 3)
2013			National scrapping program: Aid of EE 2.000 (PIVE 2,3,4,5,6)
	2014	Madrid	50% discount parking fee
	2014	Catalonia	Regulatory base for financial aids
2014			National scrapping program Aid of E 1.000 or E 2.000 (PIMA Aire 4)
	2014	Madrid	Aid of E 3.000 (PIVCEM Plan)
2015			National scrapping program: Aid of EE 1.500 (PIVE 7)
2015			National scrapping program: Aid of EE 1.500 (PIVE 8)
2015			20% tax reduction on personal income tax for privately using a HEV as company car
	2016	Castilla La Mancha	Regulatory base for financial aids
2016			Directive for environmental car labeling differented by four categories
	2016	Madrid	Aid up to E 3.000 (Taxifree 2016)
	2017	Madrid	Aid up to E 3.000 (Taxifree 2017)
	2017	Madrid	Air Quality and Climate Change Plan (Plan A)
	2017	Barcelona	Information campaign about Low Emission Zone
	2017	Barcelona	Preferential access to Low Emission Zone
2017			National Air Quality Plan 2017 - 2019 (Air Plan II)
	2018	Madrid	Aid of €3.000 (PIAM Plan 2018) & PIVCEM Plan 2018)
	2018	Catalonia	Aid of €1.000
	2018	Madrid	Aid of €3.000 (TAXIFREE 2018)
	2018	Castilla La Mancha	Aid of €3.000
	2018	Madrid	Preferential access to Low Emission Zone
	2018	Madrid	Information campaign about Low Emission Zone
2019			Moves I:
2020			Moeves II:
2021			Moves III:

C.4.1 Purchase tax

Registration taxes in Spain are calculated according to the level of CO_2 emissions.
0% for vehicles emitting less than 120 g/km.
4,75% for vehicles emitting between 120 g/km and 160 g/km.
9,75% for vehicles emitting between 160 g/km and 200 g/km.
14,75% for vehicles emitting more than 200 g/km.

C.5. Poland

National and local Incentives driving the EV adoption in Poland

Year	Description
2018	Purchase tax exemption for BEV and PHEV. For other tax is 3.1% or 18.6% of a vehicle's net value depending on the engine capacit
2020	Purchase subsidy: 15% of the purchase price with a maximum amount of €4,400 and is capped at a gross purchase price of €29,000.

D. TCO

D.1 *Norway*

	ICE							BEV						
Years	2014	2015	2016	2017	2018	2019	2020	2014	2015	2016	2017	2018	2019	2020
Base Price	17106	16465	17845	17624	18300	22502	21432	27598	26483	29936	32403	32446	28471	32528
Value Added tax	4276	4116	4461	4406	4575	5625	5358	0	0	0	0	0	0	0
Registration tax	5683	5454	6001	5548	5485	6200	5862	0	0	0	0	0	0	0
Subsidy	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Purchase price	27065	26035	28307	27578	28360	34327	32652	27598	26483	29936	32403	32446	28471	32528
Depreciation 4 years	12991	12497	13587	13237	13613	16477	15673	13247	12712	14369	15553	15574	13666	15613
Road tax costs 4 years	1326	1274	1381	1148	1193	1203	1126	0	0	0	0	0	0	0
Fuel costs 4 years	4659	4382	4272	4615	4902	4946	4631	1646	1608	1509	1635	1744	1860	1350
TCO 4 years	18976	18153	19240	19000	19708	22626	21430	14893	14320	15878	17188	17318	15526	16963

D.2 *The Netherlands*

	ICE							BEV						
Years	2014	2015	2016	2017	2018	2019	2020	2014	2015	2016	2017	2018	2019	2020
Base Price	13938	14393	14603	14900	14589	16436	20280	29331	29628	30289	31322	31322	32438	26479
Value Added tax	2927	3022	3067	3129	3064	3452	4259	6159	6222	6361	6578	6578	6812	6401
Registration tax	2625	2935	3380	3091	3467	3252	3278	0	0	0	0	0	0	0
Subsidy	0	0	0	0	0	0	0	0	0	0	0	0	0	4000
Purchase price	19490	20350	21050	21120	21120	23140	27817	35490	35850	36650	37900	37900	39250	36880
Depreciation 4 years	9355	9768	10104	10138	10138	11107	13352	17035	17208	17592	18192	18192	18840	17702
Road tax costs 4 years	1920	1920	1920	1920	1920	2064	2256	0	0	0	0	0	0	0
Fuel costs 4 years	6000	6000	6000	6000	6000	6000	6000	2112	2016	2112	2112	2112	2112	2448
TCO 4 years	17275	17688	18024	18058	18058	19171	21608	19147	19224	19704	20304	20304	20952	20150

D.3 *Germany*

	ICE							BEV						
Years	2014	2015	2016	2017	2018	2019	2020	2014	2015	2016	2017	2018	2019	2020
Base Price	15000	17941	18151	15189	15945	16403	17395	29328	29328	30168	30168	30168	26807	26798
Value Added tax	2850	3409	3449	2886	3030	3117	3305	5572	5572	5732	5732	5732	5093	5092
Registration tax	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Subsidy	0	0	0	0	0	0	0	0	0	0	0	0	0	9000
Purchise price	17850	21350	21600	18075	18975	19520	20700	34900	34900	35900	35900	35900	31900	22890
Depreciation 4 years	8568	10248	10368	8676	9108	9370	9936	16752	16752	17232	17232	17232	15312	10987
Road tax costs 4 years	248	248	256	256	256	256	296	120	120	120	120	120	120	-120
Fuel costs 4 years	5082	4620	4290	4521	4752	4686	4224	2969	2939	2957	3036	2975	3076	3031
TCO 4 years	13898	15116	14914	13453	14116	14312	14456	19841	19811	20309	20388	20327	18508	13898

D.4 *Spain*

	ICE							BEV						
Years	2014	2015	2016	2017	2018	2019	2020	2014	2015	2016	2017	2018	2019	2020
Base Price	15862	15207	16273	14868	14860	16326	23091	31767	30455	30455	30455	30455	30455	28912
Value Added tax	2538	3193	3417	3122	3120	3429	4849	5083	6395	6395	6395	6395	6395	6072
Registration tax	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Subsidy	0	0	0	0	0	0	0	0	0	0	0	0	0	4000
Purchase price	18400	18400	19690	17990	17980	19755	27940	36850	36850	36850	36850	36850	36850	34984
Depreciation 4 years	8832	8832	9451	8635	8630	9482	13411	17688	17688	17688	17688	17688	17688	16792
Road tax costs 4 years	256	256	256	92	92	92	92	256	256	256	92	92	92	92
Fuel costs 4 years	4587	4059	3795	4026	4257	4257	4389	2155	2300	2176	2287	2373	2393	2230
TCO 4 years	13675	13147	13502	12753	12979	13831	17892	20099	20244	20120	20067	20153	20173	19114

D.5 *Poland*

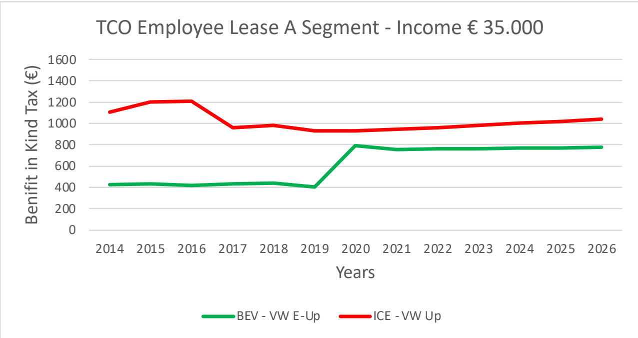
	ICE							BEV						
Years	2014	2015	2016	2017	2018	2019	2020	2014	2015	2016	2017	2018	2019	2020
Base Price	11343	11713	11884	11633	12184	13804	15766	27366	27366	28374	29187	29493	25363	25450
Value Added tax	2687	2775	2815	2756	2886	3270	3735	6294	6294	6526	6713	6783	5833	5854
Registration tax	340	351	357	349	366	414	473	0	0	0	0	0	0	0
Subsidy	0	0	0	0	0	0	0	0	0	0	0	0	0	4350
Purchase price	14370	14839	15056	14738	15436	17488	19974	33660	33660	34900	35900	36276	31196	26954
Depreciation 4 years	6898	7123	7227	7074	7409	8394	9588	16157	16157	16752	17232	17412	14974	12938
Road tax costs 4 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fuel costs 4 years	4587	4059	3795	4026	4257	4257	4389	2155	2300	2176	2287	2373	2393	2230
TCO 4 years	11485	11182	11022	11100	11666	12651	13977	18312	18457	18928	19519	19785	17367	15168

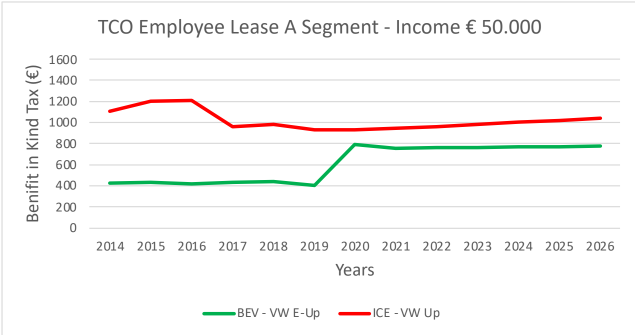
D.6 Excise duty tax on energy consumption

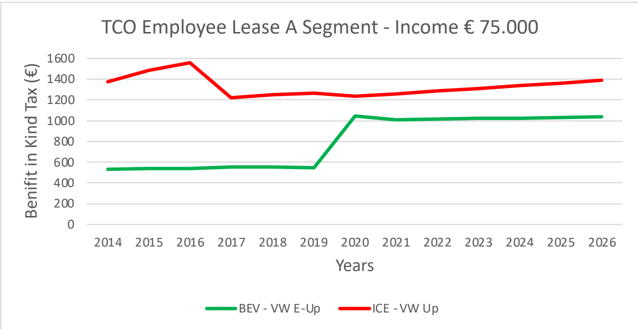
	LPG	Gasoil	Petrol leaded	Petrol unleaded
EU minimum	125	330	421	359
Netherlands	355	522	906	813
Switzerland		800	770	770
Italy	268	617	728	728
Finland	315	513	724	724
Greece	430	410	681	700
United Kingdom	295	693	693	693
France	207	594	716	683
Portugal	325	513	791	668
Germany	318	486	721	655
Sweden	346	482	731	643
Denmark	542	435	757	638
Ireland	218	515	619	619
Belgium	0	616	668	616
Estonia	193	372	563	563
Iceland		683	550	550
Malta	39	413	678	549
Norway		541	548	548
Luxembourg	162	404	570	516
Austria	261	397	587	515
Slovakia	182	368	514	514
Croatia	13	405	595	510
Latvia	285	414	594	509
Spain	57	379	506	504
Czech Republic	146	370	509	477
Lithuania	304	372	579	466
Slovenia	201	464	490	445
Poland	187	330	405	437
Cyprus	125	400	421	429
Romania	138	344	441	375
Bulgaria	174	330	425	363
Hungary	266	345	359	359

E. Annually BIK tax using company car privately in the Netherlands

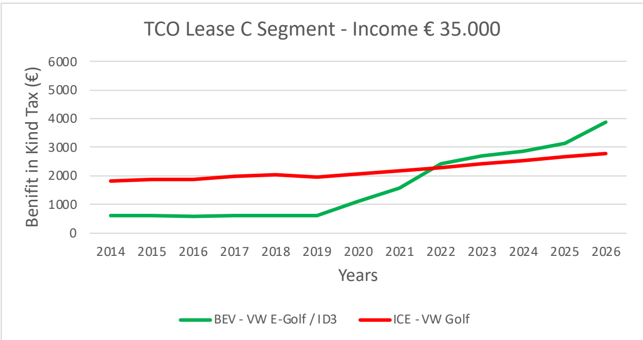
Segment A

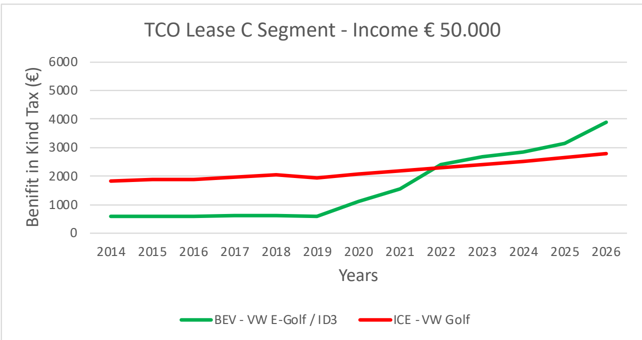


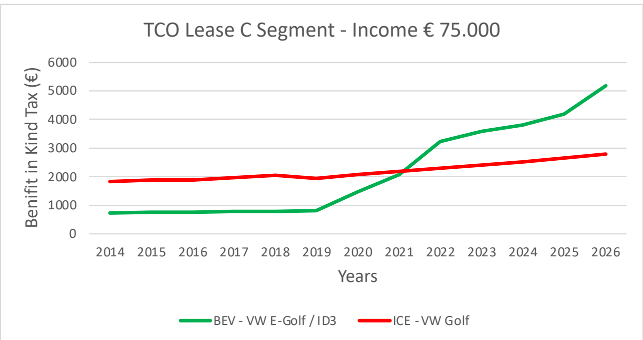




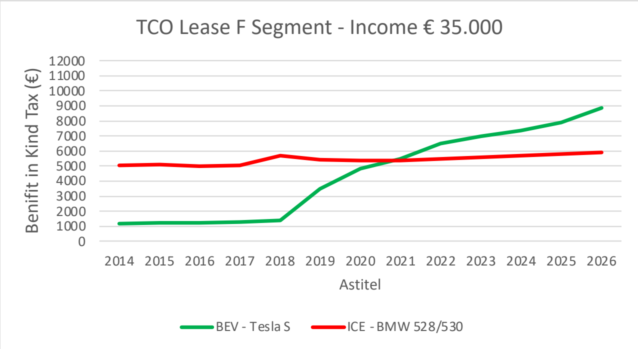
Segment C



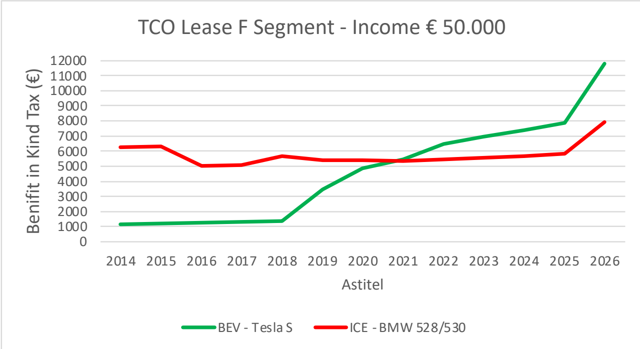




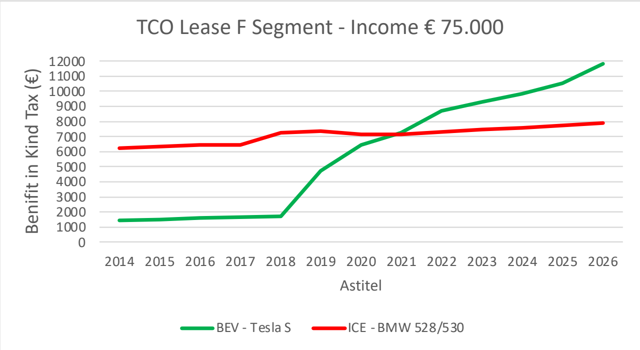
Segment F



TCO Lease F Segment - Income € 35.000
Benifit in Kind Tax (€)
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026
Astitel
BEV - Tesla S
ICE - BMW 528/530



TCO Lease F Segment - Income € 50.000
Benifit in Kind Tax (€)
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026
Astitel
BEV - Tesla S
ICE - BMW 528/530



TCO Lease F Segment - Income € 75.000
Benifit in Kind Tax (€)
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026
Astitel
BEV - Tesla S
ICE - BMW 528/530

F. Cost Benifit Analysis

F.1. Sensitivity analysis

F.1.1. Norway

F.1.1.1. Low segment

Low segment car NO	10.000 km	20.000 km	30.000 km
General parameters			
Discount rate	-55%	-5%	35%
Distance travelled	111%	6%	-30%
ICE parameters			
Consumer price *(incl VAT & incl registration tax)*	12%	1%	-
Fuel price *(VAT, tax & production cost)*	76%	4%	-
Road tax ICE	218%	22%	-
BEV parameters			
VAT	-9%	-1%	7%
Consumer price *(incl VAT & registration tax)*	-10%	-1%	-
Home charger costs *(incl VAT)*	-140%	-14%	-
Electricity price *(VAT, tax & production cost)*	-240%	-13%	-
Amount of CO_2 in electricity	3400%	3400%	3400%
Purchase subsidy	€ -2.883,00	€ -286,00	-

F.1.1.2. Medium segment

Medium segment car NO	10.000 km	20.000 km	30.000 km
General parameters			
Discount rate	3800000000000000000000000%	1900000000000000000000000%	7500000000000000000000000%
Distance travelled	-485%	-292%	-228%
BEV parameters			
VAT	51%	63%	74%
Road tax	€ 4.651,00	€ 5.611,00	€ 6.571,00
Amount of CO_2 in electricity	5105%	5105%	5105%
Purchase subsidy	-	-	-

F.1.1.3 High segment

High segment car NO	10.000 km	20.000 km	30.000 km
General parameters			
Discount rate	6999999999999999900%	1350000000000000000%	3800000000000000000000000%
Distance travelled	-1160%	-630%	-453%
BEV parameters			
VAT	104%	113%	121%
Road tax	€ 17.704,00	€ 19.230,00	€ 20.755,00
Amount of CO_2 in electricity	6642%	6642%	664200%
Purchase subsidy	-	-	-

F.1.2 The Netherlands

F.1.2.1 Low segment

Low segment car NL	10.000 km	20.000 km	30.000 km
General parameters			
Discount rate	-89%	-59%	-35%
Distance travelled	337%	118%	46%
ICE parameters			
Consumer price *(incl VAT & incl registration tax)*	39%	27%	16%
Fuel price *(VAT, tax & production cost)*	213%	75%	29%
Road tax ICE	332%	233%	135%
BEV parameters			
VAT	-21%	-15%	-8%
Consumer price *(incl VAT & registration tax)*	-22%	-16%	-9%
Home charger costs *(incl VAT)*	-423%	-297%	172%
Electricity price *(VAT, tax & production cost)*	-580%	-202%	-82%
Amount of CO_2 in electricity	53%	53%	53%
Purchase subsidy	198%	139%	81%

F.1.2.2 Medium segment

Medium segment car NL	10.000 km	20.000 km	30.000 km
General parameters			
Discount rate	3800000000000000000000000%	360000000000000000%	7500000000000000000000000%
Distance travelled	-418%	-259%	-206%
BEV parameters			
Road tax	€ 3.754,00	€ 4.651,00	€ 5.549,00
Amount of CO_2 in electricity	127%	127%	127%
Purchase subsidy	-439%	-544%	-649%

F.1.2.3 High segment

High segment car NL	10.000 km	20.000 km	30.000 km
General parameters			
Discount rate	69999999999999900%	3800000000000000000000000%	270000000000000000%
Distance travelled	-886%	-493%	-362%
BEV parameters			
Road tax	€ 12.781,00	€ 14.223,00	€ 15.666,00
Amount of CO_2 in electricity	194%	194%	194%
Purchase subsidy	-1494%	-1663%	-1831%

F.1.3 Germany

F.1.3.1 Low segment

Low segment car GER	10.000 km	20.000 km	30.000 km
General parameters			
Discount rate	1149999999999999900%	279999999999999900%	699999999999999900%
Distance travelled	3220%	1560%	1007%
ICE parameters			
Consumer price *(incl VAT & incl registration tax)*	47%	45%	44%
Fuel price *(VAT, tax & production cost)*	279%	135%	89%
Road tax ICE	2750%	2666%	2580%
BEV parameters			
VAT	-23%	-22%	-22%
Consumer price *(incl VAT & registration tax)*	-24%	-24%	-23%
Home charger costs *(incl VAT)*	-593%	-575%	-556%
Electricity price *(VAT, tax & production cost)*	-306%	-147%	-95%
Amount of CO_2 in electricity	107%	107%	107%
Purchase subsidy	91%	89%	86%

F.1.3.2 Medium segment

Medium segment car GER	10.000 km	20.000 km	30.000 km
General parameters			
Discount rate	950000000000000000000000%	1150000000000000000%	300000000000000000000000%
Distance travelled	-161%	-131%	-120%
BEV parameters			
Road tax	€ 649,00	€ 1.013,00	€ 1.377,00
Amount of CO_2 in electricity	208%	208%	208%
Purchase subsidy	-	-	-

F.1.3.3 High segment

High segment car GER	10.000 km	20.000 km	30.000 km
General parameters			
Discount rate	225000000000000000000000%	190000000000000000000000%	1200000000000000000%
Distance travelled	-182%	-141%	-127%
BEV parameters			
Road tax	€ 1.418,00	€ 2.157,00	€ 2.896,00
Amount of CO_2 in electricity	299%	299%	299%
Purchase subsidy	-	-	-

F.1.4 Spain

F.1.4.1 Low segment

Low segment car ES	10.000 km	20.000 km	30.000 km
General parameters			
Discount rate	-175%	-145%	128%
Distance travelled	1375%	638%	392%
ICE parameters			
Consumer price *(incl VAT & incl registration tax)*	90%	83%	77%
Fuel price *(VAT, tax & production cost)*	433%	201%	123%
Road tax ICE	12742%	11814%	10886%
BEV parameters			
VAT	-40%	-37%	-35%
Consumer price *(incl VAT & registration tax)*	-42%	-39%	-36%
Home charger costs *(incl VAT)*	-925%	-857%	-790%
Electricity price *(VAT, tax & production cost)*	-632%	-292%	-180%
Amount of CO_2 in electricity	176%	176%	176%
Purchase subsidy	331%	307%	283%

F.1.4.2 Medium segment

Medium segment car ES	10.000 km	20.000 km	30.000 km
General parameters			
Discount rate	5499999999999900%	115000000000000000%	380000000000000000000000%
Distance travelled	-291%	-195%	-164%
BEV parameters			
Road tax	€ 1.533,00	€ 2.060,00	€ 2.587,00
Amount of CO_2 in electricity	311%	311%	311%
Purchase subsidy	-179%	-241%	-302%

F.1.4.3 High segment

High segment car ES	10.000 km	20.000 km	30.000 km
General parameters			
Discount rate	115000000000000000%	225000000000000000%	750000000000000000000000%
Distance travelled	-422%	-261%	-207%
BEV parameters			
Road tax	€ 3.966,00	€ 4.906,00	€ 5.846,00
Amount of CO_2 in electricity	433%	433%	433%
Purchase subsidy	-464%	-574%	-683%

F.1.5 Poland

F.1.5.1 Low segment

Low segment car PL	10.000 km	20.000 km	30.000 km
General parameters			
Discount rate	-180%	-150%	-130%
Distance travelled	1234%	567%	345%
ICE parameters			
Consumer price *(incl VAT & incl registration tax)*	104%	96%	88%
Fuel price *(VAT, tax & production cost)*	615%	283%	172%
Road tax ICE	€ 3.032,00	€ 2.786,00	€ 2.540,00
BEV parameters			
VAT	-42%	-39%	-36%
Consumer price *(incl VAT & registration tax)*	-45%	-41%	-38%
Home charger costs *(incl VAT)*	-855%	-786%	717%
Electricity price *(VAT, tax & production cost)*	-1229%	-564%	-343%
Amount of CO_2 in electricity	2%	2%	2%
Purchase subsidy	322%	296%	270%

F.1.5.2 Medium segment

Medium segment car PL	10.000 km	20.000 km	30.000 km
General parameters			
Discount rate	130%	380%	625%
Distance travelled	-51%	-76%	-84%
BEV parameters			
Road tax	€ 250,00	€ 739,00	€ 1.228,00
Amount of CO_2 in electricity	51%	51%	51%
Purchase subsidy	-27%	-79%	-130%

F.1.5.3 High segment

High segment car PL	10.000 km	20.000 km	30.000 km
General parameters			
Discount rate	3800000000000000000000000%	3800000000000000000000000%	2700000000000000000%
Distance travelled	-388%	-244%	-196%
BEV parameters			
Road tax	€ 3.159,00	€ 3.975,00	€ 4.790,00
Amount of CO_2 in electricity	96%	96%	96%
Purchase subsidy	-336%	-422%	-509%

F.2 Cost-benefit analysis Assumpties

To make this cost-benefit analysis, nine assumptions had to be made.

1. Road maintenance and accident costs are not included in the model, as these costs are likely to be the same for ICE and BEV.
2. this model does not take into account insurance, repair and parking costs. It is expected that these costs will be the same for the ICE and BEV. It is to be expected, however, that the BEV will be cheaper to maintain in practice, as there are fewer parts to rotate than with an ICE. It was decided to keep the repair costs for ICEs and BEVs the same, however, because there was too little information on the subject.
3. Electricity losses during charging are not included in the model because no specific information was available.
4. The model does not take into account factors that influence fuel consumption, such as driving style, which is difficult to model because everyone drives differently.
5. Due to the lack of information on the residual value of BEVs, the model assumes that the residual value of the ICE and BEV are equal. Therefore, the residual value factor does not need to be included in the model. It is to be expected, however, that in practice the residual value of the BEV will be higher than that of the ICE, because electric motors wear out less.
6. The choice of this range for electricity consumption is based on the assumption that this range represents the average household consumer.
7. It was assumed that the amount of road tax in the respective countries would not be changed. Therefore, the road tax is a fixed value.
8. It was also assumed that the consumer advice price of the ICE vehicle and BEV would not change and is therefore a fixed value.
9. This model assumes that every BEV driver has to buy a home charger to charge his car. Because charging a BEV with a slow charger takes several hours, BEV drivers will usually have to charge their car at home at night. Since Renault, Mercedes and BMW do not clearly indicate the costs of a charging station on their websites, the model assumes that the costs of the Home Charger from Volkswagen are equal to the home chargers that Renault, Mercedes and BMW offers. In addition, it is assumed that the costs of the charging station are the same for each market segment. Furthermore, the home charger is assumed not to change in price and is therefore a fixed value in this model.

F.3 Increase of financial incentives for Small class BEVs and decrease for middle and top class BEVs

Country	New sold passenger cars	% small class	Number Small class BEV's	excess costs	Total 15 Years	Per year
Norway	141405	27%	38179	€ 2,883	€ 110,071,066	€ 7,338,071
Netherlands	355595	27%	96011	€ 7,932	€ 761,556,476	€ 50,770,432
Germany	2917678	27%	787773	€ 8,234	€ 6,486,523,376	€ 432,434,892
Spain	851210	27%	229827	€ 13,225	€ 3,039,458,108	€ 202,630,541
Poland	428527	27%	115702	€ 14,175	€ 1,640,079,961	€ 109,338,664

	Top class new sales 2021	Total amount of incentives to be paid	Finacial incentive paid by top clas BEV
Norway	36723	7338071	€ 200
Netherlands	17761	50770432	€ 2,859
Germany	44572	432434892	€ 9,702
Spain	2132	202630541	€ 95,042
Poland	1259	109338664	€ 86,846

	Top & middle class new sales 2021	Total amount of incentives to be paid	Finacial incentive paid by top clas BEV
Norway	104520	7338071	€ 70
Netherlands	53339	50770432	€ 952
Germany	198978	432434892	€ 2,173
Spain	15619	202630541	€ 12,973
Poland	5705	109338664	€ 19,165

G Charging infrastucture

G.1 Number of slow (AC) charging poles per country

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Netherlands	0	0	400	1250	2782	5770	11860	17786	25120	32875	36010	49520	64236
Germany	0	0	0	0	1500	2400	2606	4587	14213	22213	23112	34203	37213
United Kingdom	0	0	0	1503	2804	5435	7182	8174	9997	13062	14732	22359	27222
France	0	0	0	0	800	1700	1700	9865	13620	20153	22569	24274	25774
Norway	0	0	2800	3105	3688	4511	5185	5185	7040	8292	9333	10337	13547
Italy	0	0	0	0	1350	1350	1350	1679	1898	2424	2860	8312	12150
Sweden	0	0	0	0	500	1000	1000	1600	1654	2576	3237	6575	8804
Belgium	0	0	0	0	0	331	559	1335	1485	1493	2716	6070	8006
Austria	0	0	0	0	1060	1160	1327	1327	1644	3234	3429	3742	6885
Switzerland	0	0	0	0	400	600	1300	3399	3460	3460	4422	5414	6676
Spain	0	0	0	0	400	800	800	1378	3312	4312	4410	4500	6045
Finland	0	0	0	0	0	250	357	706	706	706	706	1786	3244
Denmark	0	0	0	0	449	496	813	1043	2114	2114	2170	2244	2699
Portugal	0	0	0	1080	1128	1154	1172	1192	1222	1322	1340	1471	1976
Turkey	0	0	0	0	0	0	11	69	69	69	69	150	1235
Luxembourg	0	0	0	0	0	0	70	202	202	327	831	900	1051
Poland	0	0	0	0	0	0	115	290	290	410	488	529	1039
Hungary	0	0	0	0	0	60	120	158	163	206	508	592	1008
Ireland	0	0	0	49	231	497	666	715	837	837	845	845	812
Slovakia	0	0	0	0	0	0	32	62	255	347	347	350	656
Slovenia	0	0	0	0	0	0	141	348	348	348	390	452	612
Czech Republic	0	0	0	0	50	125	150	209	282	392	392	410	590
Croatia	0	0	0	0	0	0	0	61	202	381	473	497	483
Romania	0	0	0	0	0	0	15	58	58	95	95	211	317
Iceland	0	0	0	0	0	0	5	11	11	32	40	110	288
Greece	0	0	0	0	0	0	0	31	31	36	40	40	253
Estonia	0	0	0	0	0	0	15	25	191	191	193	202	223
Bulgaria	0	0	0	0	0	0	0	18	18	63	63	70	119
Malta	0	0	0	0	0	0	26	36	36	97	100	102	101
Latvia	0	0	0	0	0	0	13	60	60	60	73	83	79
Lithuania	0	0	0	0	0	0	10	15	15	39	69	79	79
Liechtenstein	0	0	0	0	0	0	0	0	10	10	41	44	51
Cyprus	0	0	0	0	0	0	0	0	36	36	36	38	46

G.2 *Number of fast (DC) charging points per country*

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Germany	0	0	0	0	18	47	317	784	1266	2490	3352	5088	7456
United Kingdom	0	0	0	0	36	176	481	1121	1534	2575	3222	4735	6248
Norway	0	0	1	18	58	144	249	698	1052	1993	2714	3426	5172
France	0	0	0	0	9	102	134	543	1005	1425	1713	2040	3751
Netherlands	0	0	0	0	21	108	173	353	539	639	860	1072	2429
Spain	0	0	0	0	6	91	118	184	232	596	618	1003	2128
Sweden	0	0	0	0	5	20	135	343	469	788	902	1030	1608
Austria	0	0	0	0	3	13	66	208	263	504	546	594	1347
Italy	0	0	0	0	1	6	13	70	166	393	573	864	1231
Switzerland	0	0	0	0	4	27	99	207	278	503	652	786	1158
Poland	0	0	0	0	0	4	4	8	32	113	281	308	652
Czech Republic	0	0	0	0	0	3	9	36	78	141	268	365	610
Denmark	0	0	0	0	3	56	117	271	314	370	387	449	555
Portugal	0	0	0	6	7	17	17	22	58	194	194	236	494
Finland	0	0	0	0	0	17	48	112	121	171	197	333	484
Belgium	0	0	0	0	0	47	55	77	110	222	242	359	476
Hungary	0	0	0	0	1	3	3	22	37	54	74	124	287
Ireland	0	0	0	6	15	48	70	88	121	158	161	207	270
Slovakia	0	0	0	1	3	3	18	37	57	74	115	233	268
Latvia	0	0	0	0	0	0	0	8	12	12	151	155	235
Estonia	0	0	0	0	160	160	163	164	168	178	184	187	201
Croatia	0	0	0	0	0	0	0	7	21	47	79	116	187
Romania	0	0	0	0	0	0	0	1	5	16	25	100	185
Slovenia	0	0	0	0	4	4	10	44	89	105	107	127	135
Turkey	0	0	0	0	1	1	1	7	7	7	7	30	118
Lithuania	0	0	0	0	0	0	0	3	11	44	58	84	100
Iceland	0	0	0	0	0	0	6	11	19	56	66	75	98
Greece	0	0	0	0	0	0	2	2	2	2	8	18	81
Bulgaria	0	0	0	0	0	0	0	0	4	24	34	52	76
Cyprus	0	0	0	0	0	0	0	0	0	0	0	0	24
Liechtenstein	0	0	0	0	0	0	0	0	2	4	18	18	20
Luxembourg	0	0	0	0	1	2	2	9	10	10	9	12	12
Malta	0	0	0	0	0	0	0	0	0	0	0	0	0

G.3 BEV per charging point related to the BEV adoption

	Norway		
Year	BEV/AC	BEV/DC	BEV %
2008	NA	NA	0,0
2009	NA	NA	0,1
2010	0,6	1782,0	0,3
2011	1,3	221,2	1,5
2012	1,8	112,8	3,1
2013	3,4	107,4	5,8
2014	7,0	146,0	12,6
2015	11,8	88,0	17,1
2016	13,9	92,8	15,7
2017	15,7	65,5	20,8
2018	18,5	63,6	31,2
2019	23,5	70,9	42,3
2020	23,6	61,8	51,6

	Netherlands		
Year	BEV/AC	BEV/DC	BEV %
2008	Na	Na	0,0
2009	Na	Na	0,0
2010	0,3	Na	0,0
2011	0,8	Na	0,2
2012	0,8	100,0	0,2
2013	0,7	38,5	0,6
2014	0,6	39,5	0,7
2015	0,5	26,5	0,7
2016	0,5	23,8	1,1
2017	0,6	32,5	1,9
2018	1,2	50,6	5,4
2019	2,1	98,0	13,8
2020	2,7	71,0	20,2

	Germany		
Year	BEV/AC	BEV/DC	BEV %
2008	Na	Na	0,0
2009	Na	Na	0,0
2010	Na	Na	0,0
2011	Na	Na	0,1
2012	4,7	395,2	0,1
2013	5,1	258,6	0,2
2014	7,3	59,8	0,3
2015	5,6	32,5	0,4
2016	2,4	26,9	0,3
2017	2,4	21,6	0,7
2018	3,6	24,8	1,0
2019	3,9	26,3	1,7
2020	8,3	41,3	6,4

	Spain		
Year	BEV/AC	BEV/DC	BEV %
2008	Na	Na	0,0
2009	Na	Na	0,0
2010	Na	Na	0,0
2011	Na	Na	0,1
2012	2,6	94,7	0,1
2013	2,5	11,2	0,1
2014	3,5	17,1	0,1
2015	3,3	15,4	0,1
2016	2,0	19,3	0,2
2017	2,4	10,9	0,3
2018	3,7	16,4	0,5
2019	6,0	16,4	0,8
2020	7,5	12,6	2,1

	Poland		
Year	BEV/AC	BEV/DC	BEV %
2008	Na	Na	0,0
2009	Na	Na	0,0
2010	Na	Na	0,0
2011	Na	Na	0,0
2012	Na	Na	0,0
2013	Na	20,3	0,0
2014	1,3	38,3	0,0
2015	0,8	27,4	0,0
2016	1,2	10,9	0,0
2017	2,2	7,9	0,1
2018	3,0	5,3	0,1
2019	5,5	9,4	0,3
2020	6,3	10,1	0,8

G.4 *Ratio fast power (DC) charging points to 100 km highway*

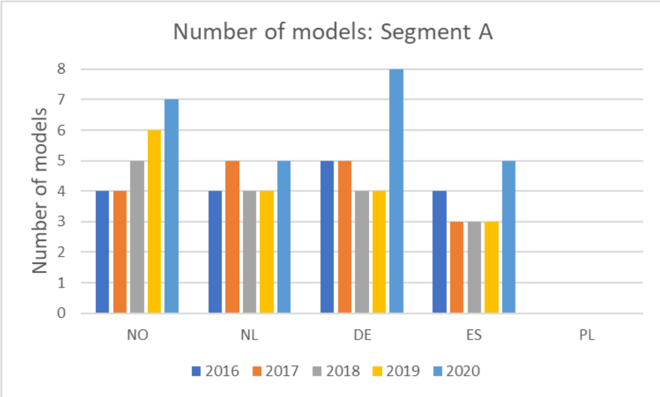
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Norway	0	0	0	3	11	28	48	133	201	381	519	655	989
Iceland	0	0	0	0	0	0	16	30	51	151	178	203	265
United Kingdom	0	0	0	0	1	5	13	29	40	68	85	125	164
Estonia	0	0	0	0	104	104	106	106	109	116	119	121	131
Netherlands	0	0	0	0	1	4	6	12	18	21	28	35	80
Switzerland	0	0	0	0	0	2	7	14	19	34	45	54	79
Austria	0	0	0	0	0	1	4	12	15	29	31	34	77
Sweden	0	0	0	0	0	1	6	16	22	37	42	48	75
Germany	0	0	0	0	0	0	2	6	10	19	26	39	57
Slovakia	0	0	0	0	1	1	4	8	12	15	24	48	56
Finland	0	0	0	0	0	2	5	13	14	19	22	37	54
Czech Republic	0	0	0	0	0	0	1	3	6	11	22	29	49
Denmark	0	0	0	0	0	4	9	21	24	28	30	34	42
France	0	0	0	0	0	1	1	5	9	12	15	18	32
Lithuania	0	0	0	0	0	0	0	1	3	14	18	26	31
Ireland	0	0	0	1	2	5	8	10	13	17	18	23	29
Belgium	0	0	0	0	0	3	3	4	6	13	14	20	27
Poland	0	0	0	0	0	0	0	0	1	4	11	12	26
Romania	0	0	0	0	0	0	0	0	1	2	3	13	24
Italy	0	0	0	0	0	0	0	1	2	6	8	12	18
Slovenia	0	0	0	0	1	1	1	6	11	13	14	16	17
Portugal	0	0	0	0	0	1	1	1	2	6	6	8	16
Hungary	0	0	0	0	0	0	0	1	2	3	4	6	15
Croatia	0	0	0	0	0	0	0	1	2	4	6	9	14
Latvia	0	0	0	0	0	0	0	0	1	1	9	9	14
Spain	0	0	0	0	0	1	1	1	1	4	4	6	14
Bulgaria	0	0	0	0	0	0	0	0	1	3	5	7	10
Cyprus	0	0	0	0	0	0	0	0	0	0	0	0	9
Luxembourg	0	0	0	0	1	1	1	5	6	6	5	7	7
Turkey	0	0	0	0	0	0	0	0	0	0	0	1	4
Greece	0	0	0	0	0	0	0	0	0	0	0	1	4
Liechtenstein	0	0	0	0	0	0	0	0	0	0	0	0	0
Malta	0	0	0	0	0	0	0	0	0	0	0	0	0

H Model availability

H.1 Segment A

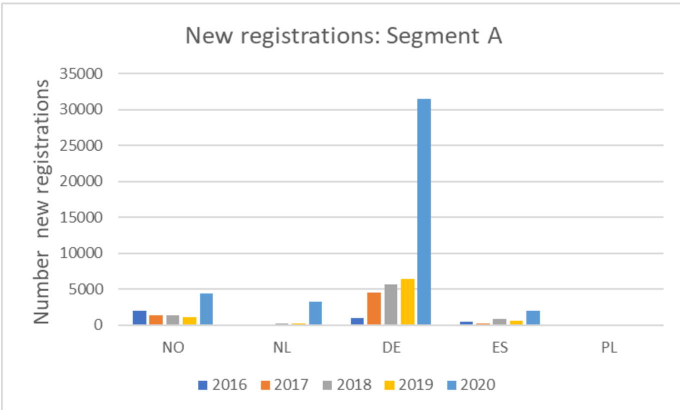
H.1.1 Number of model types

	Number of models: Segment A				
Years	NO	NL	DE	ES	PL
2016	4	4	5	4	0
2017	4	5	5	3	0
2018	5	4	4	3	0
2019	6	4	4	3	0
2020	7	5	8	5	0



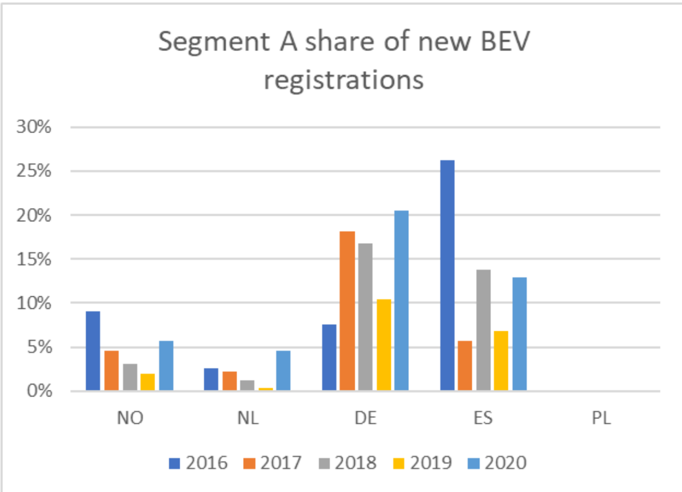
H.1.2 Number of new registrations

	New registrations: Segment A				
	NO	NL	DE	ES	PL
2016	2003	104	953	521	0
2017	1412	157	4545	203	0
2018	1418	266	5709	822	0
2019	1154	250	6420	654	0
2020	4421	3240	31532	2049	0



H.1.3 Share of new registrations

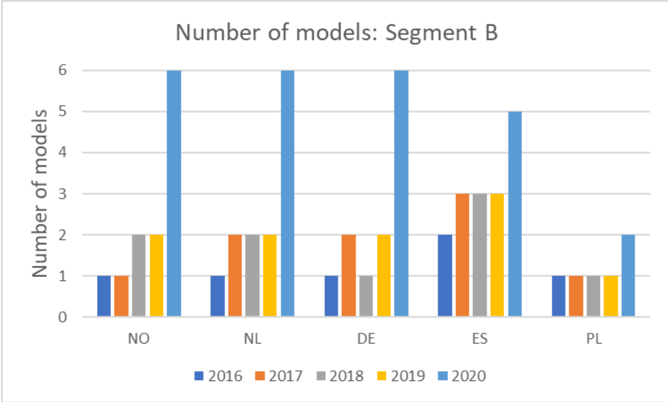
	Segment A share				
	NO	NL	DE	ES	PL
2016	9%	3%	8%	26%	0%
2017	5%	2%	18%	6%	0%
2018	3%	1%	17%	14%	0%
2019	2%	0%	10%	7%	0%
2020	6%	5%	20%	13%	0%



H.2 Segment B

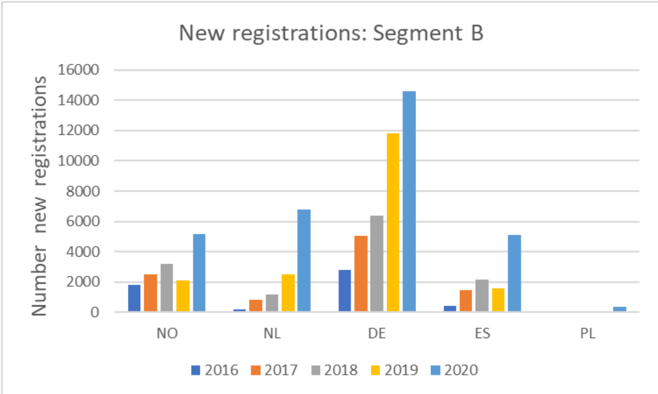
H.2.1 Number of model types

	Number of models: Segment B				
	NO	NL	DE	ES	PL
2016	1	1	1	2	1
2017	1	2	2	3	1
2018	2	2	1	3	1
2019	2	2	2	3	1
2020	6	6	6	5	2



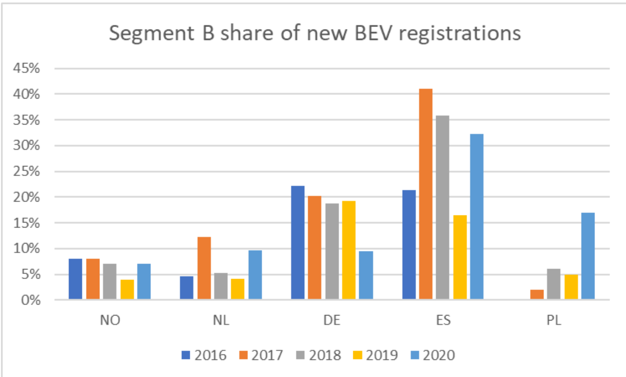
H.2.2 Number of new registrations

	New registrations: Segment B				
	NO	NL	DE	ES	PL
2016	1818	183	2805	423	1
2017	2533	863	5080	1452	11
2018	3194	1169	6360	2141	49
2019	2134	2484	11793	1562	73
2020	5182	6804	14590	5138	366



H.2.3 Share of new registrations

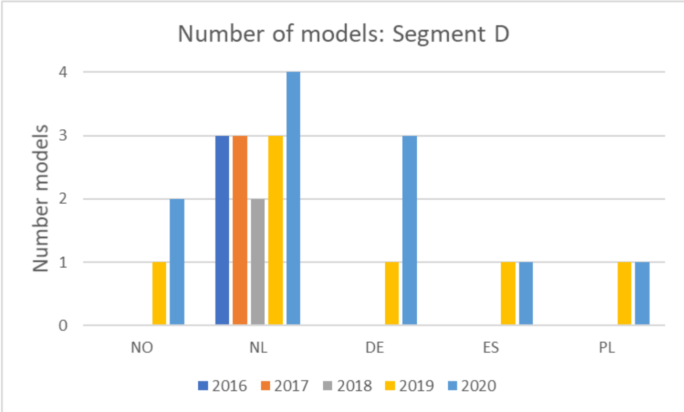
	Segment B share				
	NO	NL	DE	ES	PL
2016	8%	5%	22%	21%	0%
2017	8%	12%	20%	41%	2%
2018	7%	5%	19%	36%	6%
2019	4%	4%	19%	16%	5%
2020	7%	10%	9%	32%	17%



H.3 Segment D

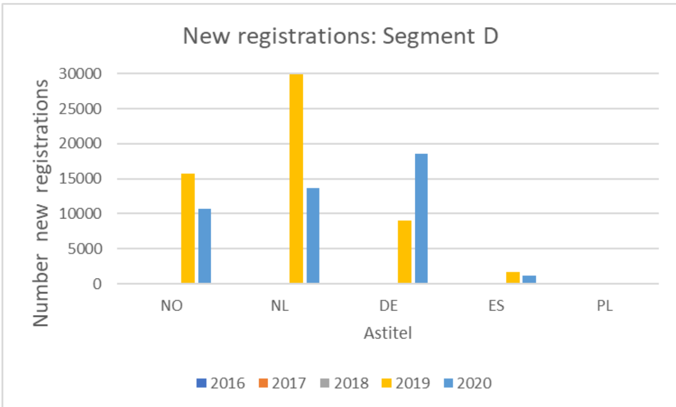
H.3.1 Number of model types

	Number of models: Segment D				
	NO	NL	DE	ES	PL
2016	0	3	0	0	0
2017	0	3	0	0	0
2018	0	2	0	0	0
2019	1	3	1	1	1
2020	2	4	3	1	1



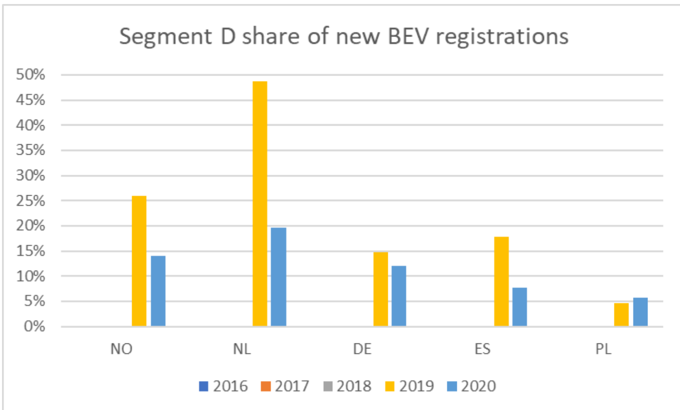
H.3.2 Number of new registrations

	New registrations: Segment D				
	NO	NL	DE	ES	PL
2016	0	0	0	0	0
2017	0	1	0	0	0
2018	0	5	0	0	0
2019	15683	29922	9013	1687	63
2020	10687	13728	18617	1216	124



H.3.3 Share of new registrations

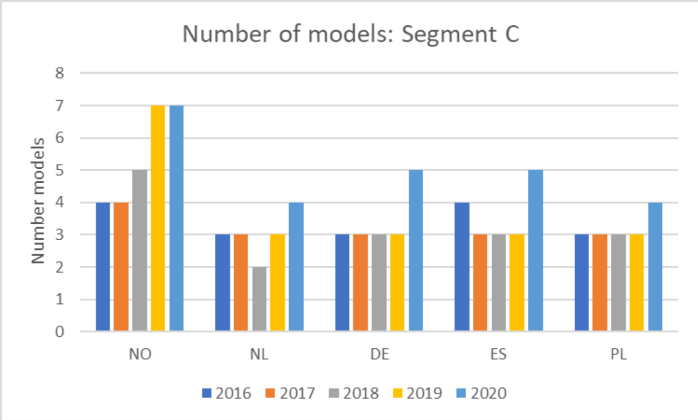
	Segment D share				
	NO	NL	DE	ES	PL
2016	0%	0%	0%	0%	0%
2017	0%	0%	0%	0%	0%
2018	0%	0%	0%	0%	0%
2019	26%	49%	15%	18%	5%
2020	14%	20%	12%	8%	6%



H.4. Segment C

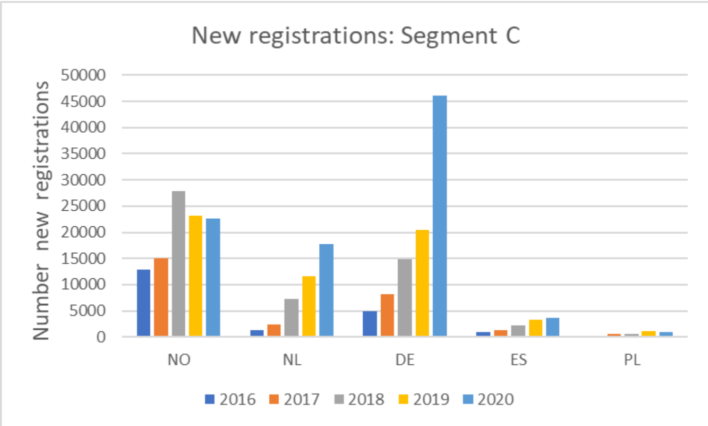
H.4.1 Number of model types

	Number of models: Segment C				
	NO	NL	DE	ES	PL
2016	4	3	3	4	3
2017	4	3	3	3	3
2018	5	2	3	3	3
2019	7	3	3	3	3
2020	7	4	5	5	4



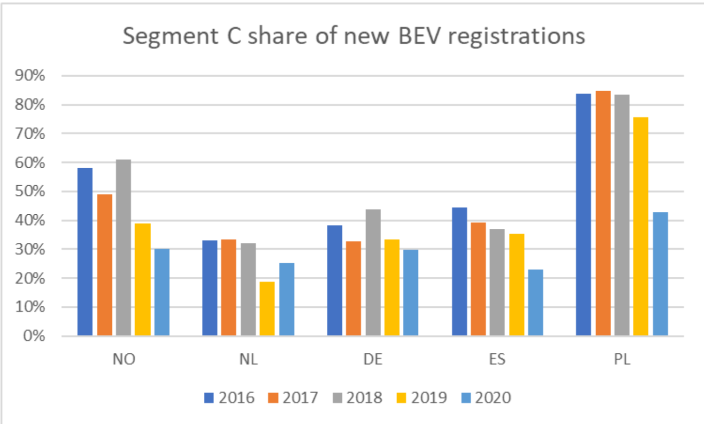
H.4.2 Number of new registrations

	New registrations: Segment C				
	NO	NL	DE	ES	PL
2016	12867	1298	4844	884	171
2017	15086	2341	8186	1389	577
2018	27936	7205	14913	2208	650
2019	23228	11522	20491	3364	1038
2020	22681	17784	46088	3653	933



H.4.3 Share of new registrations

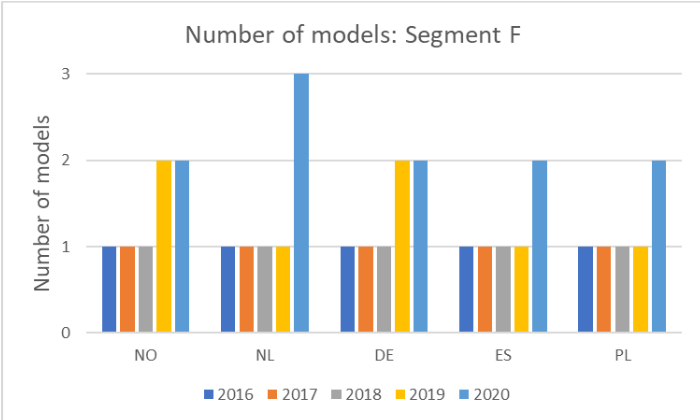
	Segment C share				
	NO	NL	DE	ES	PL
2016	58%	33%	38%	45%	84%
2017	49%	33%	33%	39%	85%
2018	61%	32%	44%	37%	84%
2019	39%	19%	33%	35%	76%
2020	30%	25%	30%	23%	43%



H.5 Segment F

H.5.1 Number of model types

	Number of models: Segment F				
	NO	NL	DE	ES	PL
2016	1	1	1	1	1
2017	1	1	1	1	1
2018	1	1	1	1	1
2019	2	1	2	1	1
2020	2	3	2	2	2



H.6 Models related to a segment

Segment	Model Car	Segment	Model Car	Segment	Model Car
A	Citroen C-zero	D	Tesla model 3	M	Audi e-tron
A	Fiat 500e	D	Volvo Polestar 2	M	BMW iX3
A	Mitsubishi i-MiEV	D	VW ID.4	M	Ford Mustang Mach-E
A	Renault Twingo	D	Xpeng G3	M	Jaguar I-Pace
A	Seat Mii	F	Porsche Taycan	M	Maxus Euniq 6
A	Skoda Citigo	F	Tesla model S	M	Mercedes EQC
A	Smart fortwo	F	Tesla model Y	M	Tesla model X
A	VW e-up!	J	Citroen Berlingo	N	Citroen SpaceTourer
B	Honda e	J	JAC iEV7s	N	Maxus Euniq MPV 7
B	Mini	J	Kia Niro	N	Mercedes EQV
B	Opel Corsa	J	Kia Soul	N	Nissan NV200
B	Peugot 208	J	Opel Ampera-e	N	Peugot Traveller
B	Renault Zoe	J	Opel Zafira Life		
B	Smart forfour	L	Aiways U5		
C	BMW i3	L	DS3 Crossback		
C	Chevrolet Bolt	L	Hyundai Kona		
C	Citroen C4	L	Lexus UX		
C	Hyundai Ioniq	L	Mazda MX-30		
C	Nissan Leaf	L	Mercedes EQA		
C	Seat CUPRA el-Born	L	MG ZS		
C	VW e-golf	L	Opel Mokka		
C	VW ID.3	L	Peugot 2008		
		L	Volvo XC40		

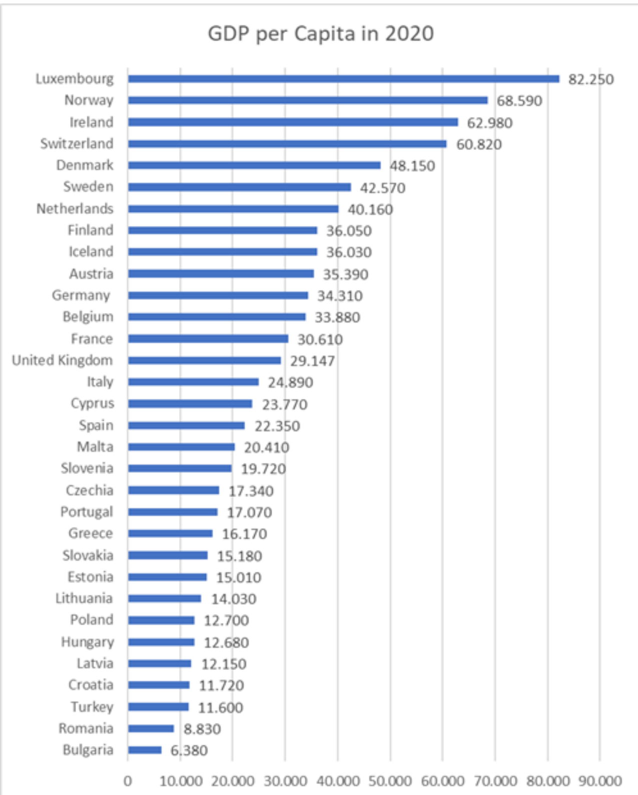
I. Number of BEV registrations related to model segments

Segment	Model	2016					2017					2018					2019					2020					2021				
0		NO	NL	DE	ES	PO	NO	NL	DE	ES	PO	NO	NL	DE	ES	PO	NO	NL	DE	ES	PO	NO	NL	DE	ES	PO	NO	NL	DE	ES	PO
A	Citroen C-zero	214	2	113	496		58	25	176	160		146	29	102	42		122	9	142	51		13	13	129	38			1			
A	Comarth X-Tamy																														
A	Fiat 500e																					13		872			607	774	12516	945	
A	Mia electric																														
A	Mitsubishi i-MiEV	273	6	16	1		250	1	35			205					79					25					5				
A	Peugot iOn	335	16	154	17		169	16	269	29		249	23	147	29		114	9	174	24		16		170	26						
A	Renault Twingo																							1091				629	7973	407	
A	Seat Mii																					939	1130	2149	980		105	554	3983	526	
A	Skoda Citigo																2					1825	1904	4746	300		1151		3103	40	
A	Smart fortwo	33		78			69	39	2987			189	100	4204	751		68	49	5287	579		42	74	11536	705		11	84	17413	760	
A	Tazzari EM1																														
A	Tazzari Zero																														
A	Think City																														
A	VW e-up!	1148	80	592	7		866	76	1078	14		629	114	1256			769	183	817			1548	119	10839			959	247	30797	116	
A	ZD D2																													11	
B	Audi A1																														
B	Citroen E-Mehari				21					12					29					11											
B	Dacia Spring Electric																											221	4045	1059	415
B	Honda e																					190	111	1127	100	11	203	32	1256	74	14
B	Mini																					303	1287					1220		697	
B	Opel Corsa																					456	1587	6016	718		917	954	10858	438	
B	Opel Mokka																							18			779	872	6672	531	
B	Peugot 208																					1865	1646	2631	1261		1484	1873	8517	957	
B	Renault Zoe	1818	183	2805	402	1	2533	781	4322	1327	11	3141	1017	6360	1421	49	2090	2208	9431	1050	73	2346	2071	305	2425	355	804	1604	24736	1373	282
B	Smart forfour							82	758	113		53	152		691		44	276	2362	501		22	102	4493	634		3	133	6610	304	
C	BMW 1 Series																														
C	BMW i3	3953	498	2863	338	91	5036	881	4319	683	117	5687	1613	5095	681	164	4851	2860	9382	916	709	2714	1220	8633	403	205	1889	697	12181	339	181
C	BYD e6				4																										
C	Chery Arrizo 5																1					NA									
C	Chevrolet Bolt											34					5					9					2				
C	Citroen C4																					4		12			1738	561	1454	691	
C	Ford Focus	47					37					151					9														
C	Hyundai Ioniq					55					221	2523		1695		217	3037	1596	1591	296	104	2209	929	1915	761	48	877	381	2210	765	36
C	Hyundai Ioniq 5																										3557	1712	6971	431	68
C	Mercedes A-class																														
C	Nissan Ariya																													1	
C	Nissan Leaf	4162	663	1121	519	25	3374	511	841	530	239	12303	3369	2380	1261	269	6127	3800	2620	1509	225	5221	1629	3597	885	491	5313	1173	5051	705	516
C	Renault Fluence																														
C	Seat CUPRA el-Born																								4		17	1206	607	336	13
C	Volvo C30																														
C	VW golf	4705	137	860	23		6639	949	3026	176		7238	2223	5743	266		9198	3266	6898	643		4770	3052	17438	588		2		1587		
C	VW ID.3																					7754	10954	14493	1012	189	3209	2193	26693	917	221
D	Tesla model 3							1					5				15683	29922	9013	1687	63	7770	8369	15202	1216	124	12058	2565	35262	2853	893
D	Volvo Polestar 2																					2831	2951	1015			4103	2556	2614		
D	VW ID.4																						2408	2400			8645	4215	12734	998	209
D	Xpeng G3																					86					438				
D	Xpeng P5																										2				
E	Lexus ES																										762				
F	Audi e-tron GT																										650	285	1591	49	30
F	Mercedes EQS																										18	53	554	14	23
F	Porsche Taycan																2		31			1221	434	3203	200	106	1723	630	5063	314	211
F	Tesla model S	2051	1693	1474	46	20	3712	2051	2241	225	40	3633	5633	1248	163	20	1149	526	981	175	17	351	293	777	109	17	37	4	15	4	4
F	Tesla model Y																						2				8267	1580	4400	340	76
F	Xpeng P7																										34				
G	BMW i4																										26	69		1	
G	Tesla Roadster																														
J	Anhui Jianghuai iEV7S																													10	
J	Citroen Berlingo	30										103					49					34					26		147		
J	Citroen Space Tourer																										114				
J	JAC iEV7s											1													1						
J	Kia EV6																										290	1644	1069	282	124
J	Kia Niro											34					719	3678	1446	371		1486	6484	3543	635		2448	5879	5928	1554	1428
J	Kia Soul		60	1384	88		815	58	2933	97		1469	45	3292	201		510	140	1591	42		1758	659	2364	77		1802	346	2536	128	
J	Maxus Euniq 5																										241			1	
J	Mercedes B-class	1895	117	437	14		1444	57	542	9		6	100	884					364												
J	Opel Ampera-e						1121	228	231			920	860	385			1057	882	120			666	1379	680			1		14		
J	Opel Combo																										5		32		
J	Opel Zafira Life																							237			126		433		
J	Peugot Partner											126					79					60									
J	Peugot Rifter																										7		77		
J	Renault Kangoo			140																											
J	Seat Altea																														
L	Aiways U5																						428					11		1	
L	Audi Q4 e-tron																										3241	2435	4470	352	104
L	DFSK Seres 3																										2			31	1
L	DS3 Crossback																5					266	24	218			111	63	282	75	

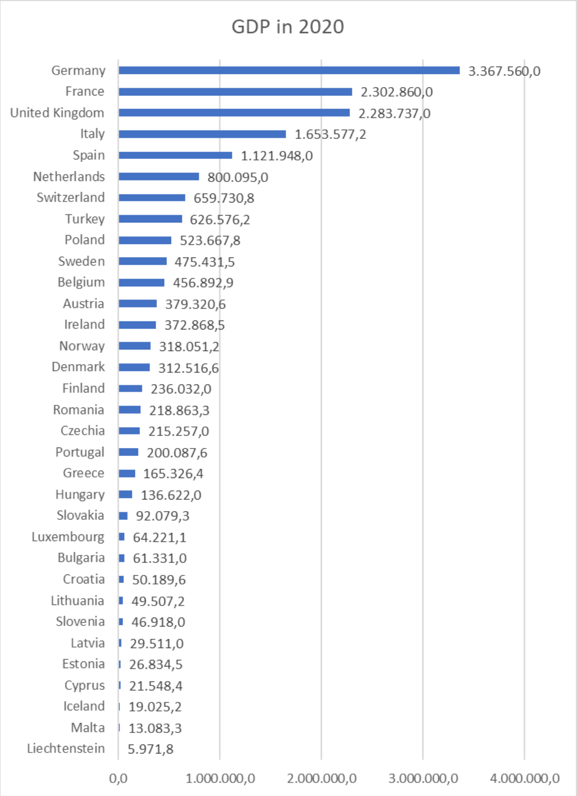
L	Green Tour HS-EV4																													2	
L	Hyundai Kona											842	551	112	222		3451	5526	3521	1099		4999	7761	14008	1112		3281	892	17240	887	
L	Lexus UX																					96		20				30	107		
L	Mazda MX-30																					1222	977	3753	319	222	1701	536	3428	103	221
L	Mercedes EQA																							37			1600	1290	5781	667	197
L	Mercedes EQB																										2		166	12	225
L	MG Marvel R																										228	16		17	
L	MG ZS																3	1019				3720	2206				2538	794		330	
L	Peugot 2008																					1457		1197	583		3066	1539	4101	861	
L	Volvo C40 Recharge																										30	357	161	35	9
L	Volvo XC40																					1191	2590	109			5087	2487	1070	103	
M	Audi e-tron											7	163				5377	4116	3578	165	71	9226	3764	8135	343	114	5745	1094	8691	138	175
M	BMW iX																										807	311	1176	82	76
M	BMW iX3																							71			1883	2733	2983	133	
M	Ford Mustang Mach-E																					19		185		2	6160	4142	2667	355	275
M	Hongqi E-HS9																										25				
M	Jaguar I-Pace											1081	3495	191	66	16	3080	769	954	166	75	1305	466	1341	128	46	694	18	546	68	26
M	Maxus Euniq 6																					77									
M	Mercedes EQC																84	125		47	18	3614	790	2208	232	191	3946	219	3825	92	
M	NIO ES8																										200				
M	Skoda Enyaq iV																										5711	6621	13026	532	360
M	Tesla model X	1430	427	430	9	5	4748	1238	1090	162	31	4981	2966	652	160	33	1966	463	716	188	14	616	292	714	140	17	35	2	35	10	3
N	Citroen Jumpy																							75					147		
N	Citroen SpaceTourer																					1									
N	Fiat Fiorino																														
N	Maxus e Deliver 3																														1
N	Maxus e Deliver 9																										11				
N	Maxus V80																					35					9				
N	Mercedes EQV																					107	79			31	161	84	1568	85	53
N	Nissan NV200		61	186		7	195	46	190		21	341		280		10	577		293		3	274	59	453		11	142	31	182		4
N	Peugot Expert																							10					180		
N	Peugot Traveller																					1									
N	VW Caddy																							8					26		
N	VW Crafter																					11					8				
N	VW Transporter																							39					82		

J. Consumer characteristics

J.1 GDP per capita 2020



J.2 GDP


GDP in 2020
Germany 3.367.560,0
France 2.302.860,0
United Kingdom 2.283.737,0
Italy 1.653.577,2
Spain 1.121.948,0
Netherlands 800.095,0
Switzerland 659.730,8
Turkey 626.576,2
Poland 523.667,8
Sweden 475.431,5
Belgium 456.892,9
Austria 379.320,6
Ireland 372.868,5
Norway 318.051,2
Denmark 312.516,6
Finland 236.032,0
Romania 218.863,3
Czechia 215.257,0
Portugal 200.087,6
Greece 165.326,4
Hungary 136.622,0
Slovakia 92.079,3
Luxembourg 64.221,1
Bulgaria 61.331,0
Croatia 50.189,6
Lithuania 49.507,2
Slovenia 46.918,0
Latvia 29.511,0
Estonia 26.834,5
Cyprus 21.548,4
Iceland 19.025,2
Malta 13.083,3
Liechtenstein 5.971,8
0,0
1.000.000,0
2.000.000,0
3.000.000,0
4.000.000,0

K Interwiews

K1. Questionnaire

We know that several factors are barriers for the acceleration of EV adoption (or the acceleration to electric driving), namely:

- Unfamiliarity with electric driving (many people have never driven electric before);
- Unfamiliarity with electric charging (where to find charging points and what does it cost to charge there);
- Fear of an empty battery ('range anxiety');
- Uncertainty about vehicle costs (purchasing and using an electric car)

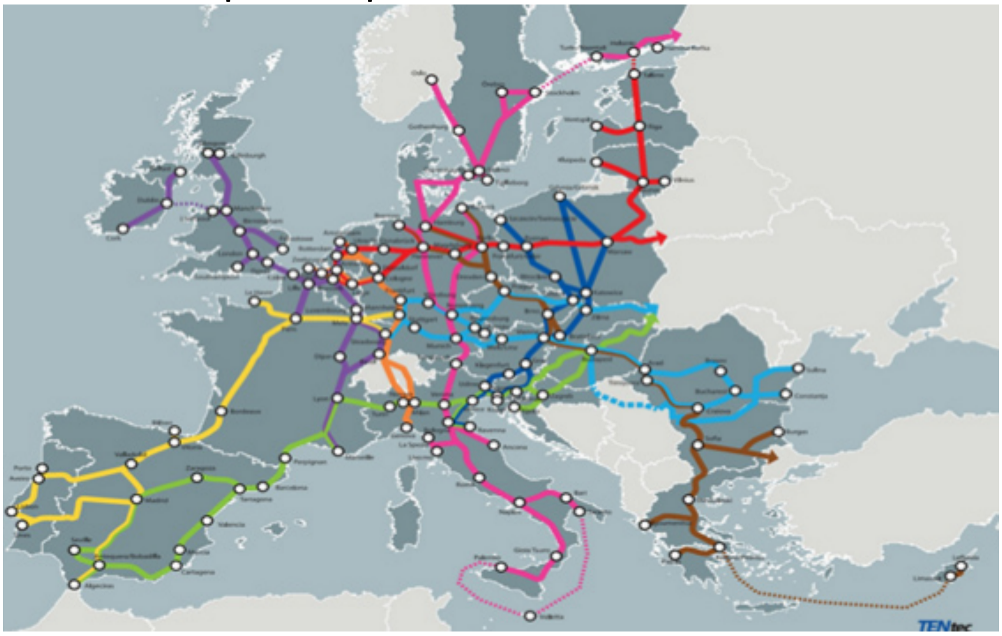
1. What do you see as the most important factors that are influencing the adoption of EVs?
2. Do you see a difference in policy strategies between the different countries in Europe?
3. Is there a policy on different types of people in Europe?
4. Are there lobby activities from the EU to member states? And are there lobby activities from member states to the EU?
5. Which incentive has in your opinion the most effect on EV adoption and why? (VAT exemption Norway)
6. Why is Norway the only country that gives exemption from VAT?
7. Have there been certain incentives in the past without effect? Why was this?
8. What are the EU's future plans for incentives?
9. Are there in your opinion certain barriers for consumers when buying an EV?
10. How could these barriers be overcome?
11. What is your opinion about the price of electricity for the EV in relation to petrol price for normal cars?
12. What is the price trend for EVs in the coming years?
13. What is your opinion about the charging infrastructure compared to the increase in EVs?
14. What is your opinion on the increase in the number of models in relation to the increase in EV adoption?
15. Do you see a relationship between GDP per capita and the age distribution on the adoption of EVs?
16. What is your opinion on the willingness to pay for an EV?
17. What is your opinion on the driving range of EVs now and in the future and the concerns about this?
18. The electric car was initially marketed as a sustainable replacement for the normal car. What is your opinion on why people buy EVs now and in the future? Is it because of sustainability or other car preferences like status, speed, price, etc?

How can the scaling up of EV deployment be accelerated at the European level?

K.2 List of interviewees

	Name	Knowledge about country:	Group	
1	Bert van Wee	Netherlands	Research	Prof. dr. at Delft University of Technology
2	Rick Wolbertus	Netherlands	Research	Doctor of Philosophy - PhD, Evaluating Electric Vehicle Charging Infrastructure Policies
3	Aleksander Rajch	Poland	National authority	Director Of External Affairs of Polish Association of Alternative Fuels
4	Arjan van Vliet	Netherlands	National authority	Innovation Manager of Ministry of Infrastructure and Water Management
5	Pieter van Kerkhof	Netherlands	National authority	Advisor Sustainable Mobility at Netherlands Enterprise Agency (RVO.nl)
6	Bart Vrolijk	Spain	Embassy	Head of Economic Department of the Dutch Embassy in Madrid
7	Bas van Oorschot	Norway	Embassy	Account & Project Manager Nordics at Allego
8	Gijs Konings	Germany	Embassy	Policy Advisor Circular Economy & Sustainable Mobility bij Embassy of the Kingdom of the Netherlands in Germany
9	Sanne Kaasjager	Poland	Embassy	Head Economic Department of the Dutch Embassy in Poland
10	Sonja Munnix	Netherlands		Senior Advisor at Netherlands Enterprise Agency (RVO.nl)
11	Wout Benning	Netherlands	Automotive	Policy Advisor Sustainability and Technology at RAI Association
12	Wouter Karssen	Netherlands	Automotive	Owner of Autoblog.nl & Host BNR Autoshow (radio show)

L Trans-European transport network corridors



Atlantic, Baltic-Adriatic, Mediterranean, North Sea-Baltic, North Sea-Mediterranean, Orient-East Mediterranean, Rhine-Alpine, Rhine-Danube, Scandinavian Mediterranean