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Deliverable D1.1 Electric Road Mobility Evolution Scenarios

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Electric Vehicles Management for carbon neutrality in Europe

Deliverable D1.1 Electric Road Mobility Evolution Scenarios

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Executive Summary

The *Electric Road Mobility Evolution Scenarios* deliverable presents a set of electric road mobility scenarios worldwide, in Europe, and the countries of the EV4EU project members (Denmark, Greece, Portugal and Slovenia) that will be considered in future Work Packages and Tasks of the EV4EU project to analyse the impact of the proposed solutions on mass deployment of electric vehicles.

For this purpose, this document presents information on the Worldwide, European, Danish, Portuguese, Slovenian and Greek electric vehicle (EV) markets, including EV sales and stock, charging point infrastructures and electricity demand. For all these cases and according to the available literature, we present the evolution scenarios until 2050, the deadline set by the European Commission to achieve carbon neutrality.

Additionally, this deliverable analyses the main factors impacting electric road mobility and EV evolution. This document discusses political, economic, social, technological, environmental, legal and behavioral factors that act as the main barriers and challenges to the mass deployment of electric vehicles.

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Acronym

AFID	Alternative Fuels Infrastructure Directive
APS	Announced Pledge Scenario
BEV	Battery Electric vehicle
CCS	Combined Charging System
CLEPA	European Association of Automotive Suppliers
COP 21	21st Conference of the Parties
COP 26	26th Conference of the Parties
CP	Charging Point
CS	Charging Station
EAFO	Alternative Fuels Observatory
ETS	Economic Transition Scenario
EU	European Union
EV	Electric Vehicle
FCEV	Fuel-Cell Electric Vehicle
GHG	Greenhouse Gas Emissions
ICCT	International Council on Clean Transportation
ICE	Internal Combustion Engine
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
NECP	National Energy and Climate Plan
NEDC	New European Driving Cycle
NZS	Net Zero Scenario
PES	Planned Energy Scenario
PESTEL	Political, Economic, Social, Technological, Environmental and Legal
PHEV	Plug-in Electric Vehicle
PMEA	*Plano para Mobilidade Eléctrica dos Açores*
PNEC	*Plano Nacional de Energia e Clima*
PV	Photovoltaic
RES	Renewable Energy Sources
RFID	Radio Frequency Identification
RNC	Roteiro para Neutralidade carbónica 2050
RSMA	Relatório de Monitorização da Segurança de Abastecimento
SDG	Sustainable Development Goals
SPS	Stated Policies Scenario
TES	Transforming Energy Scenario
UK	United Kingdom
ZEV	Zero-Emissions Vehicle

1 Introduction

1.1 Scope and Objectives

This document presents a set of scenarios and targets regarding the evolution of electric road mobility worldwide, in Europe and in the countries of the EV4EU project members (Denmark, Greece, Portugal and Slovenia). This analysis will consider different time horizons according to the available literature. Targets defined by several countries to achieve carbon neutrality until 2050 will be used as major guidelines for this report. Afterwards, an analysis of the parameters that impact electric road mobility is presented and discussed.

The objectives of this work are two-fold. First, it provides a set of road mobility scenarios, per country and at the European level, that will be used in the following Work Packages and Tasks. The scenarios will be critical to evaluating the mass deployment of the proposed solutions. Second, this work identifies the main factors that can influence the evolution of electric road mobility. These factors include the main barriers and the challenges that can have a higher impact on the mass deployment of electric mobility.

To achieve these goals, we performed an extensive search of the existing literature. Information about historical data (Electric Vehicle (EV) sales, number of Charging Points (CPs), etc.) is mainly published on websites by public entities. Concerning the projections for the future, two types of documents have been used. We first selected documents published by public entities. These documents often define the targets but do not specify the path. In that case, some assumptions are proposed to offer realistic scenarios. We also considered documents published by consultants. In that case, some trends can be found and compared with the existing targets.

1.2 Definitions

Some definitions are adopted in the present document. EVs refer to all vehicles with electric engines connected to the electric system. EVs can be classified as Battery Electric Vehicles (BEVs), which include purely battery power EVs, or Plug-In Electric Vehicles (PHEVs), which have both a battery-powered electric motor and an Internal Combustion Engine (ICE). Hybrid vehicles that cannot be connected to the power network are included in the ICE category. Fuel-Cell Electric Vehicles (FCEVs) are not considered in the present document.

A Charging Station (CS) refers to a station where one or more EVs can be charged. CPs are the number of sockets available to charge EVs. A CS can have multiple CPs. According to their charging capacities, EV chargers are classified as slow (22 kW or lower) or fast (higher power) chargers [1]. Concerning their location, CPs are split into public and private charging points. More detailed options are illustrated in Figure 1.1.

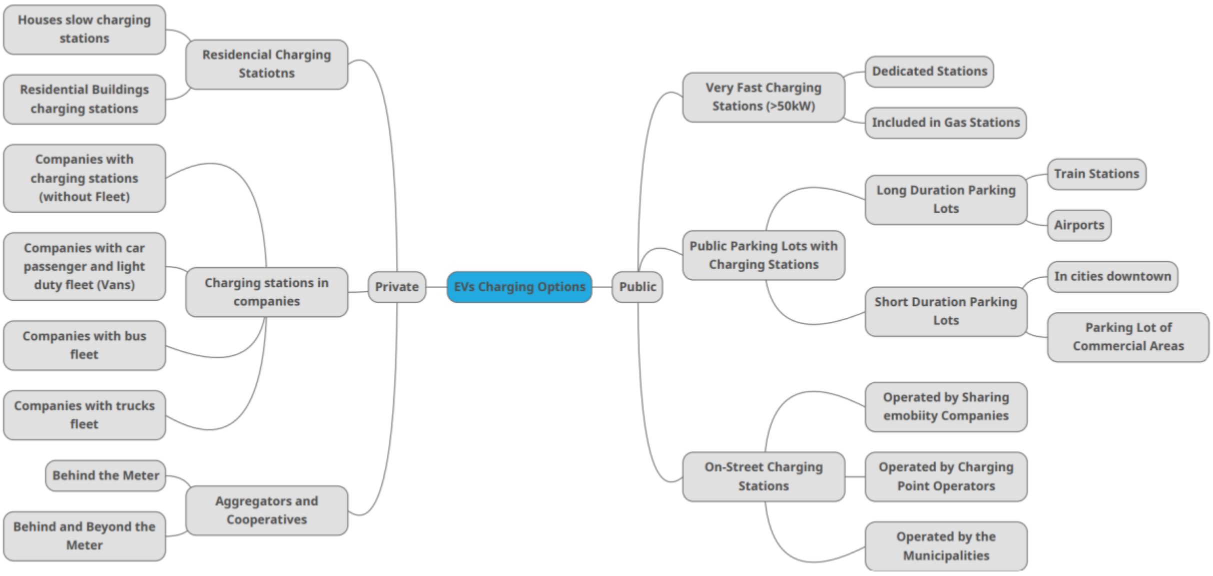


Figure 1.1 – EV charging options (Source: Authors)

1.3 Structure

The current document is divided into nine sections. Sections 2 and 3 introduce the Worldwide and European EV situation and evolution perspectives. Sections 4, 5, 6 and 7 address the EVs situation at the country level namely in Denmark, Greece, Portugal and Slovenia, respectively. The main factors that can influence the evolution of EVs are discussed in Section 8 and the main conclusions are presented in Section 9.

1.4 Relationship with other deliverables

The scenarios illustrated in the present document will be used in most of the project tasks. In most cases, the methods that will be developed will be tested and/or demonstrated on a limited scale. However, considering the scenarios proposed in the present deliverable, it is possible to evaluate the impact of the proposed methods at a larger scale following the trends of massive adoption of electric mobility.

2 Worldwide Evolution Scenarios of Electric Vehicles

Increased awareness of climate change is leading to the development of strategies toward a net-zero economy. The energy transition driven by investments in renewable technology and electrification of the sectors is changing the global society. Some efforts are being made to reduce Greenhouse Gas Emissions (GHG) through climate agreements and Sustainable Development Goals (SDG) [2]. In 2015, 185 countries signed the Paris Agreement at the 21st Conference of the Parties (COP 21). This agreement aims to achieve the decarbonisation of economies and limit, by 2050, the global average temperature increase to below 2ºC above pre-industrial levels [3]. More recently, at the 26th Conference of the Parties (COP 26), several entities, including government car manufacturers and investors, issued a joint declaration proposing ambitious targets to achieve 100% Zero-Emissions Vehicle (ZEV) sales of new vehicles by 2040 globally, and by 2035 in "lead markets" [4].

According to [5], [6], power generation (40%) and transport sectors (23%) are responsible for about two-thirds of the total GHG. The transport sector is also one of the sectors with the lowest use of renewable energy sources [7]. On the contrary, the power sector is one of the sectors with more renewable penetration with a growing tendency. According to [8], the share of renewables in electricity generation should increase from 26% in 2020 to 90% in 2050. Considering these factors, the electrification of the transport sector, mainly road transport, is presented as a promising strategy to achieve carbon neutrality targets [9].

The mass adoption of EVs has already started. This sentence can be supported by the number of car manufacturers proposing models using electric engines (around 450 models available globally in 2021 [1]), the investments made and planned by car manufacturers (estimated investment of $515 billion over the next five to ten years [10]), the reduction of battery pack costs (132 $/kWh in 2021 [11]), the increase of the global market share of sales (around 9% in 2021 [1]), the number of EVs on the roads (around 16.5 million [1]), the EV charging infrastructure development (number of charging stations, charging stations per EV, installed power, etc.) and finally the increase of the EVs acceptance by the end users. In this regard, a survey presented in [12], mentions that 90% of EV owners are "likely" or "very likely" to purchase an EV as their next vehicle, which can be seen as a good indicator of the user's satisfaction and adoption.

In the next sub-sections, an overview of the EVs global market (Section 2.1) and the EVs evolution global scenarios (Section 2.2) are presented.

2.1 Electric Vehicles: Global Market

This section presents an overview of the EV industry and covers the EVs market (Section 2.1.1), the charging infrastructure (Section 2.1.2) and energy demand (Section 2.1.3).

2.1.1 Worldwide Electric Vehicles Sales and Stock

Global EV sales are increasing significantly in recent years. According to [1], in 2021, global EV sales achieved 6.6 million units representing around 8.57% of the market share. China and Europe lead the EV market, accounting for 85% of global EV sales, followed by the United States (12%) [1]. These values are similar in different reports such as in REN21 [13], Bloomberg [14], IRENA [8] and EV-Volumes [15]. The Global EV sales and the market share are illustrated in Figure 2.1.

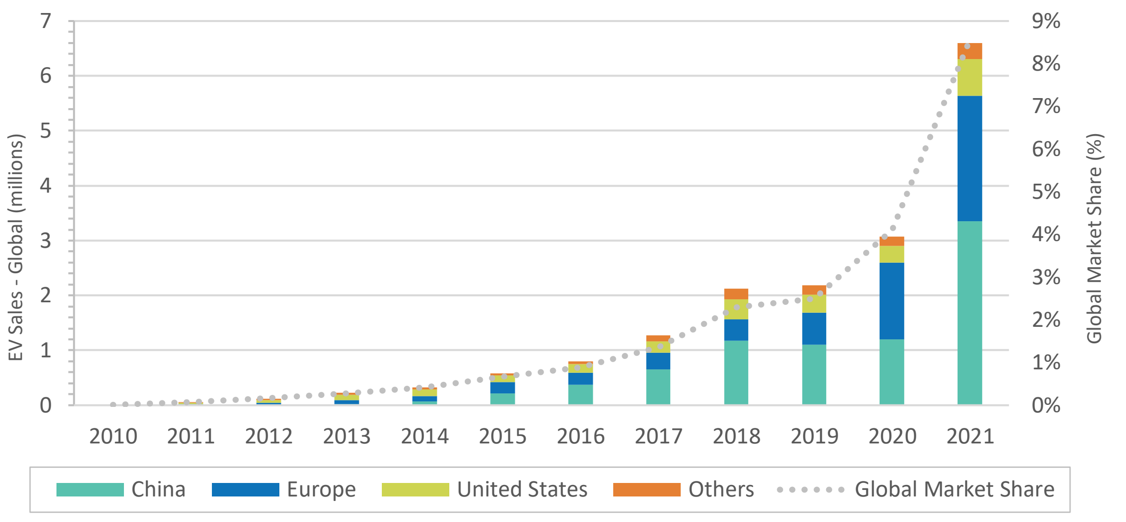


Figure 2.1 – Global sales and market share of EV passenger cars. (Source: [1], [16]**)**

Another aspect that is important to address is the market share of pure BEV and PHEV. The capacity of the batteries typically used in these two technologies directly impacts travel distance, energy consumption and management strategies. Considering the most recent data, the average battery capacity values are 10.6 kWh in PHEVs and 43 kWh in BEVs [17]. Figure 2.2 presents the global EV car passenger stock considering BEV (68%) and PHEV (32%) technologies. The global EV car stock represents 1.4% of the global fleet [1].

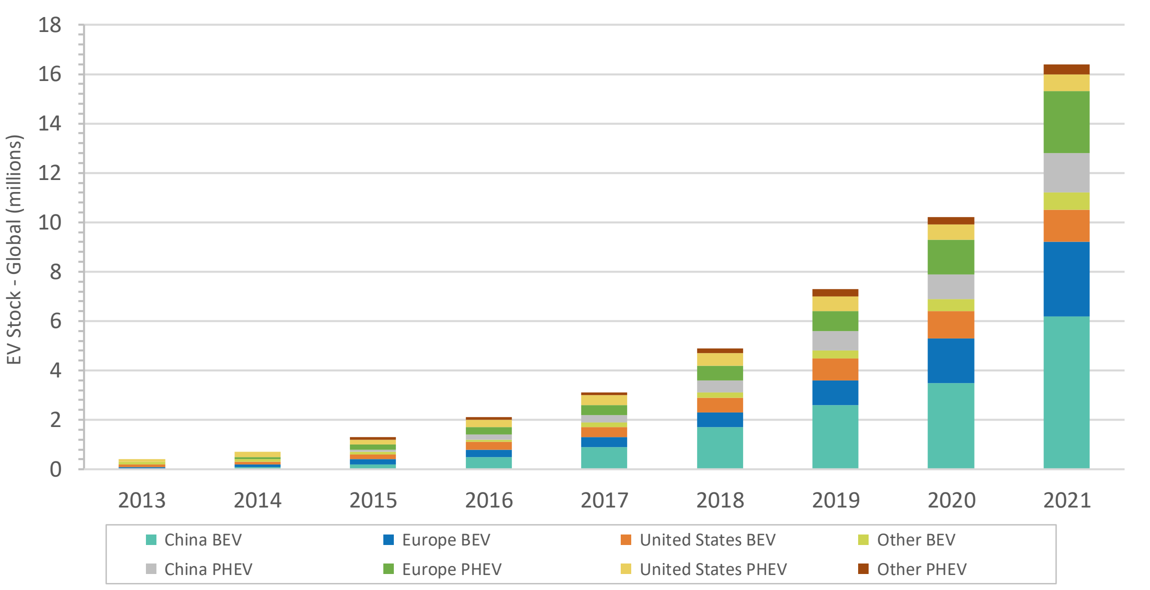


Figure 2.2 – Global EV passenger cars stock divided by BEV and PHEV. (Source: [1]**)**

In 2021, the percentage of BEVs / PHEVs was 79.5% / 20.5% in China, 65.0% / 35.0% in US and 54.5% / 45.5% in Europe (Figure 2.2). Several reasons can be identified to justify these differences. The Chinese government offers the highest incentives for the acquisition of BEVs, especially for the car makers industry. Another important factor may be the success of Chinese battery manufacturers, who are taking the lead in this market [18]. Users´ concerns about BEVs may be greater in Europe than in other regions, and BEVs and PHEVs have similar European incentives [19].

Beyond the EV passenger cars, other types of vehicles can be mentioned as EVs. Table 2.1 presents the size of the fleet and the EV sales share in 2021 of vans and trucks, passenger buses and two and three-wheelers (motorcycles, bicycles, etc).

Table 2.1: Electric mobility market (Source: [14]**)**

Transport mode	EV Share of Sales (2021)	Size of EV fleet
Vans and Trucks	1%	613 450
Buses	44%	685 005
Two and three-wheelers	42%	274 767 231

Table 2.1 suggests that the electrification of vans and trucks is challenging, and innovative solutions should be proposed. Several barriers to EV van and truck adoption have been identified, namely, the price of the vehicles, the operational costs, the lack of incentives, the range, the lack of charging infrastructure, and the charging time [20]. The electrification of buses presents an impressive share of sales, suggesting that the bus fleet operators have already realized the advantages of this technology and the adequacy of the existing solutions. The share of sales of two and three-wheelers is also interesting, and the size of the fleet arrives at 274 million units [21]. This type of vehicle poses some of the most serious unresolved questions within the context of sustainable urban mobility. Two and three-wheelers represent close to 30% of total motorised vehicles worldwide, and in some cities, this percentage can achieve 90%. This can be an important insight in developing technical solutions for electric mobility.

2.1.2 Worldwide Charging Infrastructure

As mentioned previously, charging infrastructure is a key factor in EV development. Some reports on the development of charging infrastructures only mention the number and power of public charging stations installed in charging station areas (dedicated or in gas stations) and on-street charging stations. This may be because EV users expect the same services they have for conventional ICE vehicles [1]. However, it has also been reported that "*most EV charging takes place at residences and workplaces*" [1]. Coordination between the existing and unexplored options will be studied in future deliverables of the EV4EU project.

According to [1], the number of public charging points reached 1.8 million in 2021. Of these charging points, around one-third were fast chargers. The evolution of charging points is presented in Figure 2.3.

Figure 2.3 shows that in 2021 around 0.5 million charging points were installed, with a significant increase in fast charging ones. The ratio between the number of EVs and the number of CPs is around 9.3 EVs/CP. Considering the reference value of 10 EVs per CPs proposed in the Deployment of Alternative Fuels Infrastructure (AFID) [22], [23], one can state that the existing charging points are, on average, adequate for the number of EVs. However, this metric was 7.8 in 2020, which means that in 2021, there was a faster evolution of EVs compared with the charging infrastructure.

Concerning private charging points, around 6.5 million outlets were installed in houses and companies in 2019 [24].

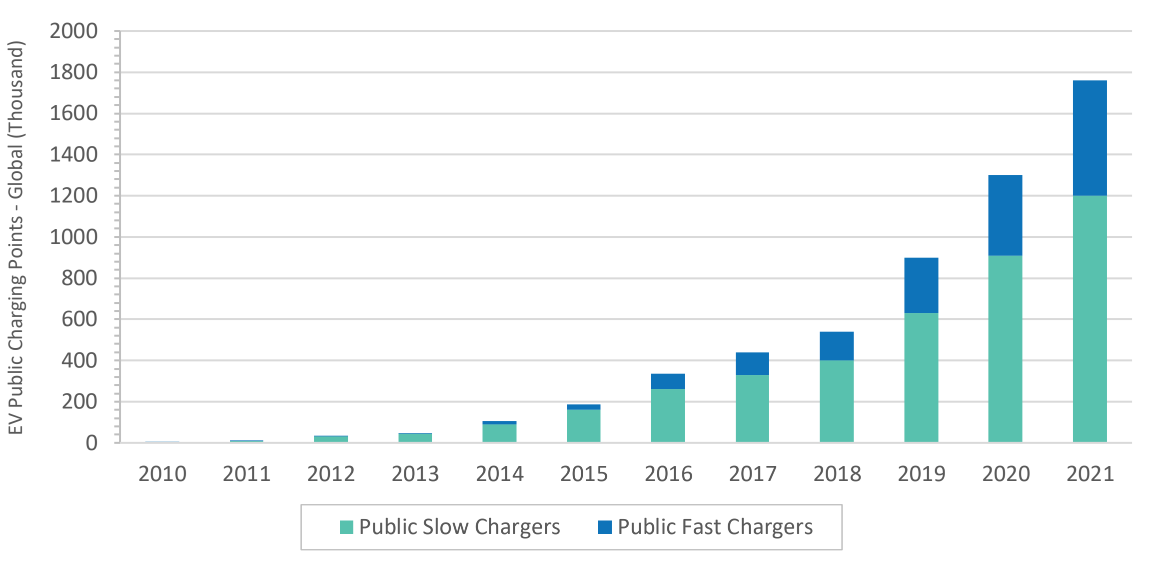


Figure 2.3 – Worldwide EV charging points (Source: [1], [25]**)**

2.1.3 Worldwide Electricity Demand

The energy demand for EVs depends on the characteristics of the vehicles (energy consumption per kilometre (kWh/kW)) and the average travelled distance. According to [25], the global EV energy consumption in 2021 was 31.4 TWh, including 28 TWh for BEVs and 3.4 TWh for PHEVs (see Figure 2.4).

The electricity consumption per EV depends on the electricity demand and the EV stock. Assuming an average consumption of 200 Wh/Km, it is possible to determine the average travelling distance per EV. As shown in Table 2.2, the PHEV values are lower due to the possibility of using the ICE.

Considering the average battery capacity of BEVs of 55kWh and PHEVs of 14kWh [1], it is possible to mention that the global battery capacity was, in 2021, around 600 GWh for BEVs and 70 GWh for PHEVs [1].

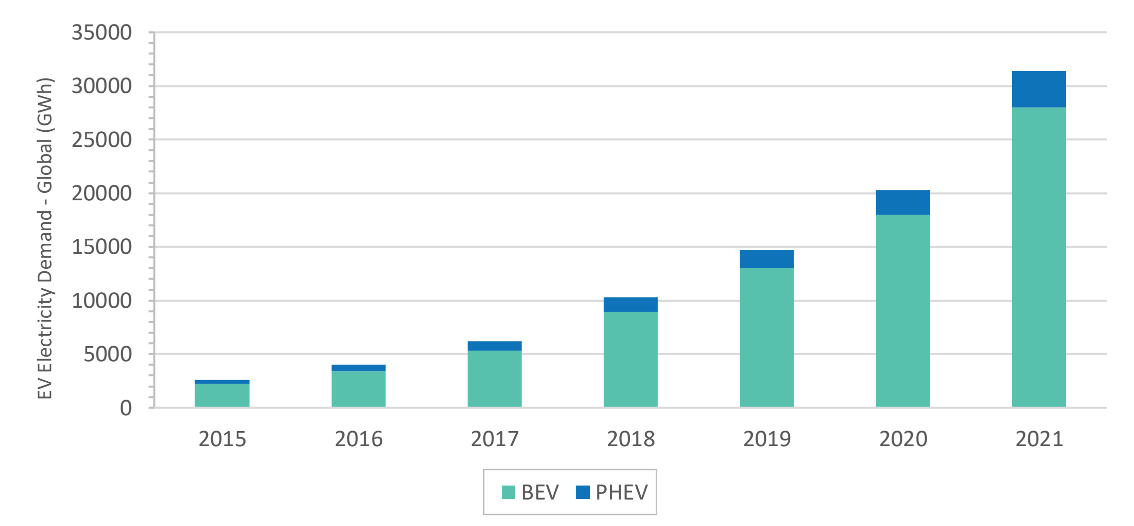


Figure 2.4 – Global Energy Demand by EV technology (Source: [1], [25]**)**

Table 2.2: Electric mobility electricity consumption and distance (Based on: [1], [25]**)**

Type of EV	Annual Electricity Consumption per EV	Daily Electricity Consumption per EV	Daily travelling distance
BEVs	2 295.1 kWh/year	6.87 kWh/day	34.35 km
PHEVs	6 53.85 kWh/year	1.77 kWh/day	8.87 km*

* Only considering the electric propulsion

2.2 Electric Vehicles Evolution Scenarios Worldwide

Several reports have been proposed recently presenting different scenarios concerning the evolution of EVs worldwide such as Bloomberg [14], IRENA [26], [27] and IEA [1], [25], [28]. Based on the mentioned references, several scenarios are described and compared namely:

- Bloomberg [14] analysed two scenarios for the evolution of EVs until 2035: *i)* Economic Transition Scenario (BBG-ETS) driven by new policies and economic and technological trends that affect the EV market; *ii)* Net Zero Scenario (BBG-NZS) investigates a path to zero emissions in the transport sector and considers the economy the decisive factor in achieving carbon neutrality in 2050;
- IRENA proposed in 2020 [26] two scenarios concerning EV stocks evolution for 2050 namely the Planned Energy Scenario (PES) and the Transforming Energy Scenario (TES). PES scenario has been proposed "*based on governments' current energy plans and other planned targets and policies*" [27]. TES "*describes an ambitious, yet realistic, energy transformation pathway based largely on renewable energy sources and steadily improved energy efficiency*". A new scenario (called "1.5°C Scenario") has been published in [8] by IRENA considering the context of the energy transition and the pathway to reach the 1.5° C targets of the Paris agreement through six technological avenues including the electrification of the sectors which includes EVs. In fact, the 1.5°C Scenario can be seen as an update of the TES scenario previously proposed. In the present document, the scenarios proposed by IRENA are called, IRN-PES; IRN-TES and IRN-PRT, respectively;
- IEA [1], [25] addresses three scenarios until 2030: *i)* Stated Policies Scenario (IEA-SPS) embraces current policy plans up to 2030; *ii)* Announced pledge Scenario (IEA-APS) based "*on existing climate-focused policy pledges and announcements, presumes that EVs represent more than 30% of vehicles sold globally in 2030*"; *iii)* Net Zero Emissions by 2050 Scenario (IEA-NZE) "shows a narrow but achievable pathway for the global energy sector to achieve net zero CO2 emissions by 2050, with advanced economies reaching net zero emissions in advance of others. This scenario also meets key energy-related United Nations Sustainable Development Goals (SDGs), in particular by achieving universal energy access by 2030 and major improvements in air quality" [28].

The scenarios are described in the next subsections focusing on EVs sales and stock (Section 2.2.1), charging infrastructure (Section 2.2.2) and energy demand (Section 2.2.3).

2.2.1 Worldwide Electric Vehicles sales and stock Evolution

EVs scenarios proposed in different documents consider the market behaviour and the targets defined in different agreements at the international, regional and national levels. Considering these two visions, the evolution of EVs can be substantially different.

The scenarios proposed in the available reports have different time horizons. To facilitate the comparison between scenarios, in the present document, we analysed the evolution of scenarios every 5 years from 2021 until 2050. The proposed scenarios are presented in Figure 2.5.

We used an interpolation function when no data was available between dates. If the scenarios were not completed for later years, we estimated the values (linear trend). For example, considering the Bloomberg report [14], we interpolated the data for 2030 and estimated values for 2045 and 2050 in the BBG-ETS scenario, and interpolated for 2030, 2040 and 2045 in the BBG-NZS scenario (Figure 2.5).

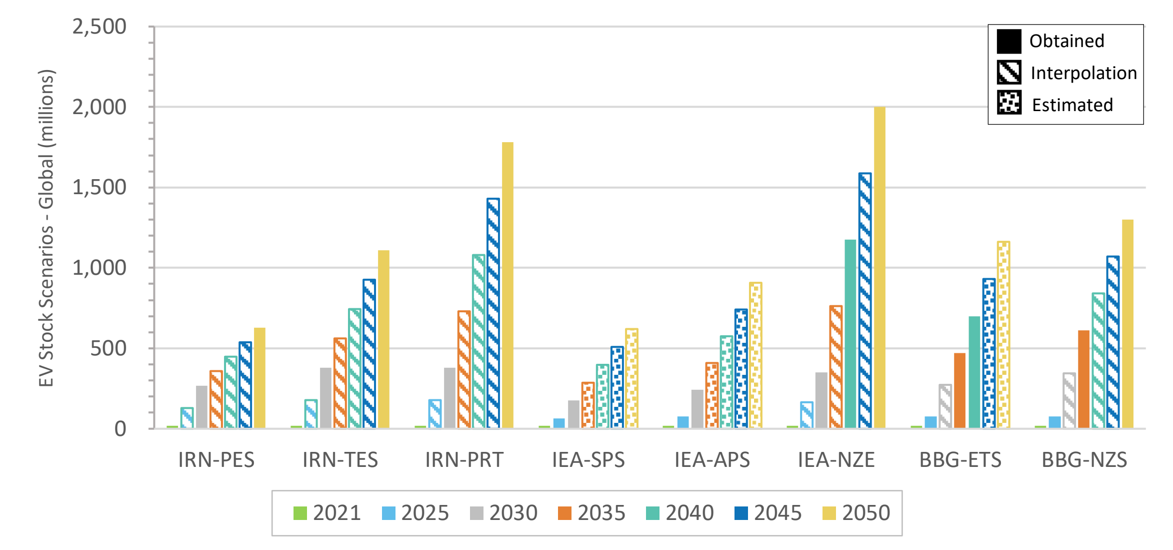


Figure 2.5 – Global EV stock scenarios (Source: [1], [8], [14], [25], [26], [28]**)**

Figure 2.5 shows that the IRN-PRT scenario proposed by IRENA and the IEA-NZE by IEA are the most ambitious ones, considering above 1800 million EVs, including passenger vehicles, buses and light and heavy commercial vehicles. This value represents around 90% of the global fleet by 2050 (the remaining 10% are FCEVs [28]). Compared with the existing fleet (around 16.73 million passenger EVs and over 1.3 million commercial EVs [14]), these scenarios estimate a significant increase in the EV stock: an increase in global EV stock of 40 million EVs/year until 2030 and about 95 million EVs/year between 2030 and 2050. The scenarios IRN-PRT and IEA-NZE represent an increase of 70% compared with the IRN-TES and an increase of 300% compared with the scenarios IRN-PES and IEA-SPS by 2050. Scenario IRN-PRT already considers the impact of recent confits and volatility in energy prices. Concerning the scenarios proposed by Bloomberg [14], BBG-ETS is aligned with scenario IRN-TES. The BBG-NZS is the most disruptive scenario proposed in [14], predicting a total of 1300 million EVs in 2050, being less ambitious than the ones proposed by IRENA and IEA.

2.2.2 Worldwide Charging Infrastructure Evolution

As mentioned before, several options can be used for EV charging, from public to private solutions. In that analysis, only IEA 2030 [1] and Bloomberg 2035 [14] present evolution perspectives. The scenarios for public charging points are illustrated in Figure 2.6.

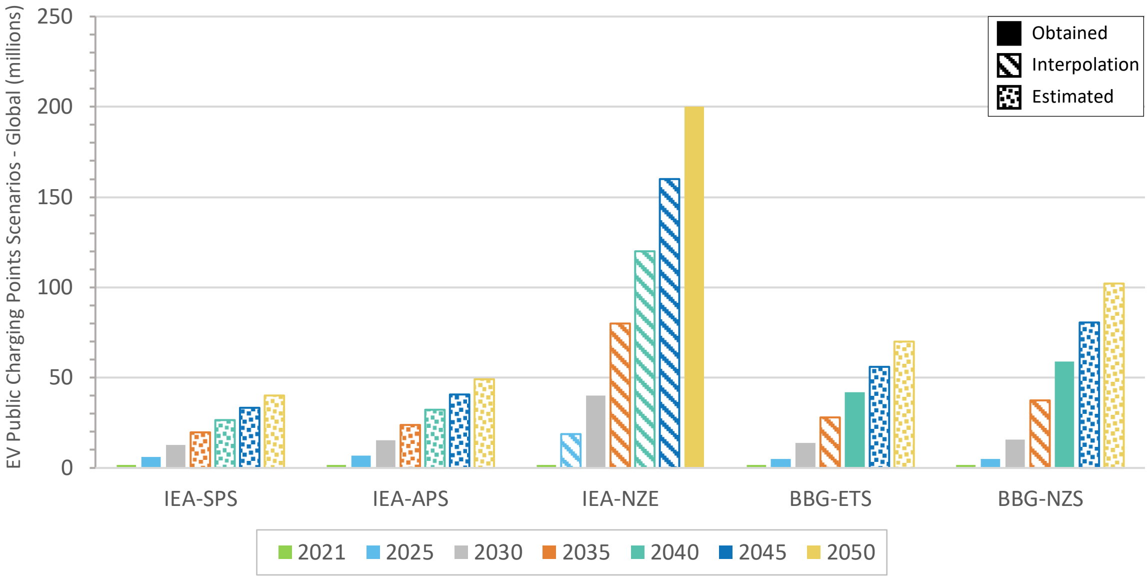


Figure 2.6 – Global EV public charging points evolution (Source: [1], [14], [25], [28]**)**

Figure 2.6 shows that the scenario IEA-NZE is more ambitious than all the others. In fact, for public charging stations, IEA-NZE is 400% and 200% higher than the IEA-APS and BBG-NZS, respectively, by 2050.

The IEA-NZE scenario for private charging stations is even more ambitious with 3500 million chargers in 2050 compared with ≈440 million in 2040 for the BBG-NZS scenario and ≈200 million in 2030 for IEA-APS [1].

The differences in the number of charging points imply the investment and the available charging capacity. According to [1], [28], the public EV charging capacity should be around 660 GW in IEA-APS scenario in 2030 and 12 400 GW in IEA-NZE scenario in 2050. Investment in charging infrastructure is mentioned in [14] achieving $ 1 026 billion and $ 1 410 billion until 2040, in BBG-ETS and BBG-NZS scenarios respectively. The investments in charging infrastructure are also mentioned in [8], corresponding to $ 86 billion/year between 2021 and 2030 and $ 153 billion/year between 2031 and 2050.

2.2.3 Worldwide Electricity Demand Evolution

Electricity demand depends on the number of electric vehicles proposed in Figure 2.5. The proposed values for electricity demand in each scenario are presented in Figure 2.7.

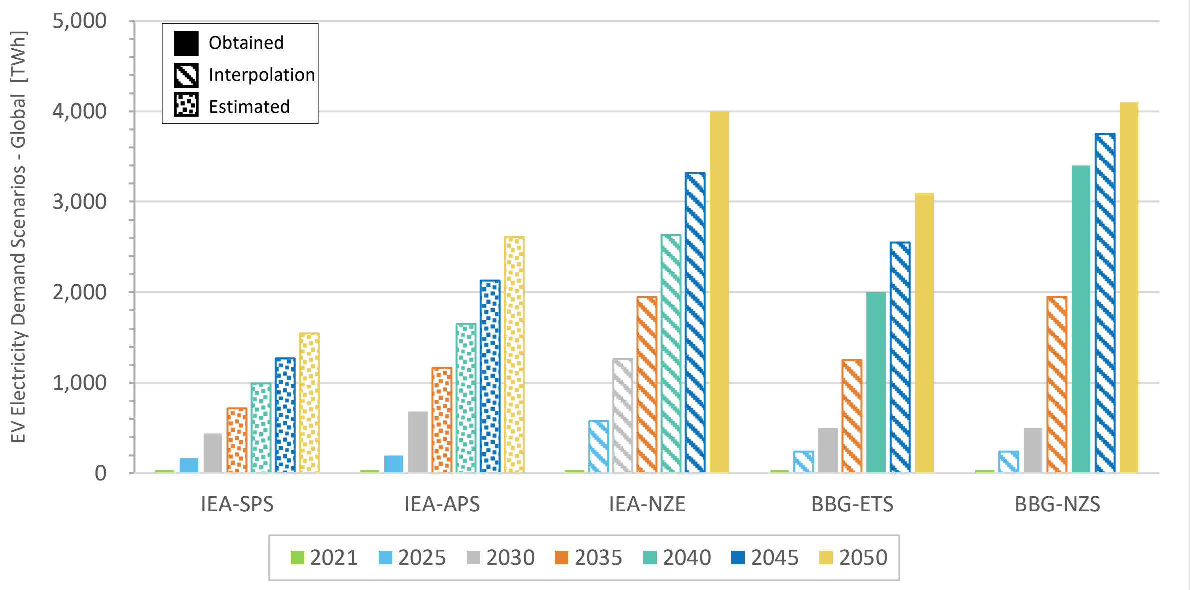


Figure 2.7 – Global yearly electricity demand by electric vehicles (Source: [1], [8], [14], [25], [28]**)**

IEA-NZE and BBG-NZS scenarios have more electricity consumption with around 4 000 TWh. These scenarios only consider car passengers. Comparing the energy demand (Figure 2.7) and the number of EVs stock in each scenario (Figure 2.5), it is possible to observe significant differences. This means that different assumptions have been adopted in different reports. Considering a similar approach to the one presented in Section 2.1.3, it is possible to estimate the EV annual and daily consumption and the travelling distance in each scenario by 2050. These results are presented in Table 2.3.

Table 2.3: Electric mobility electricity consumption and distance (Based on: [1], [8], [14], [25], [28]**)**

Scenario	Annual Electricity Consumption per EV	Daily Electricity Consumption per EV	Daily travelling distance
IRN- PES	---	---	---
IRN-TES	---	---	---
IRN-PRT	---	---	---
IEA-SPS	2 493 kWh/year	6.83 kWh/day	34.16 km
IEA-APS	2 878 kWh/year	7.89 kWh/day	39.43 km
IEA-NZE	2 000 kWh/year	5.48 kWh/day	27.40 km
BBG-ETS	2 668 kWh/year	7.31 kWh/day	36.55 km
BBG-NZS	3 154 kWh/year	8.64 kWh/day	43.20 km

3 Electric Vehicles Evolution Scenarios and Targets in Europe

Considering the agreements described in Section 2, European countries are adopting ambitious strategies to achieve carbon neutrality or, at least, to reduce the GHG emissions significantly. Under the European Green Deal, European Commission presented in July of 2021 the "Fit for 55" package with 19 interlinked proposals of new legislation (6) or revision (13) of current EU climate and energy laws [29]. The main aim of "Fit for 55" is to achieve climate neutrality by 2050 and a 55 % reduction of net GHG, compared with 1990 levels [29]. Transports and Energy are two of the most important sectors addressed in this package. Regarding road transport, the directives in this package define that by 2035 all vehicles sold in Europe should be 100% zero emissions. Since the average lifespan of a vehicle is around 15 years, it is estimated that by 2050 around 100% of the vehicles will not have emissions [30].

The following subsections will overview the European EV market (Section 3.1) and the EV evolution scenarios (Section 3.2).

3.1 Electric Vehicles: European Market

This section provides an overview of the EV industry in Europe and covers the EVs market (Section 3.1.1), the charging infrastructure (Section 3.1.2) and energy demand (Section 3.1.3).

3.1.1 European Electric Vehicles Sales and Stock

EV sales in Europe[1] are increasing significantly in the last few years. In 2021 were sold 2.29 million EVs, representing a market share of 17% and an increase of more than 63.5% compared with the EV sales in 2020 (Figure 3.1) [15], [31]. Concerning the European market stock, EVs represent 1.6% (5.5 million units [25]) of global car stock [32]. This evolution is different in each European country. For example, in Norway, EV stock represents 25% of the total stock and car sales 86%. On the contrary, in Poland, EV stock represents less than 0.2% of the total stock, and car sales are around 1.4% [25].

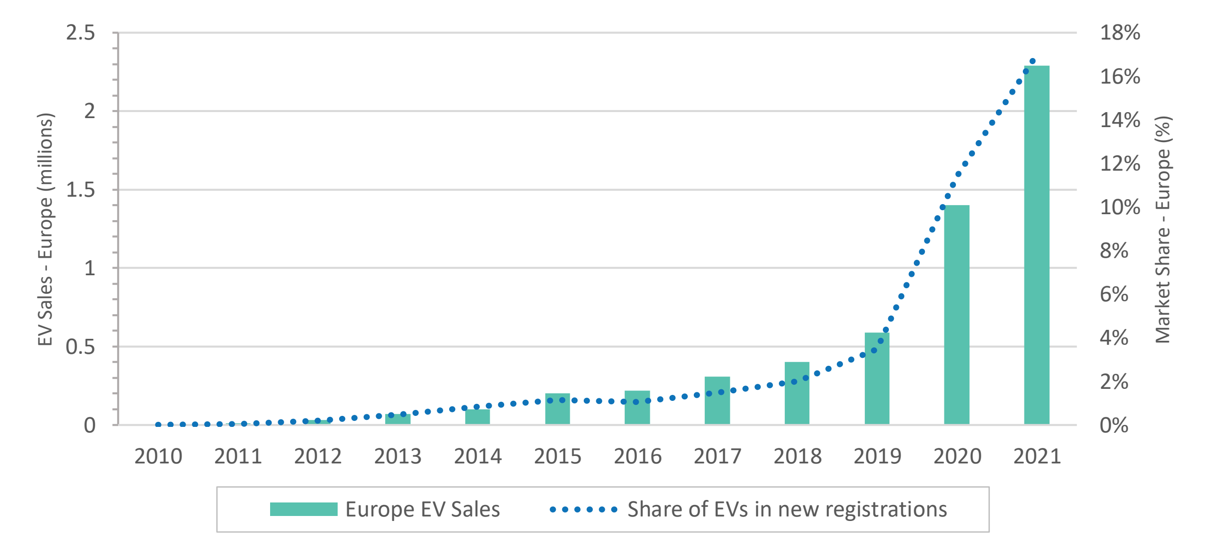


Figure 3.1 – European sales and market share of EV passenger cars. (Source: [16], [31], [33]**)**

[1] In the present report the values presented for "Europe" refers to EU-27+EFTA+UK
EFTA: European Free Trade Association (Iceland, Liechtenstein, Norway, and Switzerland)

As observed in Figure 3.2, in 2021, PHEVs accounted for over 45% of EVs, a much higher percentage when compared to global EV sales (see Figure 2.2). This can be explained by the users 'concerns about changing to new technologies such as EVs. However, according to [34], this situation is expected to change due to the difference in incentives created for BEVs and PHEVs.

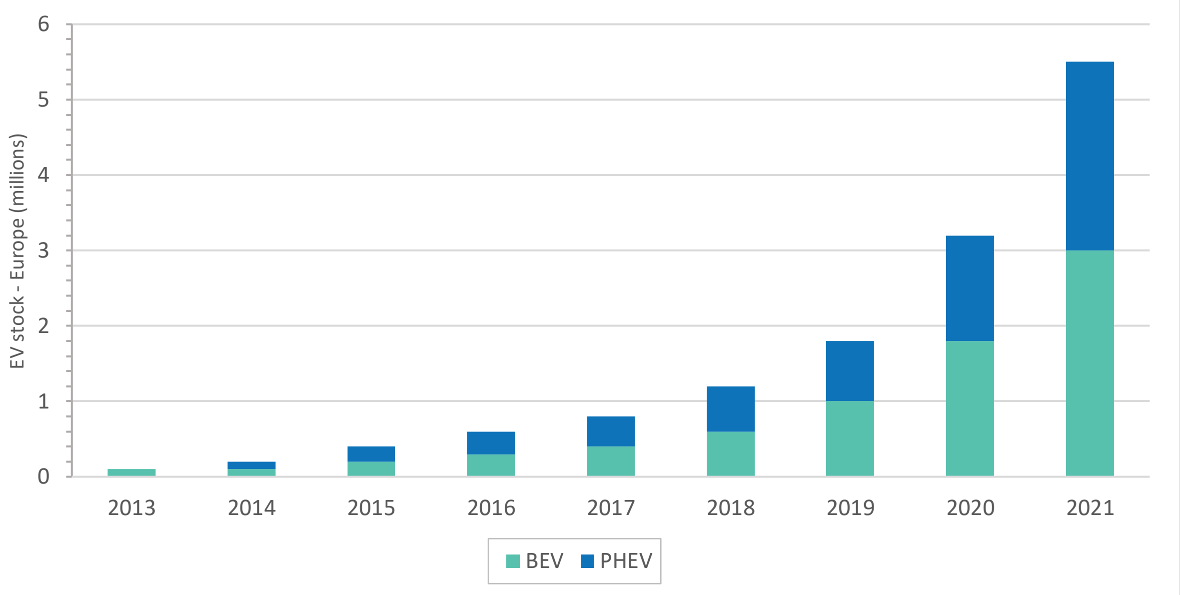


Figure 3.2 – European EV passenger cars stock divided by BEV and PHEV. (Source:[1], [25]**)**

3.1.2 European Charging Infrastructure

In Europe, the number of public charging points was around 334 000 in 2021 [35]. As presented in Figure 3.3, 86.6% of the public charging points are slow chargers and 13.1% are fast chargers [36]. Comparing the existing European public charging points with the worldwide ones (Figure 2.3), it is possible to see a higher percentage of slow chargers. Some explanations can be mentioned for this difference namely the existing infrastructure inside the cities where the cars can be charged at a lower price during the night [37].

According to [36], currently, the force Alternative Fuel Infrastructure Directive [23] does not define a clear mandatory target for charging infrastructures. However, some European countries are launching initiatives to accelerate the deployment of fast charging points, mainly on highways, opening the possibility of intercity and international travel [38]. The impact of these initiatives can be seen in the increase of 350% of fast chargers between 2018 and 2021 [38], [39].

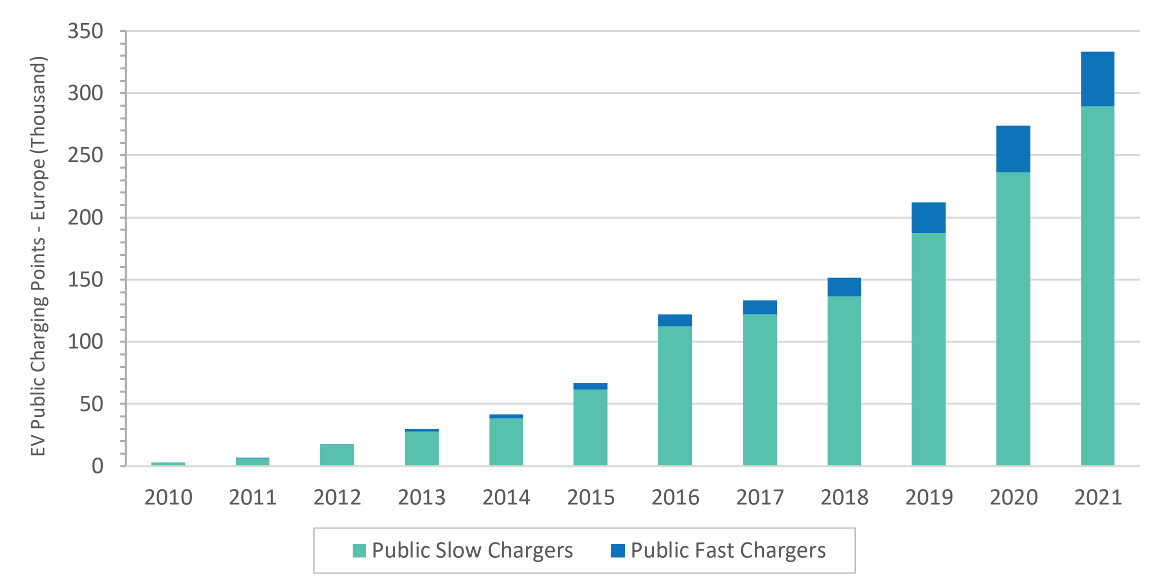


Figure 3.3 – EV charging points in Europe (Source: [1], [25]**)**

Like in EV sales, EV charging infrastructure differs considerably in each European country. Several metrics can be used to evaluate the adequacy of EV charging infrastructure such as the number of charging stations per kilometre of the road [40], per kilometre square of the country, per 1000 inhabitants or per EV [41]. Other parameters can be important such as the installed capacity of charging stations per existing batteries capacity or per batteries energy usage. The number of EVs per public charging point is one of the metrics adopted by the European Commission [22], [23]. The defined target introduced in AFID in 2014 [22], [23] is to have at least 1 charging point per 10 EVs. In this metric, in 2020 and according to [22], countries such as Cyprus, Finland, Greece and Sweden are over the target while UK, Belgium and Ireland were exactly in the 1 charging point to 10 EVs. On the other hand, the Netherlands is one of the countries with the highest number of public charge points per EV. In EU-28 the ratio is 1 charging point per 7 EVs [22]. However, in the same document, it is stated that between 2017 and 2019 there was an increase from 1 CP for 5 EVs, to 1 CP for 7 EVs, showing a faster development of EVs stock compared with the charging infrastructure.

More recently, in the Alternative Fuel Infrastructure Regulation (AFIR) proposal [42], put forward by the European Commission in mid-2021 (included in the “Fit for 55” package [43]), the targets for two other metrics were proposed. The targets are defined for the installed charging capacity per BEV (1.0 kW) and the installed charging capacity per PHEV (0.66 kW). In both metrics, the installed charging capacity refers to the maximum simultaneously available power output that can be limited not only by the charging point's capacity but also by charging stations’ power output limits imposed by contracts or electric grid capacity [42]. Additionally, it is important to mention that these metrics, when analysed at a country level, don't reflect the neglected areas that have EV scarcity [44].

3.1.3 European Electricity Demand

In 2021, the electricity consumption of EVs in Europe was 8000 GWh, including 6700 GWh for BEVs and 1300 GWh for PHEVs (see Figure 3.4). The EV annual and daily consumption, and the travelling distance are presented in Table 3.1.

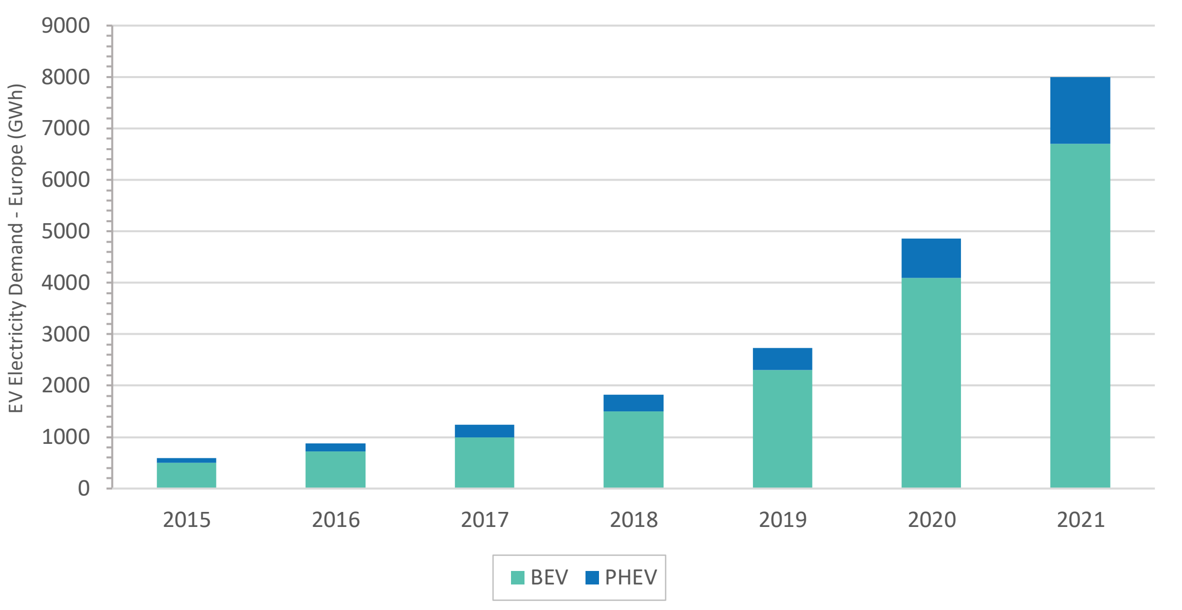


Figure 3.4 – Electricty demand in Europe by EV technology (Source: [1], [25]**)**

Table 3.1: Electric mobility electricity consumption and distance in Europe (Based on: [25]**)**

Type of EV	Annual Electricity Consumption per EV	Daily Electricity Consumption per EV	Daily travelling distance
BEVs	2233 kWh/year	6.12 kWh/day	30.59 km
PHEVs	520 kWh/year	1.42 kWh/day	7.12 km*

* Only considering the electric propulsion

3.2 Electric Vehicles Evolution Scenarios in Europe

European countries are proposing strategies to promote the development of electric mobility as a path toward carbon neutrality. Based on these strategies several entities are proposing scenarios for electric mobility anticipating the impact of directives and policies. In the present section several documents are analysed corresponding to different scenarios:

- IEA [1], [25] addresses two scenarios until 2030: *i)* Announced pledge Scenario (IEA-APS) based on climate policy pledges up to 2030. *ii)* Stated Policies Scenario (IEA-SPS) embraces current policy plans up to 2030. In [25], values are presented for EU27+4 (UK, Norway, Iceland, and Switzerland).
- Virta [31], proposes two scenarios for Europe until 2030, namely the “Low estimates” (VRT-LOW) and “High estimates” (VRT-HGH). The main difference between the two scenarios is the existence of “EVs roaming around Europe”. EVs roaming means that EVs can be plugged in and charged in different charging networks [45], [46]. The Scenarios are presented for EU28+2 (EU27+UK, Norway and Switzerland).
- Fraunhofer [47] presents a scenario (FRH-SCN) for EV sales considering that EV sales share can reach 100% and that sales growth follows an S-shaped diffusion curve adjusted based on Norwegian EVs sales. The scenario was defined based on 2020 EV sales in EU27+4 (UK, Norway, Iceland, and Switzerland).
- European Alternative Fuels Observatory (EAFO) published a report [48] in 2017 where three scenarios for 2050 are proposed for EU-28 (EU-27 + UK). According to EAFO, until 2017, scenarios proposed in the literature did not provide a complete vision of road mobility in the

EU. The proposed scenarios are *i)* ZEV Base Case (EFO-ZBV) where zero-emissions vehicles have a moderated adoption*; ii*) PHEV Bridging (EFO-PHV) where PHEVs have a strong market share towards 2030; and *iii)* ZEV leader (EFO-ZLD) where zero-emissions vehicles have a strong adoption.

- Strategy& [49], presents a scenario (SPC-SCN) for EVs stock and sales in EU27+3 (UK, Norway and Switzerland) until 2035. In the proposed scenario, it is stated that the global car stock will decrease by more than 11% due to car-sharing adoption.
- Strategy& in collaboration with the European Association of Automotive Suppliers (CLEPA) proposes in [50] three scenarios for EVs sales in EU27+EFTA+UK for 2040. The first scenario called the "Mixed-technology scenario" (CLP-MTS) already considers COVID-19 government recovery, the upcoming EURO 7 emissions norm and 50% CO2 reduction by 2030, based on the 2020 95g New European Driving Cycle (NEDC) stricter passenger car target. The second scenario, the "EV-only scenario" (CLP-EVS) follows the STEP scenario proposed in [1] the "Fit for 55" package and additional incentives for BEVs and charging infrastructure. The third scenario, called the "Radical scenario" (CLP-RAD), considers a 100% CO2 reduction by 2030. In that case, zero-emissions vehicles should be adopted in 2030.
- In [51], ElementEnergy proposes two scenarios for EV adoption in EU27+EFTA+UK+Turkey until 2050. The main difference between "Baseline" (ELM-BAS) and "2028 Purchase price parity" (ELM-PPP). The main assumption of the scenarios is that price parity is a critical aspect in the EVs adoption. In the Baseline scenario, it is assumed that price parity will be achieved in 2030 for car passengers but not for other segments. In the "2028 Purchase price parity" scenario it is assumed that the price parity in 2030 in all car segments.
- In [39], Transport & Environment discusses the importance of charging infrastructure to achieve the EU target of 100% of new passenger cars and vans sales being zero emission by 2035. The document proposes a scenario of EVs stocks in EU-27 until 2035.
- The International Council on Clean Transportation (ICCT) also proposes a scenario for EVs stock evolution in EU-27 until 2030 [52]. The scenario was developed based on the methodology proposed in [53].
- In [54], Eurelectric in collaboration with EY also proposes a vision for EVs evolution (EUR-SCN). This scenario considers the experience and insights from European industry leaders who are actors in the EVs value chain.
- In 2021, ChargeUp also published a report [55] proposing the minimum charging infrastructure requirements. The document presents three scenarios. The first one (CHU-MIN) is based on the minimum number of public charging stations according to the methodology presented in [55]. The second scenario (CHU-ACS) considers a high share of AC charging points and the third (CHU-HPS) considers a higher share (45% instead of 35% in the CHU-MIN scenario) of public charging points.

3.2.1 European Electric Vehicles Sales and Stock Evolution

The scenarios presented in the documents described in Section 3.2 have been performed considering different assumptions, countries and time horizons. To have a fair comparison, all the scenarios were adjusted to EU-27+EFTA+UK countries. When the values were provided in the percentage of EV sales [51], [56], it is assumed a constant car stock (333.3 million) and a constant yearly new car registration (14.5 million) until 2050 [48]. It is also considered a car lifetime of 15 years meaning that the stock share of EVs is taken into account [48]. The scenarios are presented in Figure 3.5.

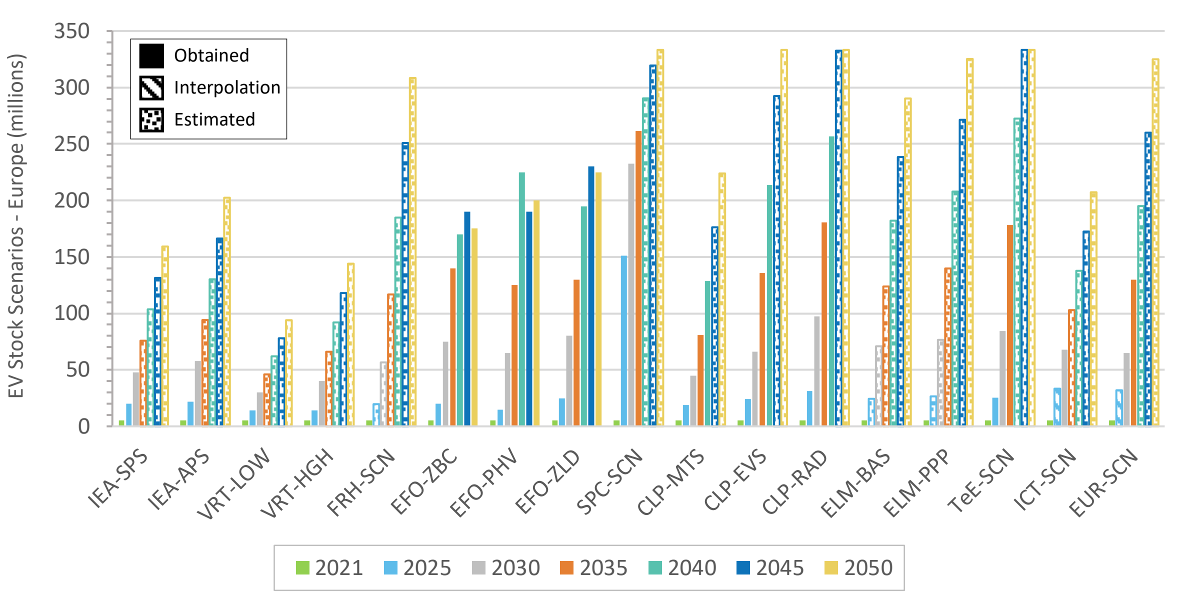


Figure 3.5 – EV Stock Scenarios – Europe (Source: [1], [25], [31], [39], [48]–[51], [54], [56]**)**

From all the scenarios presented in Figure 3.5, SPC-SCN has the fastest development of EVs between 2021 and 2035. In [49], it is suggested a share of 93% of EVs of global car stock in 2035. Scenarios TeE-SCN and CLP-RAD are the ones where 100% of EV share is achieved earlier (around 2045). The less ambitious is the VRT-LOW. However, in [31], the projections are only estimated until 2030. Scenarios EFO-PHV and EFO-ZLD present some decrease in EV market share in 2050. This happens because, according to [48], PHEVs will be replaced by FCEVs, not BEVs. These scenarios were proposed in 2017 considering COP21 commitments.

3.2.2 European Charging Infrastructure Evolution

The fast adoption of EVs requires the evolution of charging infrastructure. The European Commission established a set of targets, in which some of which are summarized in [57]:

- In Action Plan on Alternative Fuels Infrastructure [23], it is defined the goal of 440.000 publicly accessible recharging points in 2020. As shown in Figure 3.3, this value is not yet achieved in 2021. In the same document, it is mentioned the need for 2 million charging points by 2025.
- In 2019, in the Green Deal, the estimation is updated to 1 million public charging points until 2025 [57], [58].
- In 2020, the Sustainable and Smart Mobility Strategy [59], defines the targets of 1 million and 3 million public recharging points needed by 2025 and 2030, respectively.

Beyond the mentioned targets, some projections have been published by IEA [1], [25], VIRTA [31], Transport & Environment [39], Eurelectric [54], Fraunhofer [56] , EAFO [48] Strategy& and PWC [49], CLEPA [50] , Element Energy [51] and ICCT [52].The targets and projections are presented in Figure 3.6.

Comparing the target and the projections presented in Figure 3.6, it is possible to see that the scenarios IEA and VIRTA foresee a higher number of charging points in 2025 but a lower number in 2030. In Transport & Environment and Eurelectric scenarios, the projections are much more optimistic being the number of charging points around 5 million in 2030 (EUR-SCN) / (TeE-SCN) and 10 million (TeE-SCN) in 2035. Following this trend, the number of charging points in 2050 can arrive at more than 20/25 million according to these scenarios. Another important aspect mentioned in [54], is the expected number of private charging stations in Europe for 2025 (11.7 million), 2030 (29 million) and 2035 (56 million).

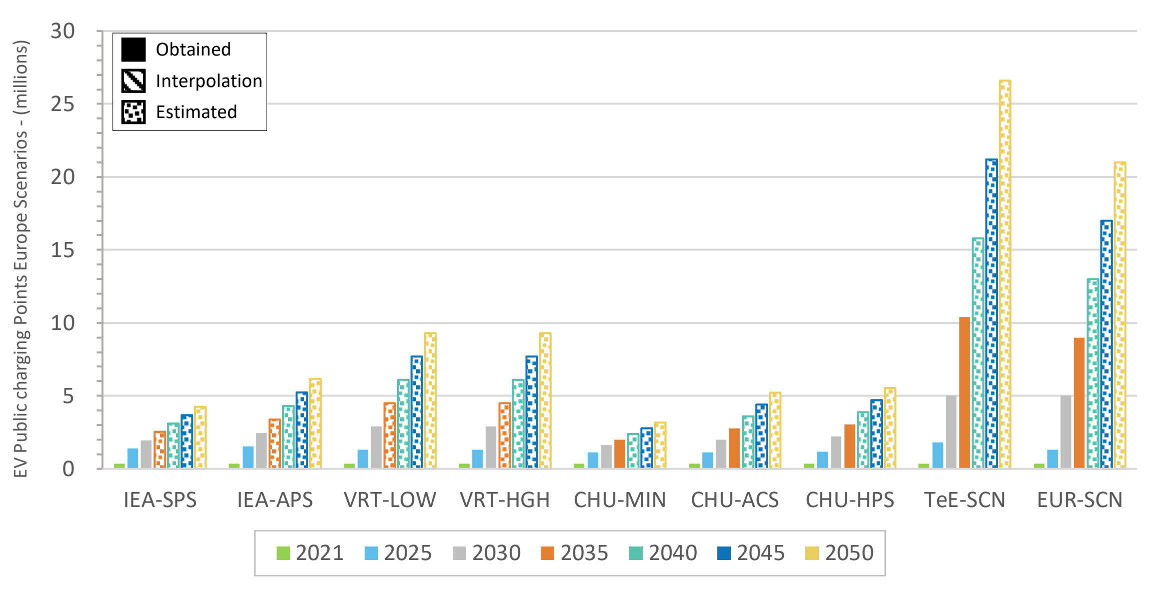


Figure 3.6 – Public Charging Points Scenarios – Europe (Source: [1], [25], [31], [39], [54], [60]**)**

3.2.3 European Electricity Demand Evolution

From the reports analysed (see Section 3) only IEA [1], [25], Eurelectric [54] and ChargeUp [60] address the impact of EVs on electricity demand until 2030. However, in [54], the power demand is mentioned in relative values considering a different base scenario compared with other reports. The perspectives of the electricity consumption of EVs in Europe are presented in Figure 3.7.

According to Figure 3.7, the EVs electricity demand can be higher than 450 TWh in the IEA-APS scenario by 2050. A more conservative scenario is presented by ChargeUp where an electricity consumption of 96 TWh in 2030. Following a linear trend, this means around 290 TWh in 2050. Importantly, the scenarios proposed by IEA are much more conservative in terms of EVs stock evolution than those proposed considering more recent energy transition trends.

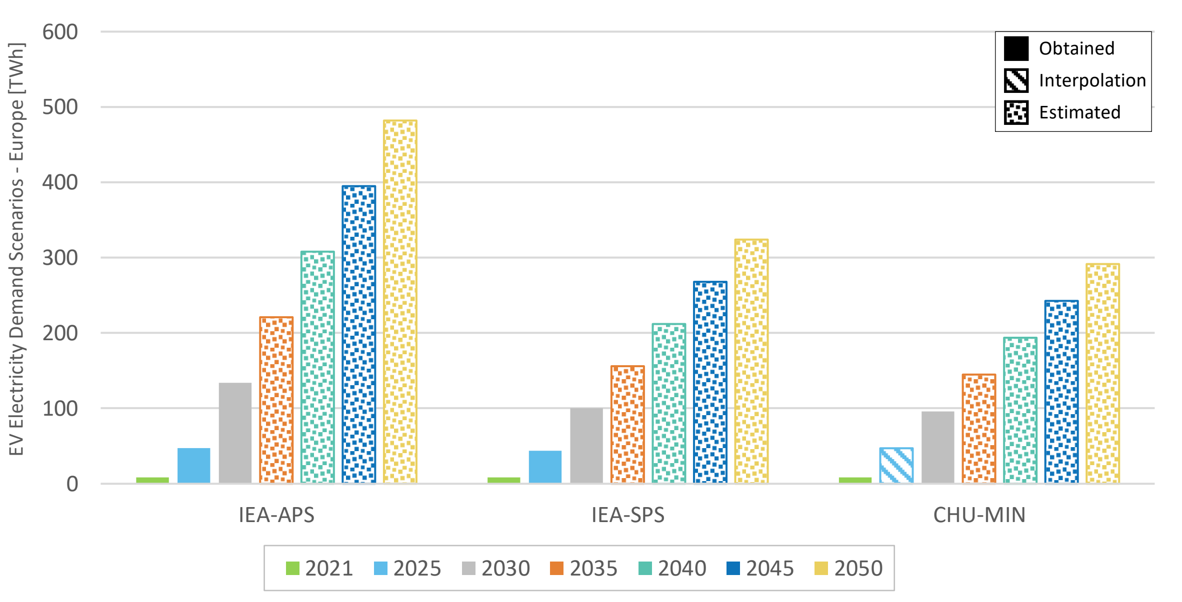


Figure 3.7 – Electricity Demand Scenarios – Europe (Source: [1], [25], [60]**)**

4 Electric Vehicles Evolution Scenarios and Targets in Denmark

In 2019 the Danish transport sector was responsible for 44% of all CO_2 emissions. The majority of emissions derive from road transport, which is accountable for 67%, while maritime transport and aviation account for 31% [61]. Table 4.1 reports the main means of transport, in Denmark, in 2021 and 2022.

Table 4.1: Means of transport in Denmark per 1st of January for 2021 and 2022. (Source: [62])

Category	2021	2022
Passenger cars, total	2 723 667	2 787 553
Buses, total	12 298	11 923
Vans, total	376 435	373 470
Lorries, gross weight 3501-6000 kg	1 814	1 827
Lorries, above 6000 kg gross weight	25 694	25 890
Road tractors, total	14 674	15 430
Trailers, total	1 119 800	1 149 834
Semi-trailers, total	45 517	48 229
Motorcycles, total	165 527	168 418
45-mopeds, total	30 329	28 520
Agricultural tractors, total	85 658	85 293
Caravans, total	121 672	118 422
Ships, total	1 852	1 832
Cargo vessels, total	639	648
Passenger ships and ferries	145	136

In this report, we mainly focus on passenger cars, the main drivers of emissions on Danish roads. In the following, the share of electric passenger cars is discussed in Section 4.1. Section 4.2 discusses scenarios of EV evolutions in 2030 and 2045.

4.1 Electric Vehicles: Danish Market

This section presents an overview of the EV industry in Denmark, starting with the EVs market (Section 4.1.1), the charging infrastructure (Section 4.1.2) and the energy demand for EVs (Section 4.1.3).

4.1.1 Electric Vehicles Sales and Stock in Denmark

According to [1], over the past 5 years, there has been a remarkable improvement in EV customer acceptance for a lot of countries and the Nordic ones in particular. By the end of 2021, one in each car sold in Denmark was electric. At this time, the most popular EV model was Tesla Model 3, and the plug-in hybrid was Ford Kuga [63].

The number of BEVs and PHEVs doubled during the last year and reached 5.2% of the Danish passenger car stock of 2.79 million [64]. Figure 4.1 and Figure 4.2 show the rapid growth in EVs, especially over the last two years. The large increase in BEVs and PHEVs sales in 2021, compared to 2020, can be seen in Figure 4.1.

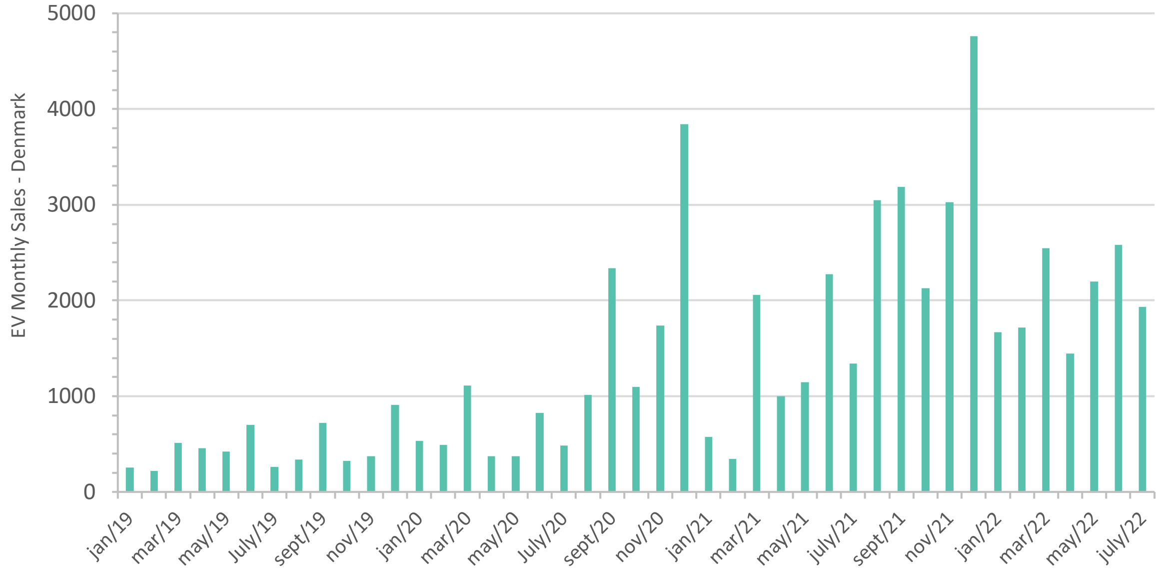


Figure 4.1 – Monthly sales of EVs in Denmark since Jan 2019 (Source: [65]**)**

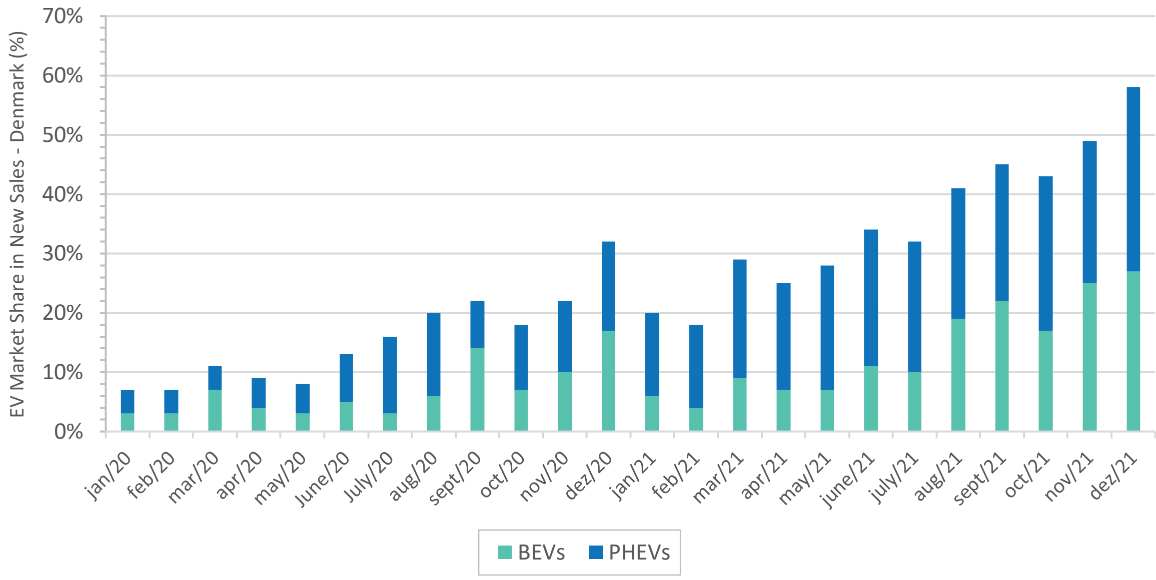


Figure 4.2 – Share of EVs and plug-in-hybrid cars in new car sales (Source: [66]**)**

Table 4.2: Evolution of car sales per type between 2020 and 2021. (Source: [67]**)**

Car type	2020 Total	2021 Total	Percentage difference
Gasoline	120 675	95 678	-20.7%
Diesel	45 808	25 522	-44.3%
BEV	14 219	24 881	75.0%
PHEV	18 280	40 523	121.7%

Figure 4.3 shows the share of EVs per family that has bought a car in 2020 and 2021. It can be seen that EV preference is much stronger for families living in the capital region, likely due to fewer kilometres per day in cities [67], stronger public charging infrastructure, higher disposable income, etc.

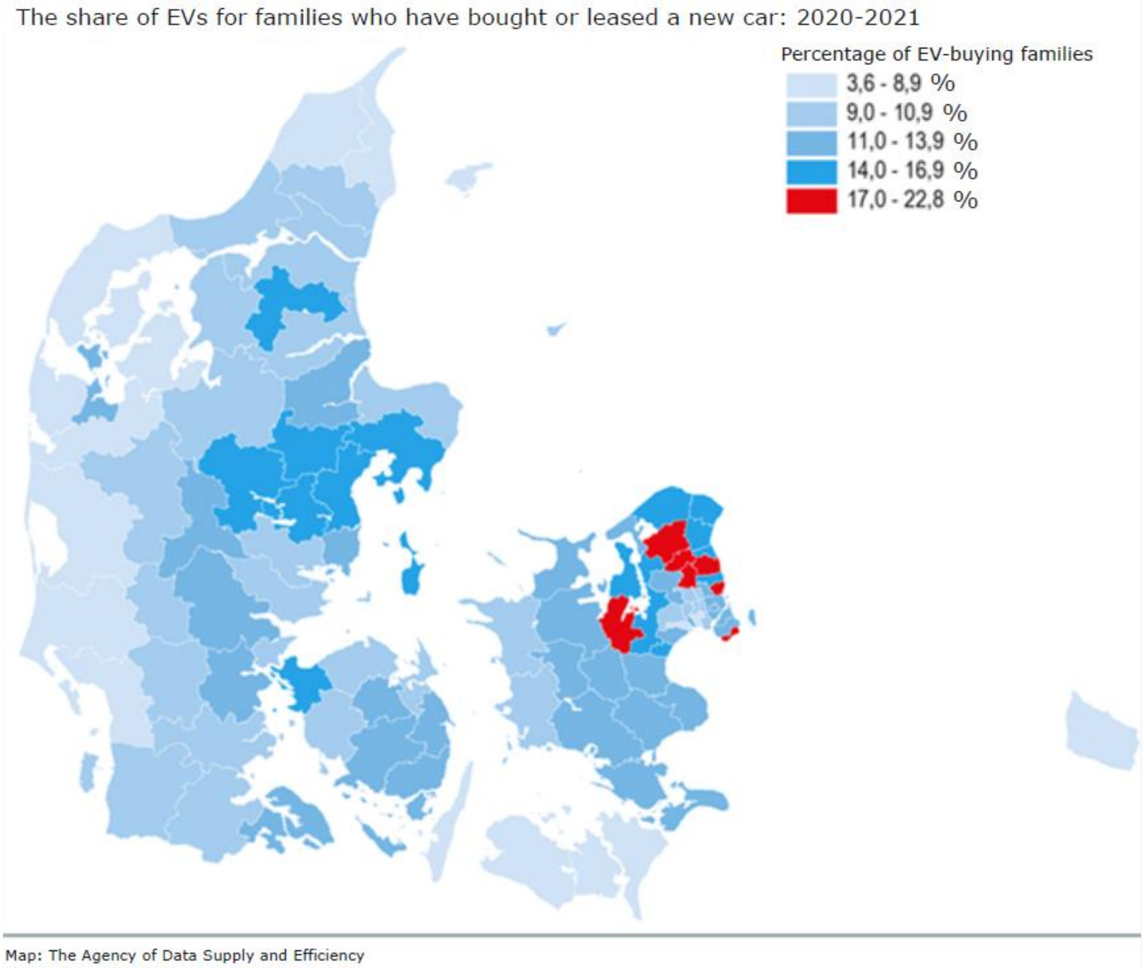


Figure 4.3 – Share of EVs considering families that bought/leased a car in 2020 and 2021 (Source: [68], [69]**)**

4.1.2 Charging Infrastructure in Denmark

Last year the number of publicly access EV charging points increased by 68 % [66]. The most common type of connector is TYPE 2 – single or three-phase AC plug. as presented in Table 4.3.

Table 4.3: Connectors type distribution in Denmark for public chargers (Source: [70]**)**

Connector type	Amount
Type 2	7 012
CCS2	408
CHAdeMO	214
Tesla Supercharger	151
Tesla Destination Charger	33

4.1.3 Electricity Demand in Denmark

Data regarding the electricity consumption related to EV charging in Denmark is not directly available. This happens because apart from charging in dedicated public charging infrastructure, users often employ residential chargers, whose demand is not easy to quantify. Therefore, an estimate of electricity demand due to BEVs and PHEVs can be derived based on the number of vehicles, the average driven kilometres, and a km to kWh conversion rate.

An average driven distance of 45 km/day is taken for Denmark [71]. Further, a conversion of 5 kWh/km is taken for EVs, even though this figure depends on driver behaviour, ambient temperatures and technology. A concrete number of PHEV cars does not exist because electricity consumption heavily depends on how drivers use the battery and whether they frequently recharge the battery or rely more on the use of petrol. For those cars, half the energy needed in electricity are assumed. These considerations give us the numbers presented in Table 4.4.

Table 4.4: Electricity demand due to EV charging

Year	Energy needs of BEVs [GWh]	Energy needs of PHEVs [GWh]
2020	47	30
2021	82	67

4.2 Electric Vehicles Evolution Scenarios in Denmark

This section provides an overview of the evolution of the EV industry in Denmark, starting with the EVs market evolution perspectives (Section 4.2.1), the charging infrastructure needs (Section 4.2.2) and the energy demand required by EVs (Section 4.2.3).

4.2.1 Electric Vehicles Sales and Stock Evolution in Denmark

According to [72], the turning point in EV adoption is expected in 2025. Technological maturity and the development of charging infrastructure are driving this transition. The Danish government set the goal of full climate neutrality by the end of 2050, which means that the transport sector should be fully electrified by then, including personal passenger vehicles. The commission for the green conversion of passenger cars [72] presented four different tax models, which resulted in a large forecasting interval of low-emission passenger cars, from 0.5 to 1 million by 2030 (see Table 4.5).

Table 4.5: Projected number of EVs depending on the adopted tax model. (Source: [61]**)**

Tax model	Projected number of EVs in 2030	EVs stock share
1	500 000	17.9 %
2	600 000	21.5 %
3	750 000	26.9 %
4	1 000 000	35.8 %

The proposed tax models vary from relatively soft restrictions (tax model 1) to stimulate the expansion in EV purchase with low socio-economic expenses, to stricter restrictions (tax model 4) with large taxes on petrol and diesel cars and substantial socio-economic expenses. However, considering the current trend of EV adoption [67], by 2030 the number of EVs may even exceed the threshold of 1 million, as shown in Figure 4.4.

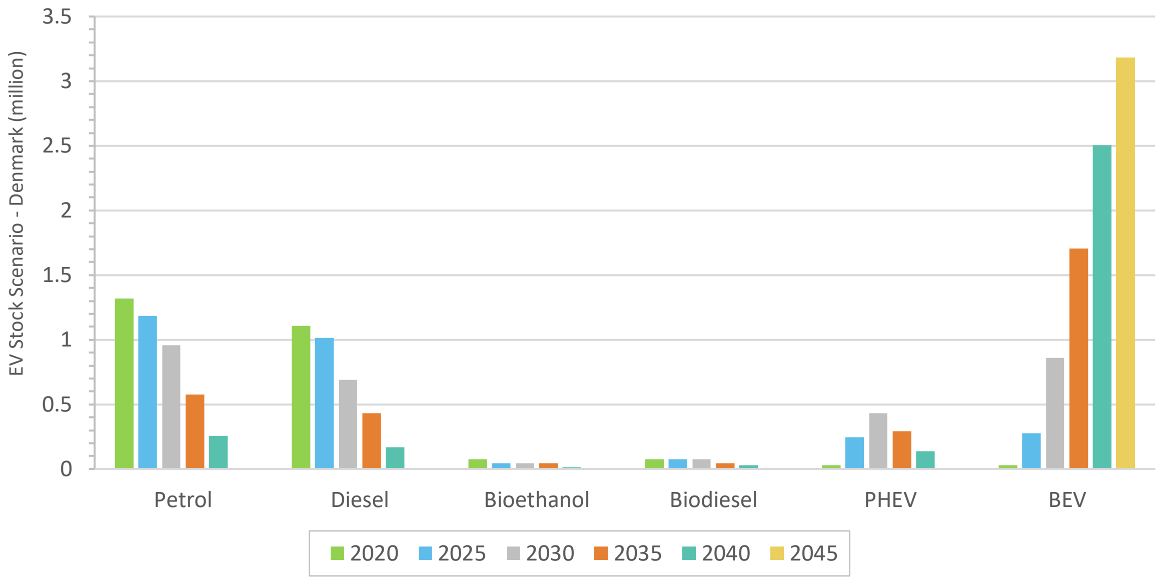


Figure 4.4 – Climate neutrality goal achievement proposal for Denmark in passenger cars. (Source: [72]**)**

The projection presented in [72] is the most optimistic one as it corresponds to the climate neutrality goal by 2045. Based on this information, and the different projections for 2030, we produce three scenarios for the evolution of the number and share of EVs, namely: pessimistic, intermediate and optimistic. We adopt the 3 and 3.2 million cars forecast for the total number of passenger vehicles for 2030 and 2050, respectively, for all scenarios. The results are presented in Table 4.6.

Table 4.6: Evolution of EV penetration scenarios by 2030 and 2050

Scenario	Number of EVs (share)	
	2030	2050
Pessimistic	0.5m (17%)	2.9m (90%)
Intermediate	1.0m (33%)	3.2m (100%)
Optimistic	1.3m (43%)	3.2m (100%)
Total number of passenger cars	3M	3.2M

Thereby, it is expected that by the end of 2035 half of Denmark´s passenger cars will be electric, and by 2045 they will fully replace internal combustion engine cars. In Denmark, PHEVs are considered an intermediate solution toward fully electric vehicles. That is why it is expected that even though their number on the roads will increase substantially by 2030, they will be fully replaced by BEVs by 2045-2050. Car selling trends show that in 2030 the passenger car stock in Denmark will cross the mark of 3 million cars.

Not only passenger cars, but also buses, vans, and trucks must become electric. This is necessary because in 2030 there will be only room for 1.5 million petrol and diesel cars to achieve the Danish government goals and none in 2045 [73].

As proposed in [73], 5% of buses and 30% of vans should be electric or plug-in hybrid by 2030. In 2045, 75% of buses and vans should be electric and the remaining 25% is expected to be covered by electrofuels[2]. Around 20% of motorcycles and military fuel consumption should be electrified by 2030 and 50% by 2045. The large majority of buses are driven in cities, and these are also the ones expected to be electrified first. There are 3330 city buses, where about 800 are operated in Copenhagen, Aarhus, Odense, Aalborg, Vejle and Frederiksberg. By 2025 Copenhagen aims to have 100% of the e-buses fleet [74].

For trucks, the future is more uncertain and technology dependent. A 5% of electric or plug-in trucks could be achieved in 2030 and 35% in 2045. The remaining fossil fuel heavy trucks are proposed to be replaced by hydrogen and electrofuels. However, the change has already started, and a Danish concrete manufacturer ordered 11 Volvo FM Electric trucks (concrete mixers) with a 450-540 kWh battery pack [75]. Also, Copenhagen municipality aims to electrify all the trucks to collect waste (around 100 vehicles by 2025) [76].

4.2.2 Charging Infrastructure Evolution in Denmark

An ideal scenario charging infrastructure deployment scenario corresponds to 1 charging point per 10 cars [77]. This analysis is also aligned with EU targets defined in AFID [23]. The required number and types of public access charging points for Denmark for 2025 and 2030 have been determined and the main results are reported in Table 4.7. The numbers correspond to the relation of 33 – 40 EVs per charging point and assumed that in 2030 there would be 1 million EVs in Denmark. However, the authors also claim that with energy management and parking space optimization the number of charging stations can be reduced to 1 per 100 vehicles.

Table 4.7: Need for public charging points in Denmark. (Source: [61]**)**

Mode	2025	2030
Ultra-fast charging point long trips (150-350 kW)	600 – 650	1 800 – 2 000
Ultra-fast charging point everyday charging (150 kW)	100 – 150	350 – 450
Fast charging points for everyday charging (50 kW)	450 – 550	1 300 – 1 600
Normal charging point for everyday charging (22 kW)	7 000 – 8 000	20 000 – 25 000
Total	8 150 – 9 350	25 000 – 30 000

4.2.3 Electricity Demand Evolution in Denmark

With the increase in EVs, it is naturally expected to lead to higher total electricity consumption. Considering the values provided in Table 4.6, it is possible to estimate how much consumption is expected from EVs in 2030 and 2050 under the three formulated scenarios. The values are provided in Table 4.8, by considering:

- 45 km/day is the average distance driven by the Danish population;
- 5 km/kWh energy consumption;
- 50 % of the consumption from plug-in EVs is considered to be electric.

[2] Electrofuels: “An electrofuel can be defined as a carbon-based fuel, ideally neutral concerning greenhouse gas emissions, that is obtained from carbon dioxide and water, employing renewable electricity as the primary source of energy” [124].

Table 4.8: Electricity demand projections due to EV charging

Scenario	Electricity consumption (GWh)	
	2030*	2050**
Pessimistic	1 368	9 050
Intermediate	2 738	10 512
Optimistic	3 559	10 512

*66% full electric, 33% PHEV
** 90% full electric, 10% PHEV

The total electricity consumption from transportation has also been investigated with intermediate years in [78], and the final trends are reported in Figure 4.5 and Figure 4.6. Note that the figures for cars and vans are comparable with the numbers reported in Table 4.8.

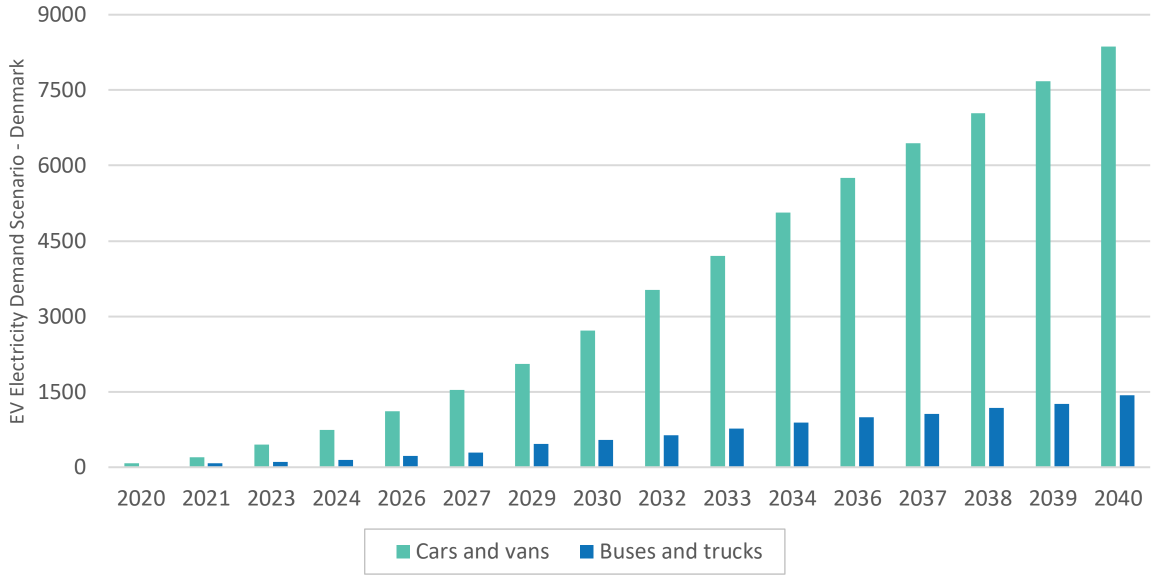


Figure 4.5 – Net electricity consumption projection for light road transport

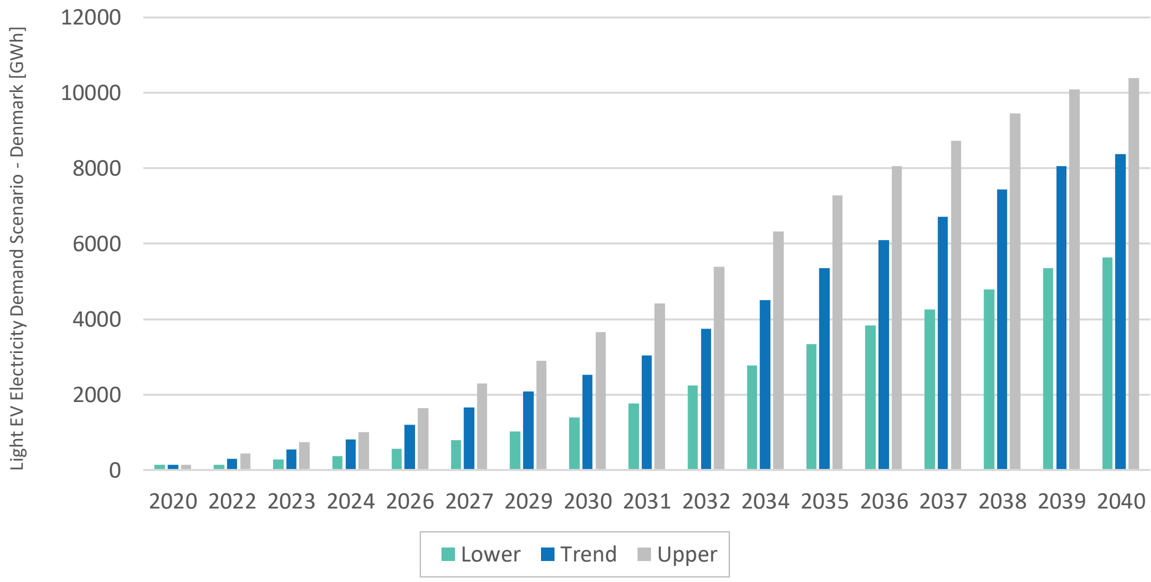


Figure 4.6 – Net electricity consumption projection for heavy road transport

5 Electric Vehicles Evolution Scenarios and Targets in Greece

Greece has an average of 785 vehicles per 1 000 citizens if all vehicle types are included [79]. In recent years, Greek authorities have made several efforts to boost the "green" transition process with flagship projects such as Astypale: Smart and Sustainable Island [80]. Two recent pieces of legislation accelerate this transition, including EV adoption. The first, chronologically, is the National Energy and Climate Plan (NECP) [81] which sets a range of energy and climate objectives by 2030. The second is the Greece's first Climate Law | A roadmap to carbon neutrality [82] which, among other objectives, bans new ICE car sales by 2030.

The next sub-sections present an overview of the EVs market (Section 5.1) and the EVs evolution scenarios in Greece (Section 5.2).

5.1 Electric Vehicles: Greek Market

This section presents an overview of the EV industry in Greece, starting with the EVs market (Section 5.1.1), the charging infrastructure (Section 5.1.2) and the energy demand for EVs (Section 5.1.3).

5.1.1 Electric Vehicles Sales and Stock in Greece

Greece is in the early stages of EV adoption. Nevertheless, EV sales and stock have been increasing rapidly in the last few years (Figure 5.1). The Greek government is also creating a set of programs and plans including incentives for EVs' acquisition and charging infrastructure development. An example is the "Κινούμαι Ηλεκτρικά"[3] plan aiming to subsidize the purchase of EVs and chargers until the end of 2021 [83].

EVs made up 6.9% of new vehicle sales in 2021. However, 89% of the EV sales were made in the Athens area (value from 2020). It is worth noting that new EV sales in 2019 were 0.5%, showing that Greece is investing in a rapid expansion of EVs and charging infrastructure. The EVs sales continuous increasing in 2022 (until July) but the sales share presents a very small increase of 0.1 percentual points (p.p.) when compared with 2021. This is due to supply chain issues that hit disproportionately harder PHEVs and BEVs. This situation is expected to be resolved within the year.

[3] "I Mode Electricity"

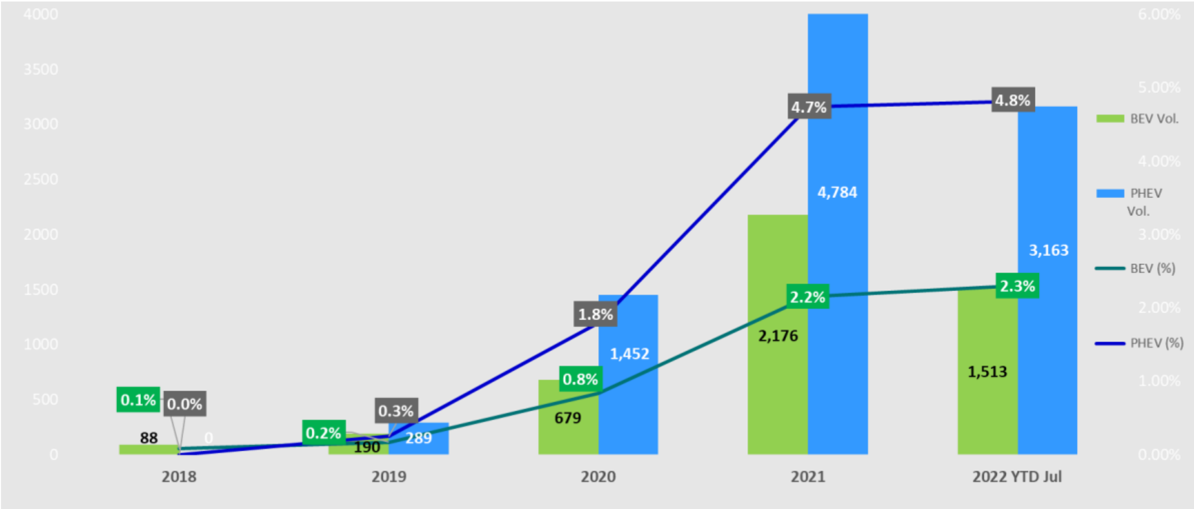


Figure 5.1 – Evolution of BEV and PHEV new vehicle registrations from 2018 to 2022 for Greece (Source: [79]**)**

The increase in EV sales also impacts on EV stock (see Figure 5.2). At the end of 2021, the EVs stock was 10 300 units, including 7 000 PHEVs and 3 300 BEVs [25], corresponding to less than 0.2% of global car stock (6.5 million vehicles in 2020 [32]).

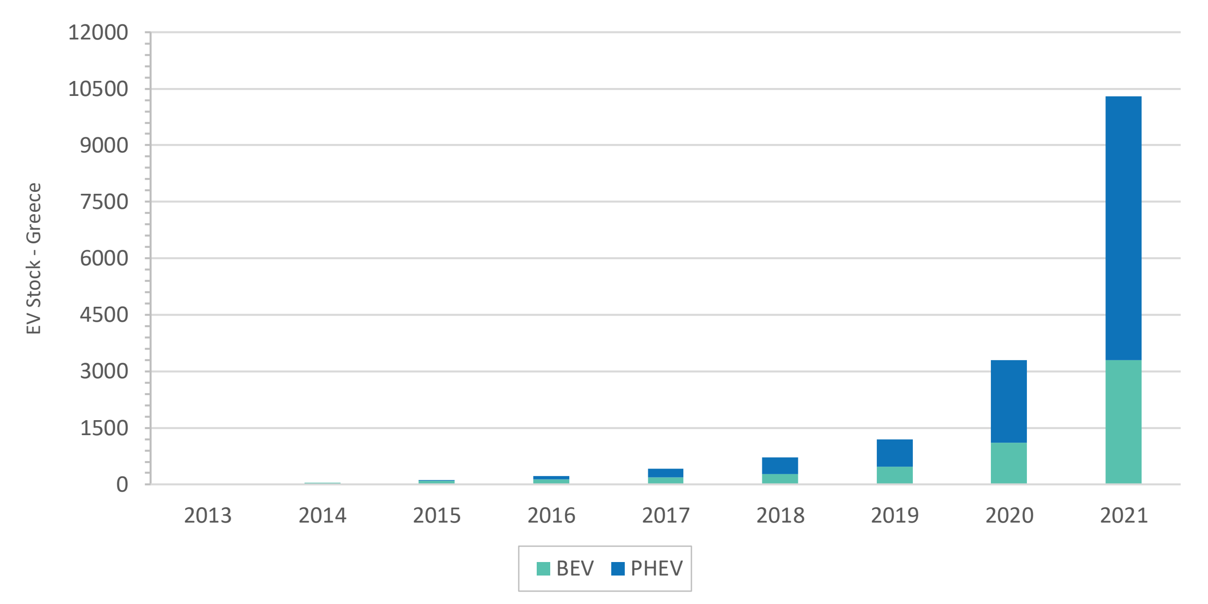


Figure 5.2 – Evolution of BEV and PHEV stock in Greece (Source: [25]**)**

5.1.2 Charging Infrastructure in Greece

Charging infrastructure is also evolving with a similar trend of EVs. As observed in Figure 5.3, the number of charging stations is increasing significantly, achieving 1100 slow chargers and 79 fast chargers in 2021 [25]. Relating the number of EVs with the number of charging stations, the relation is 1 to 9, which is in line with the targets defined in AFID [23]. Of those chargers, around 99% of slow chargers have an installed power of 22 kW and the fast chargers have a power of 43 kW (AC) / 50 kW (DC).

Just like the EVs, public charging points have a high concentration (44%) in Attica (Athens's area) including a few ones in east Attica, Mesogeia area, where the Greek demo will take place (see the right half of the zoomed area in Figure 5.4) [79].

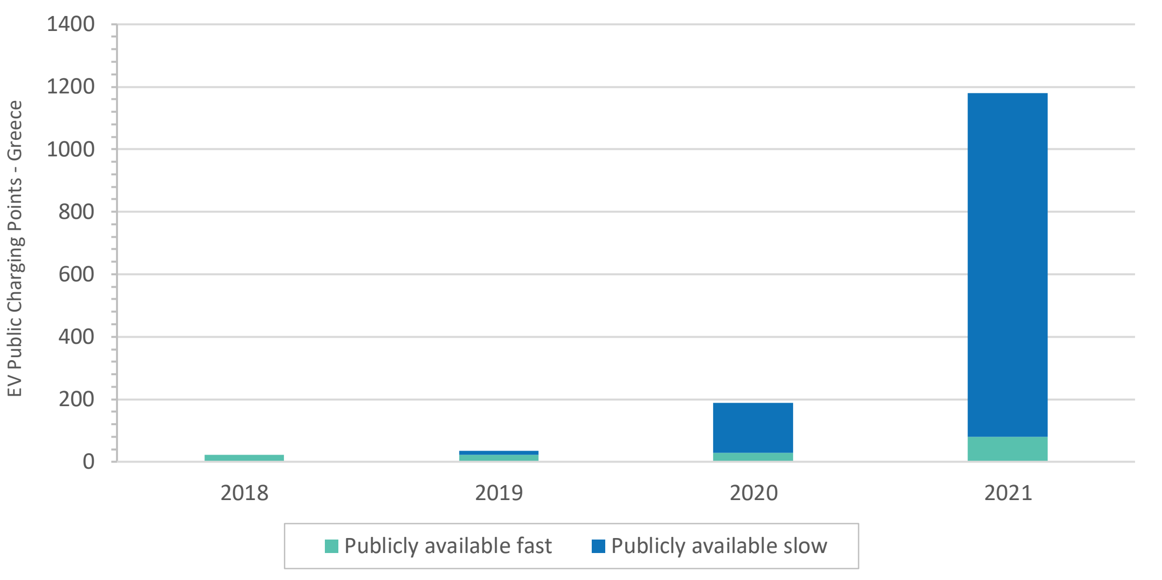


Figure 5.3 – Evolution of charging point in Greece (Source: [25]**)**

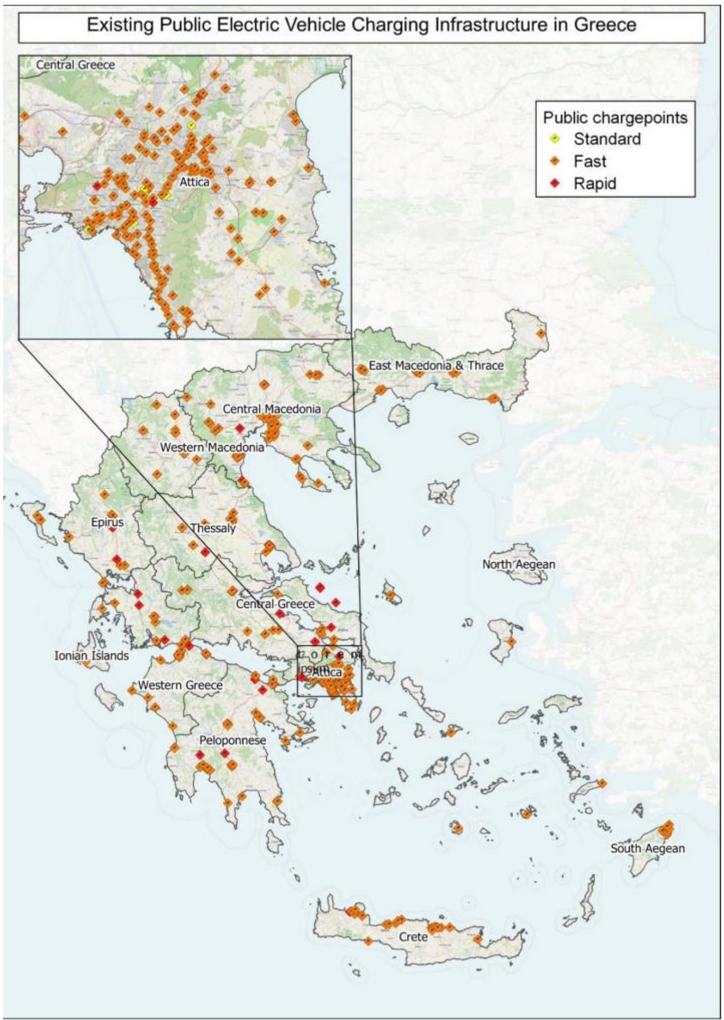


Figure 5.4 – Location of public charge points in Greece by type (Source: [79]**)**

5.1.3 Electricity Demand in Greece

The electricity demand for EVs in Greece is not available in the literature, and it was obtained from the assumptions described in Table 5.1. The reference values are similar to the ones used to determine the scenario in Denmark (see Section 4.1.3). The total EV stock was 10 300 vehicles in 2021 [25]; following the assumptions mentioned above, the current stock of EVs travel about 463 500 km/day and consequently all EVs will spend 92 700 KWh/day (see Table 5.2). Furthermore, it is assumed that the energy consumption by PHEV cars is half of the total electricity from EVs.

Table 5.1: Electricity Demand Assumptions

Description	Assumptions
The average distance driven by the Greek population	45 km/day
Energy consumption	5 km/kWh
Consumption from plug-in EVs is considered to be electric	50%

Table 5.2: Electricity demand due to EV charging

Conversion Rate	Total
Total EV stock (BEV & PHEV)	10 300
Total km/day	463 500
Total kWh/day	33 835 500
Total GWh/year (EVs)	34
Total GWh/year (PHEVs)	17

5.2 Electric Vehicles Evolution Scenarios in Greece

This section presents four uptake scenarios for Greece based on official policy decisions and/or market evolution projections. The analysis of the scenarios and the corresponding projections are courtesy of the Joint Assistance in Supporting Projects in European Regions (JASPERS) [79] and the European Investment Bank (EIB) along with the Greek Authorities (Ministry of Environment and Energy) [84] and were produced by Cenex Consultancy Services Limited [79]. The four scenarios are the following:

- NECP uptake scenario [81]: This scenario uses as a constant the targets set by the National Energy and Climate Plan (NECP) of the Greek authorities [84]. One of the most relevant targets in the NECP is that of a 30% share of EVs (both PHEV and BEV) in new passenger vehicles by 2030 for Greece. This scenario sets lower boundary targets for each year on new vehicle registrations. For example, 1.0% by 2020, 12.8% by 2025 and 30% by 2030.
- 2030 ban uptake scenario [82]: This scenario is based on a recent decision by the Greek authorities that bans all new internal combustion engine (ICE) car (non-PHEVs) sales by 2030. This applies to PHEV by 2035. This policy is more aggressive than the NECP.
- C-curve uptake scenario: The C-curve is determined based on the corresponding mathematical model and uses fitting on past data (from 2015 to 2021) to project the likely uptake of new BEVs and PHEVs.
- S-curve uptake scenario: Another relevant model for adopting any new technology is the S-curve. It splits the timeline of adoption into 4 phases: Emerging (early adopters), Growth,

Maturity, and Saturation. Similarly, to the C-curve, 2015 to 2021 data are used for the initial fitting.

The following sections start with the EVs market evolution perspectives (Section 5.2.1), the charging infrastructure needs (Section 5.2.2) and the energy demand required by EVS (Section 5.2.3).

5.2.1 Electric Vehicles Sales and Stock Evolution in Greece

Considering the scenarios described in Section 5.2, Figure 5.5 illustrates the projections for new EV sales for the four scenarios studied in Greece. For reference, the uptake curve for Norway is also included, with an offset of a few years to align with the Greek case. The S-curve is even more ambitious than the 2030 ban scenario, which means that recent growth in Greece is hopeful (based on real data from 2015 to 2021). However, policies that can sustain that growth are necessary.

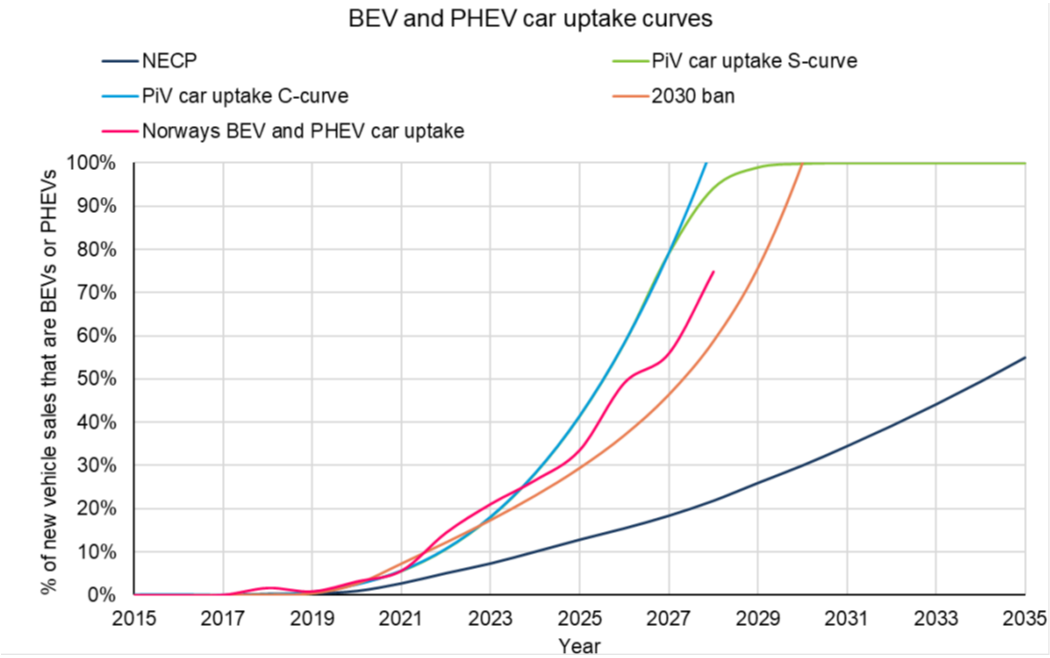


Figure 5.5 – Percentage of new EVs registration in Greece until 2035 (Source: [79]**)**

A summary overview of new EV registration in Greece in the years 2020, 2025, 2030 and 2035 is presented in Table 5.3. It is apparent that, although EV uptake is promising, BEV sales are not the main driver. BEV uptake is by far the fastest under the 2030 ban scenario because it includes a PHEV ban for 2035.

Table 5.3: Percentage of new BEVs and PHEVs registration in Greece until 2035. (Source: [69]**)**

Year	Scen. 1 (NECP)		Scen. 2 (2030 ban)		Scen. 3 (C-curve)		Scen. 4 (S-curve)	
	BEV	PHEV	BEV	PHEV	BEV	PHEV	BEV	PHEV
2020	0.84%	1.8%	0.84%	1.8%	0.84%	1.8%	0.84%	1.8%
2025	12.8%	0%	12.1%	17,4%	12.4%	29%	12.4%	29%
2030	30%	0%	82.3%	17.7%	50.5%	49.5%	49.5%	50.30%
2035	54.9%	0%	100%	0%	100%	0%	85.2%	14.8%

In 2020, Greece had a fleet of 6.5 million vehicles [32] in 2021, the registration of new vehicles was 112 364 [85]. Considering that the vehicles stock and the new registration will remain constant until

2050, it is important to notice that, even with the more optimistic scenarios presented in Figure 5.5, the EVs stock will represent less than 50% of global vehicles in 2050.

5.2.2 Charging Infrastructure Evolution in Greece

Charging infrastructure is also addressed in NECP and 2030 ban scenario. Table 5.4 illustrates the increase in public chargers under the two policy-driven scenarios. We see that the increase under Scenario 2030 ban is much higher, which is an expected outcome. Without this increase, the number of EVs projected by this scenario will not be served appropriately. An important aspect is the presence of slow chargers with an installed capacity lower than 7.5 kW in both scenarios. It is projected that these chargers will have a significant share, as there are suitable to serve public charging points in city-street parking spots in neighbourhoods without private parking spaces (e.g., Athens city centre).

Table 5.4: Projected number and type of public charging points in Greece (Source: [61], [69], [86]**)**

Charger type	2020	Scenario 1 (NECP)		Scenario 2 (2030 ban)	
		2025	2030	2025	2030
Slow Charging (<7.5 kW)	10	5 580	28 981	5 447	69 500
Slow Charging (22kW)	978	5 267	7 699	7 316	20 530
Fast Charging (50kW)	52	526	3 490	526	9 297
Ultra-Fast Charging (>150kW)	0	67	306	67	829
Total	1 040	11 440	40 476	13 356	100 156

5.2.3 Electricity Demand Evolution in Greece

As mentioned in Section 5.2.1, in Greece, the relation between the new car registration and the existing car fleet is very low, representing less than 2%. Considering a constant fleet of 6.5 million vehicles and 120 000 new registrations every year, in the most favourable scenarios where EVs represent 100% of vehicles sales in 2030, the expected EV stock, in Greece in 2050, is around 3 million. Following the assumptions presented in Table 5.1, the total electricity to supply EVs demand will be around 10 TWh/year. However, it is important to mention that in the present analysis, it is considered that the vehicles sales will remain constant which can be considered a major assumption.

The NECP declares the target of 30% of new passenger vehicles should be EVs (both BEVs and PHEVs) by 2030. The 2030 ban scenario, based on the decisions of the Greek authorities, sets this target to 100% by 2030. The number of the new passenger vehicles and the NECP scenario are based on the Greek National Energy and Climate Plan (ESEK 2019) [84] and the 2030 ban numbers are modified to meet the target accordingly. Taking into consideration that the total demand in Greece for 2021 was 52.000 GWh [87], the EV energy demand in 2030 (considering the 2030 ban scenario) will represent the 4% of the total share.

6 Electric Vehicles Evolution Scenarios and Targets in Portugal

In this chapter a summary of the current state of electric mobility in Portugal is presented, focusing on EV sales (Section 6.1.1), charging stations (Section 6.1.2) and electricity demand (Section 6.1.3). Afterwards, predictions regarding the evolution of the EV market on the same topics will be presented, depending on the different scenarios considered (Section 6.2).

6.1 Electric Vehicles: Portuguese Market

Portugal has been a pioneer in electric mobility over the last decade. The Portuguese government proposed several guidelines such as the *"Plano de Ação para a Mobilidade Elétrica"*[4] [88], first published in 2009. This document has been updated throughout the years, following the global and European trends of the EV market. One of the most important updates was done in 2015 influenced by COP 21.

6.1.1 Electric Vehicles Sales and Stock in Portugal

Concerning EV sales and stock, the market share of new EVs has been constantly increasing since 2011, as can be seen in Figure 6.1. The EVs registration market share reached 20% in 2021 [25, 89].

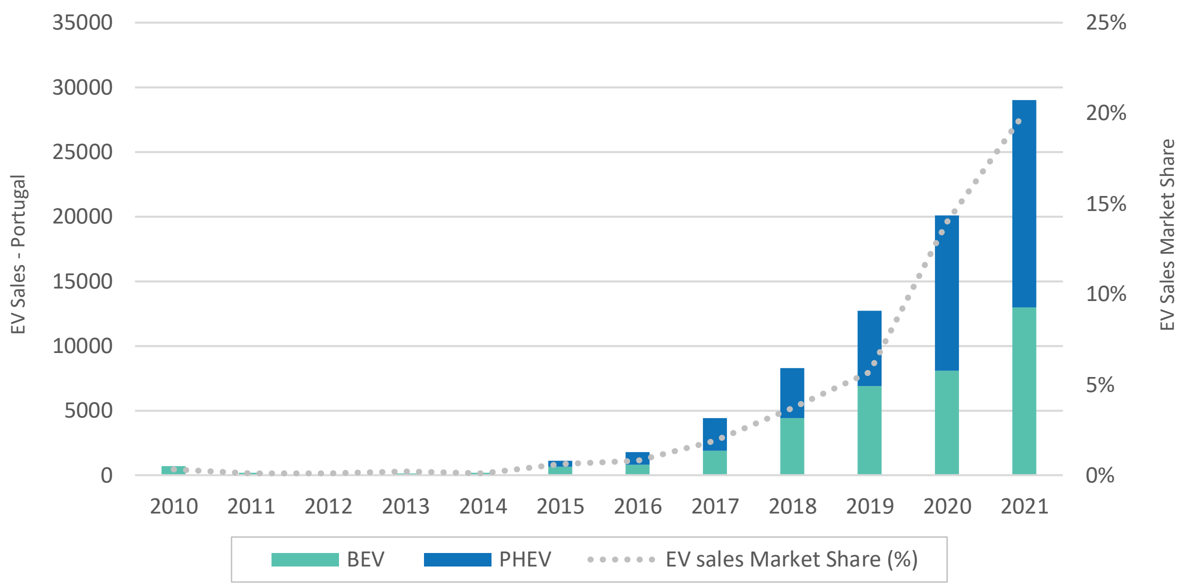


Figure 6.1 – EV sales and market share in Portugal (Source: [89]**)**

This rise in EV sales in Portugal can be explained by a multitude of factors. First, the reintroduction[5] of incentives for EV purchasing by consumers [90] caused a significant rise in the market share after 2017. The benefits initially introduced in 2009 and then brought back in 2017 include a partial sum of the purchase price, up to a maximum of 2 250 €, and a tax wave on the EVs both on the date of acquisition, and the yearly tax. Afterwards, the general citizen's mindset on the global climate crisis and

[4] Electric Mobility Action Plan
[5] The first incentives were introduced in the original "Plano de Ação para a Mobilidade Elétrica" published in 2009.

environmental concerns has been proven to be higher than ever [91]. Finally, the improvement of EV technology in terms of range, reliability and safety, charging infrastructure availability and, very importantly, the steady decrease in cost in the last years as competition in the market increases, are also critical for the increased number of EVs in Portugal.

As it pertains to the EV fleet compared with the total fleet of vehicles, the discrepancy is still significant with only a very small percentage of vehicles being electric. This can be explained by the fact that only recently have the sales of EVs begun to rise, especially in the last 3 to 4 years. On the other hand, the number of cars scrapped and the period it takes for a car to be scrapped is still too long for the recent sales to have a significant impact on the statistics. In Figure 6.2, it is possible to see the evolution of the Portuguese fleet by technology. In Table 6.1. are presented the percentages of EVs share in the global Portuguese car stock.

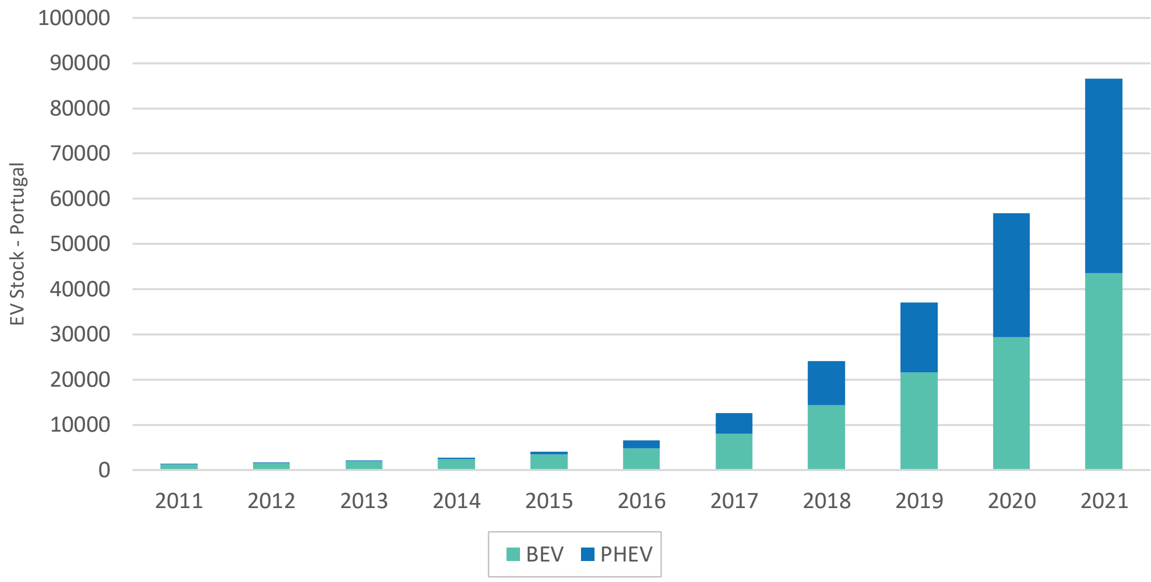


Figure 6.2 – Evolution of the Portuguese Fleet (Source: [92]**)**

Table 6.1: Market Share of Electric Vehicles in Portugal (Source: [89], [92]**)**

Type of EV	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
BEVs	0.02%	0.03%	0.04%	0.05%	0.06%	0.08%	0.13%	0.23%	0.31%	0.43%	0.63%
PHEVs	0.00%	0.00%	0.00%	0.00%	0.01%	0.03%	0.08%	0.15%	0.22%	0.40%	0.62%
EVs	0.02%	0.03%	0.04%	0.05%	0.07%	0.11%	0.21%	0.38%	0.54%	0.82%	1.25%

As can be seen in Figure 6.2, the percentage of EV cars is almost insignificant compared with ICE vehicles, having crossed the 1% threshold for the first time in 2021, reaching 1.25%.

6.1.2 Charging Stations in Portugal

Nowadays, Portugal is the fourth country in Europe with more chargers per 100 km of road, only behind the Netherlands, Luxembourg and Germany [93]. At the end of 2021, 2192 public chargers were active and in use, corresponding to 4777 charging points. Of those chargers, approximately 800 allowed the consumer to use fast charging. This quantity of chargers gives the country an average of 31 charging points per 100 km of the road [94]. However, considering the metric of the number of charging points per EV, the number is more than 19 EVs per charging point which is almost double of the target defined in AFID [23]. Afterwards, this value increase when compared with the ratio of 16.6 registered in 2020 [95].

Public charging station numbers have risen tremendously in the last 3 to 4 years, as can be seen in Figure 6.3 [89]. In 2021, around 20 new charging stations were being commissioned every week. Considering the first values available for 2022, this value should increase to 30 new charging stations every week. This increase in charging stations coincides with the rise of electric vehicles and the need for widespread access to public charging stations. However, most EV charging still occurs at home or in companies (private chargers).

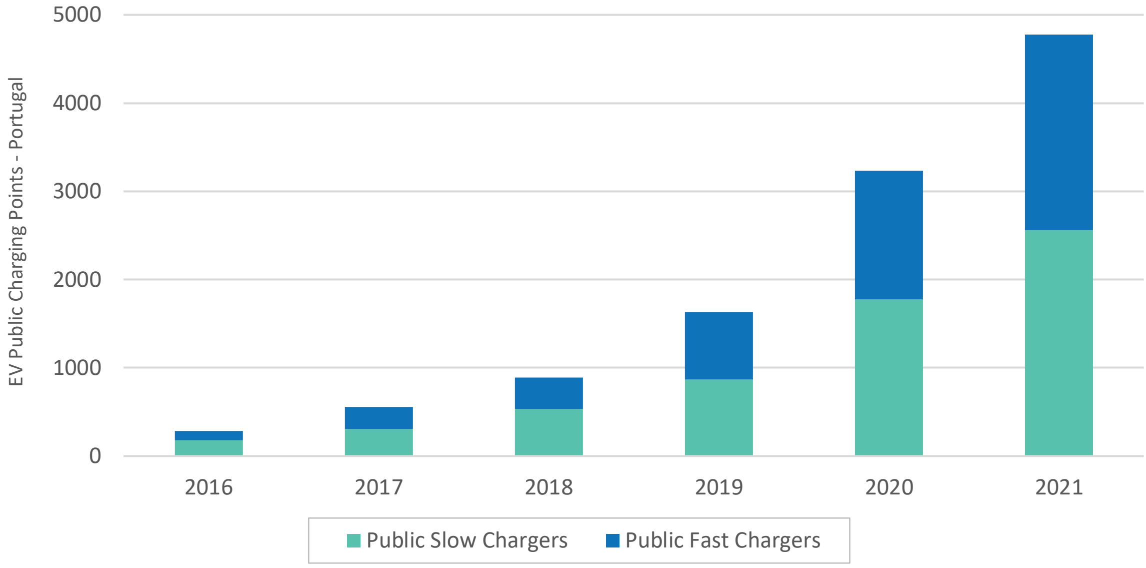


Figure 6.3 – Slow and Fast Charging Points in Portugal (Source: [89]**)**

6.1.3 Electricity Demand in Portugal

As the number of EVs and charging stations has soared in the last few years, the electricity demand due to EVs follows the same trend. The number of charges per year and the energy consumed has increased year over year as can be observed in Figure 6.4. The main driver of the increase in energy demand being the number of chargers per outlet, while the energy spent per charge has floated around similar values with a slight increase of 1 kWh in 2021 [94].

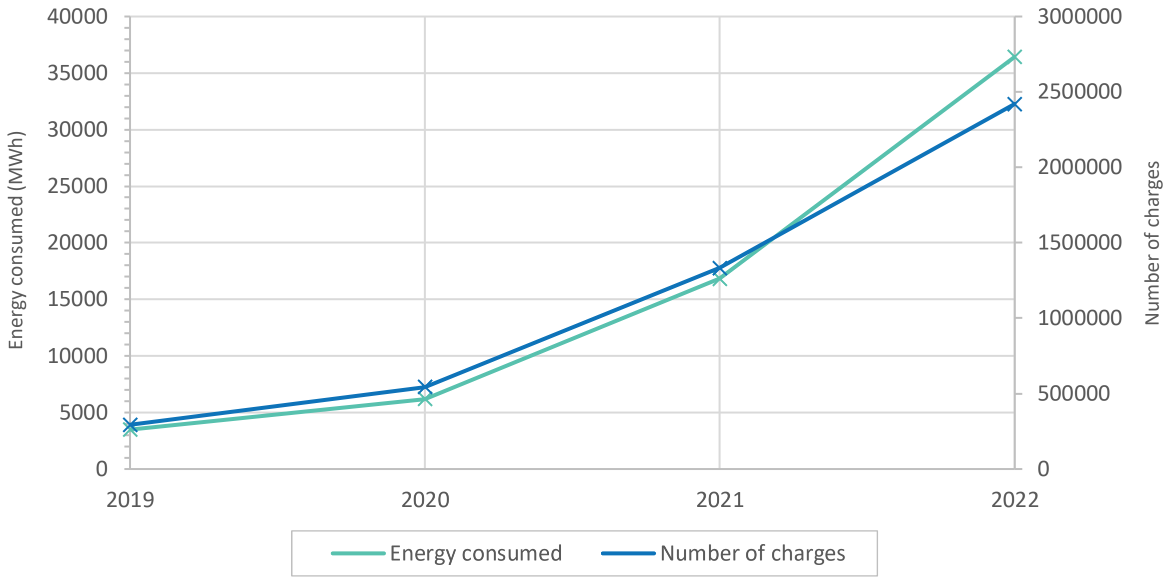


Figure 6.4 – Energy Consumed for mobility in Portugal (Source: [94]**)**

6.2 Electric Vehicles Evolution Scenarios in Portugal

In 2016, following the commitment by the international community to pursue efforts to drastically reduce GHG emissions, Portugal committed to achieving carbon neutrality by 2050 [96]. This target presents an unprecedented opportunity for an open economy that is still heavily dependent on imported fossil fuels. In a crucial area like transport with many important challenges, steps at a national level have been taken to decarbonize vehicle fleets, such as creating a network for electric mobility and introducing support policies for electric vehicles. These policies are considered in multiple documents prepared by the Portuguese government, such as the "*Roteiro para a Neutralidade Carbónica 2050*" (RNC 2050)[6] [97], The "Plano Nacional Energia e Clima 2021-2030" (PNEC 2030)[7] [96] and "Relatório de Monitorização da Segurança de Abastecimento do Sistema Eléctrico Nacional 2022-2040" (RMSA 2022-2040)[8] [98].

The RCN 2050 is based on alternative macroeconomic scenarios for the development of the Portuguese economy, in which the first set of objectives intends to assess the conservative and current evolution of the decarbonization path of the national economy. The second set of objectives sought to evaluate the evolution of emissions in a scenario of carbon neutrality, which translated into a trajectory of emissions reduction in the energy system of 60% in 2030 and 90% in 2050 compared to 2005. In this last scenario, the decarbonization of the transport sector will be 30% by 2030 and almost 100% by 2050 (98% reduction of GHG emissions compared to 2005 being the remaining emissions sequestered by land use and forests).

Within the same scope, and in articulation with the objectives of the RCN 2050, the PNEC 2030 [96] was published. PNEC 2030 is the main instrument of national energy and climate policy entities for the next decade toward a carbon-neutral future. Considering the evolution trend of recent years, PNEC 2030 sets feasible goals for the transport sector, establishing a 40% electrification share by 2030 [96].

[6] Carbon Neutrality Roadmap 2050
[7] National Energy and Climate Plan 2021-2030
[8] National Electric System Supply Security Monitoring Report 2022-2040

Taking into consideration these policies in close agreement with the market evolution in Europe, three distinct scenarios are presented for the evolution of electric mobility in Portugal:

- Conservative scenario: This scenario represents an off-track course of action, that retains the essentials of the current economic structure and the existing policies. This is reflected in the resistance to adopting EVs and failing the electrification targets for 2035 when the new ICE vehicles ban will be imposed. Additionally, considering the population and urbanization trends, car ownership will be reduced by 10% when compared to the current values [99], [100].This scenario is based on the "conservative" scenario depicted in the RMSA [98], which in turn follows the "off-track" scenario in the RCN [97].
- Progressive scenario: This scenario features the ambitious goals established in PNEC 2030, in which socio-economic evolution is compatible with economic neutrality which leads to the development of new technologies without disruptive changes in the population's routine. In this case, the concept of shared mobility gains relevance and more acceptance by the population, which will not largely affect the motorization ratio of the country, i.e., the number of passenger cars per inhabitant (a 10% reduction alongside the previous scenario), but it will largely affect the travelled distance and public transport development [98]. This scenario is based on the "ambitious" scenario presented in the RMSA [98], which is similar to the "peloton" scenario in the RCN [97].
- Disruptive scenario: From an electricity distribution and supply point of view, this is the most demanding scenario. The aggressive adoption of electric vehicles by the population, even after 2030, imposes a structural and transversal change in production chains and technologies. In this scenario, mobility demand will dramatically rise. Nevertheless, converting mobility from private vehicles to other forms of transportation (public, active, shared, autonomous) can increase the volume of passengers or goods transported, without the need to expand the fleet. In this scenario, the motorization ratio keeps constant until 2050. This scenario is based on the "yellow jersey" scenario explained in the RCN 2050 [97].

In all scenarios, the rate of fleet renewal in the Portuguese demographic context [101] , as well as the market trends in Europe [102] are factors that are considered in the demand modelling.

6.2.1 Electric Vehicles Sales and Stock Evolution in Portugal

As far as electric mobility is concerned, several forecasts were evaluated considering the evolution of light passenger vehicles (PHEV and BEV) and light duty vehicles (BEV). To distinguish between modelling and the targets set by the Portuguese government, every figure feature striped and full patterns respectively. Figure **6.5** to Figure **6.7** present the evolution EVs stock in Portugal for the different scenarios.

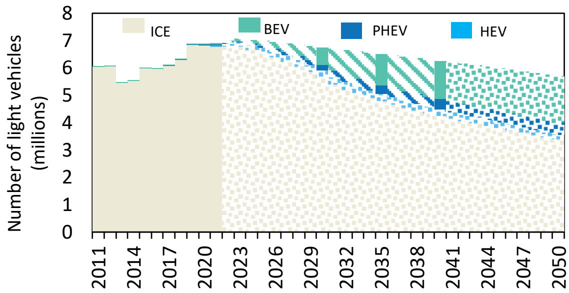


Figure 6.5 – Evolution of the Portuguese fleet in the conservative scenario

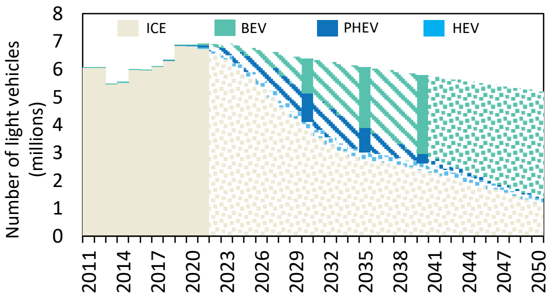


Figure 6.6 – Evolution of the Portuguese fleet in the progressive scenario

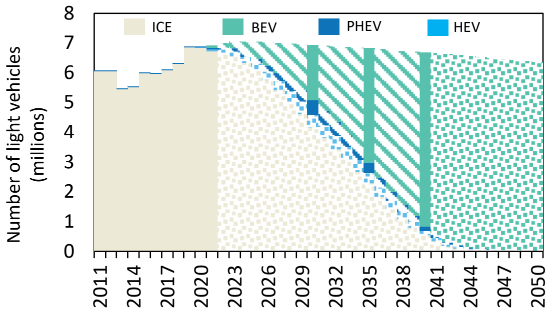


Figure 6.7 – Evolution of the Portuguese fleet in the disruptive scenario

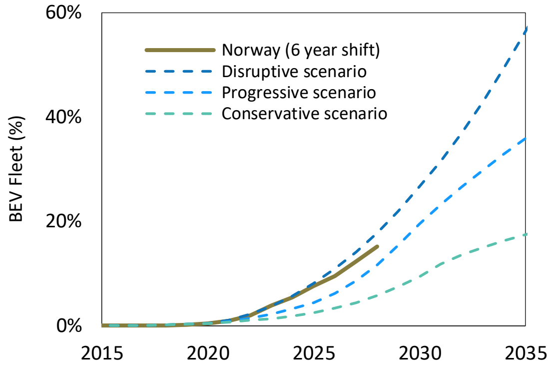


Figure 6.8 – Comparison of BEV fleet share evolution among scenarios

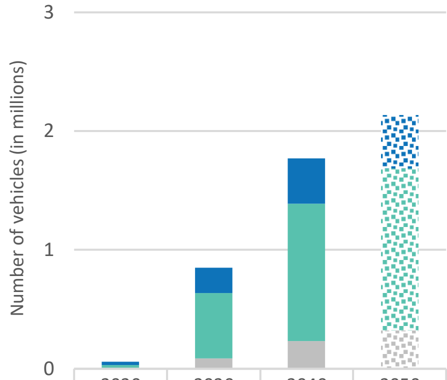
The conservative scenario predicts a slower evolution of the EVs stock share of 13% in 2030, 28% in 2040 and 37% in 2050. From Figure **6.6**, it can be observed a higher rate of adoption of EVs until the year 2030 after which a reduction to a steady pace occurs. Additionally, it is assumed that the sales of vehicles with an ICE (mainly PHEV) are still available after 2035, which does not meet the committed targets.

Regarding the progressive scenario, it includes a sharp increase in PHEV sales with a peak in 2030, which is followed by a reduction at the same pace leading to PHEV eventually being slowly replaced by BEV. In this scenario, PHEV is a desirable solution for a short/mid-term transition period between ICE and BEV. The market share of EVs is 34%, 53% and 67% of the total fleet by 2030, 2040 and 2050, respectively.

The disruptive scenario has a high adoption of new BEV and PHEV similarly to the progressive scenario, but with a deeper paradigm shift towards BEV, having the PHEV less expression on the new car sales. This fast-paced renewal of the fleet by BEV and PHEV continues even after 2030 (30% of the total fleet) with an almost total replacement by 2045 (98% of the total fleet).

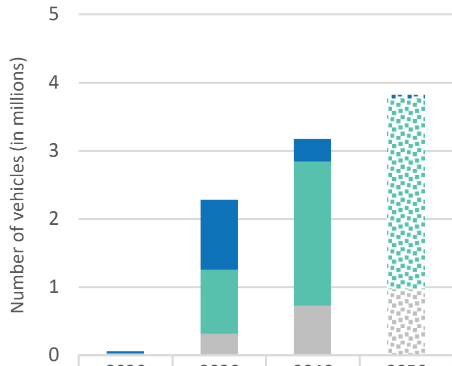
A transversal fact for all scenarios is that significant growth in electromobility will occur in the next decade with steady growth from 2030 onwards. Also, the market share of light-duty vehicles is slightly higher than the market share of light passenger vehicles, representing a favourable environment for enterprises and companies to acquire EVs. By 2040, the share of light-duty electric vehicles is 20%, 62% and 89% for the conservative, progressive and disruptive scenarios, respectively. Figure **6.8** shows a correlation between the disruptive scenario and the uptake of the Norwegian BEV fleet with a 6-year shift.

Beyond passenger vehicles, it is important to analyse the evolution of other vehicles. Figure 6.9 to Figure 6.11 present the evolution of PHEV (exclusively light passenger vehicles) and BEV, both light passenger and light duty vehicles. Heavy EV scenarios are presented in Figure 6.12 to Figure 6.14.



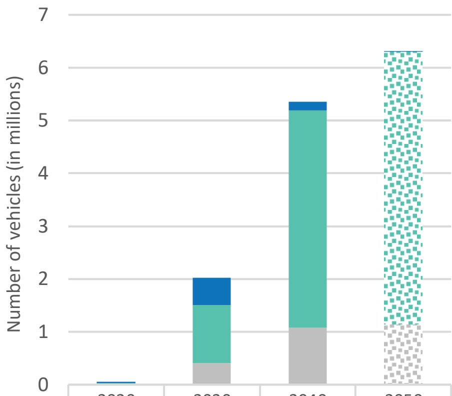
	2020	2030	2040	2050
Fleet penetration	0.83%	12.60%	28.33%	37.46%
PHEV	27,300	214,000	382,000	447,200
BEV Passenger	24,500	551,000	1,158,700	1,362,800
BEV Duty	5,000	86,000	231,000	324,700

Figure 6.9 – Evolution of light electric vehicles for the conservative scenario



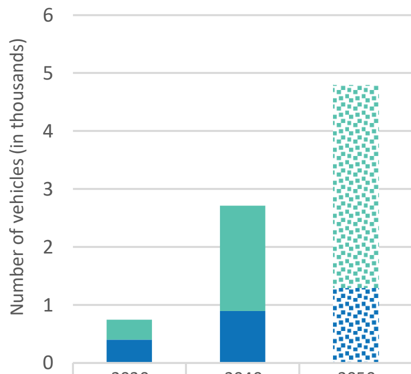
	2020	2030	2040	2050
Fleet penetration	0.83%	33.76%	50.81%	66.95%
PHEV	27,300	1,029,100	340,300	49,900
BEV Passenger	24,500	937,000	2,109,000	2,797,500
BEV Duty	5,000	313,500	728,000	967,800

Figure 6.10 – Evolution of light electric vehicles for the progressive scenario



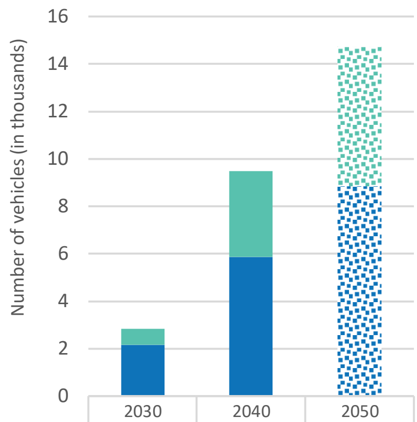
	2020	2030	2040	2050
Fleet penetration	0.83%	29.14%	80.02%	99.04%
PHEV	27,300	512,700	165,500	400
BEV Passenger	24,500	1,105,500	4,116,600	5,155,800
BEV Duty	5,000	403,700	1,071,900	1,141,900

Figure 6.11 – Evolution of light electric vehicles for the disruptive scenario



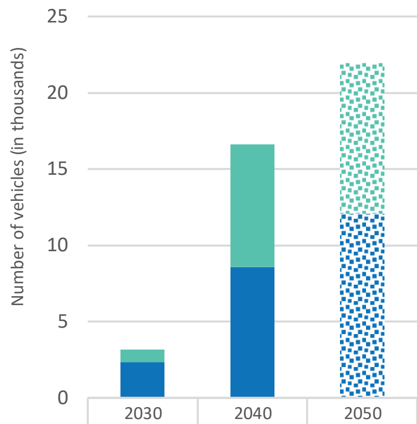
	2030	2040	2050
Truck fleet penetration	0.29%	1.51%	2.92%
BEV Truck	350	1,810	3,500
Bus fleet penetration	2.29%	5.14%	7.43%
BEV Bus	400	900	1,300

Figure 6.12 – Evolution of heavy electric vehicles for the conservative scenario



	2030	2040	2050
Truck fleet penetration	0.58%	3.01%	4.89%
BEV Truck	690	3,610	5,870
Bus fleet penetration	12.29%	33.60%	50.57%
BEV Bus	2,150	5,880	8,850

Figure 6.13 – Evolution of heavy electric vehicles for the progressive scenario



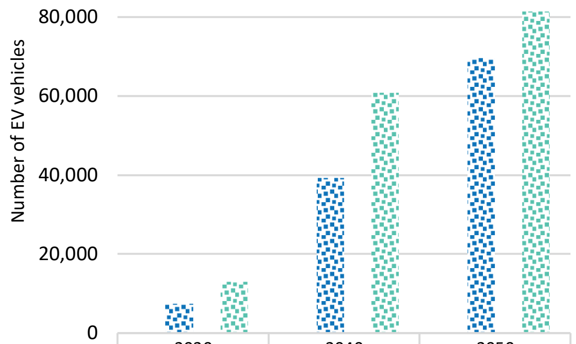
	2030	2040	2050
Truck fleet penetration	0.68%	6.67%	8.21%
BEV Truck	820	8,000	9,850
Bus fleet penetration	13.49%	49.14%	69.09%
BEV Bus	2,360	8,600	12,090

Figure 6.14 – Evolution of heavy electric vehicles for the disruptive scenario

Although more challenging, due to range and battery capacity, heavy vehicles can be electrified in the upcoming years mainly if advantageous conditions are met for transportation stakeholders (passenger and freight). In the conservative scenario, the mobility paradigm does not suffer significant changes in the future, and public transportation demand has a weak growth when compared to heavy-duty transport. In this scenario, by 2040, less than 2% of trucks will be electrified and 7% of the bus fleet. In a progressive scenario, there is a behavioural change towards different mobility modes, towards public transport which fosters the growth of electric buses (more than 1/3 of buses are electric by 2040) while electric trucks have a modest increase (3% of the total fleet). The disruptive scenario follows the same proportion compared to the light vehicles and goes even further with an almost 50% share of electric buses by 2030 and 6% for electric trucks.

These scenarios were built to be very representative of the Portuguese environment. Nonetheless, the location of the Portuguese pilot will be in the Azores archipelago which could be misrepresented due to different demographic and geographic characteristics. For example, the behavioural mobility profile of the population is different from mainland Portugal, car ownership follows a different trend, the public transport system has a lower capacity and the government set more stringent targets concerning electric mobility (the goal for 2030 is to achieve a 40% share of renewable energy sources, which is higher than the threshold set at the community level between 27 and 30%). According to PMEA [103], the main goals for the autonomous region of the Azores are the reduction of financial and energy dependence, GHG emissions reduction, improvement of air quality, low-cost mobility and more efficient use of the electric system, e.g., the use of V2G approach to peak shaving. There is a clear interest by the Azores government to invest in living lab solutions linking private and public entities aiming for energy independence. Considering these strategies, two scenarios are presented to estimate the electric mobility reality of the Azores, particularly São Miguel Island. These scenarios are referred to as base and optimistic scenarios [103] and follow the trends stated in the country's conservative and progressive scenarios.

Similarly to the development of the scenarios for Portugal, the São Miguel scenarios consider the current fleet and fleet renewal rate, the sales trend, the demographic evolution of the region and the targets for energy consumption and carbon neutrality for the archipelago.



	2030	2040	2050
Fleet penetration (Base)	9.03%	48.07%	85.50%
Base Scenario	7,400	39,240	69,630
Fleet penetration (Optimistic)	15.91%	74.63%	99.93%
Optimistic Scenario	13,040	60,930	81,380

Figure 6.15 – Evolution of light EVs in the Azores (São Miguel Island) for a base and optimistic scenarios

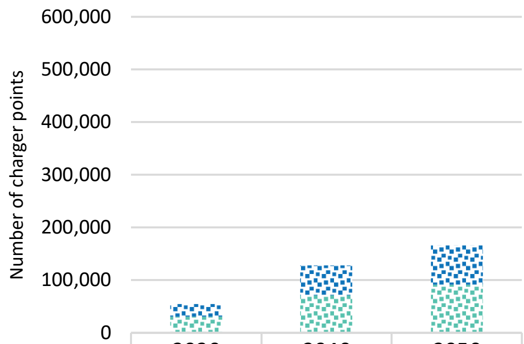
As depicted in Figure 6.15, due to the higher usage of individual transport, the growth of the electric car market share in the Azores is higher than in the Portuguese mainland.

6.2.2 Charging Infrastructure Evolution in Portugal

Portugal has developed an innovative EV charging network management model with significant benefits for users. The network is fully interoperable between different electricity suppliers, thus increasing the efficiency and availability of the charging network. This model is already implemented for part of the network, namely the fast-charging stations, and it is essential to expand it to the entire public access network in operation.

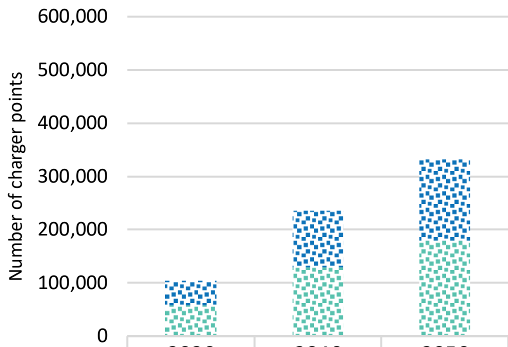
The public access charging network should keep up with the size of the EV fleet in Portugal. Given that EV sales have seen exponential increases in the last few years. It is important to ensure that the charging network continues increasing in order to maintain ratios between vehicles and charging stations, which tend to decrease slowly over time. As mentioned before, the ratio of EVs per public charging point is higher than 19. With a more detailed analysis it is possible to verify a ratio of 28 EVs per slow charging point, and 35 EVs per fast charger. By 2050, this number of EVs per charger point is expected to drop to 21 and 25 for slow and fast chargers, respectively. However, for a fair analysis, these ratios should be analysed considering the share between BEVs and PHEVs that are significantly different in the scenarios presented in Section 6.2.1.

The scenarios of charging infrastructure development are based on several assumptions such as the evolution of the battery technology, lower charging periods, larger ranges, cost reduction and higher usage of public chargers, and can be seen in Figure 6.16 to Figure 6.18.



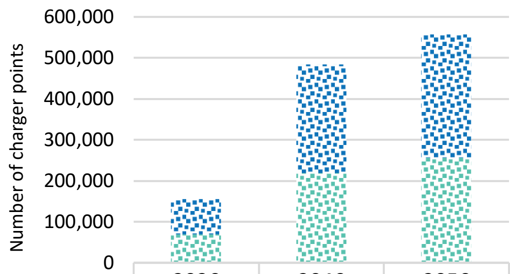
	2030	2040	2050
Fast	23,770	57,160	75,600
Slow	30,420	70,570	90,920

Figure 6.16 – Evolution of charging points for the conservative scenario



	2030	2040	2050
Fast	46,200	107,040	152,820
Slow	57,440	128,940	179,490

Figure 6.17 – Evolution of charging points for the progressive scenario



	2030	2040	2050
Slow	85,940	264,500	300,960
Fast	69,120	219,560	256,240

Figure 6.18 – Evolution of charging points for the disruptive scenario

Regarding the charging infrastructure in the Azores, the regional government is encouraging electric mobility by installing charging points (no more than 60 km apart), and establishing reserved parking areas and free parking for EVs. Considering similar assumptions followed the Portugal mainland, the charging infrastructure predicted for São Miguel Island for the different timeframes is illustrated in Figure 6.19 and Figure 6.20.

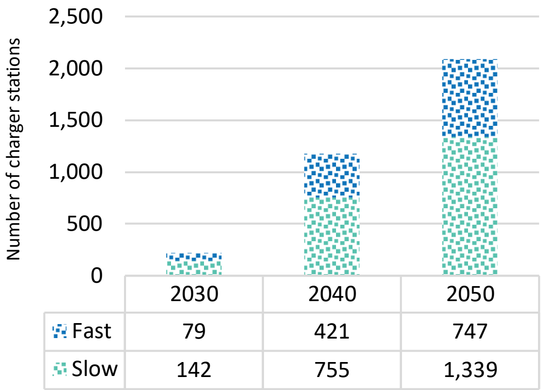


Figure 6.19 – Evolution of charging outlets for the base scenario in the São Miguel Island

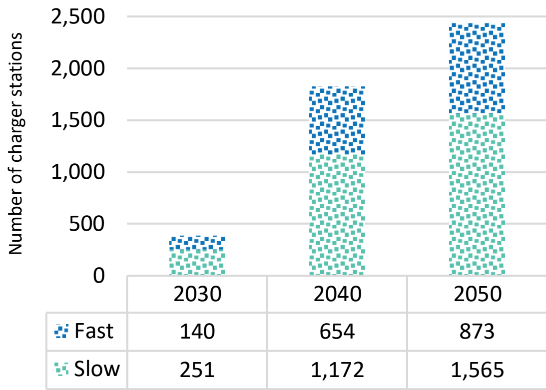


Figure 6.20 – Evolution of charging outlets for the optimistic scenario in the São Miguel Island

6.2.3 Electricity Demand Evolution in Portugal

In what concerns electric mobility for Portugal, several estimates were evaluated, considering the predicted evolution of the number of passenger and duty vehicles (light and heavy). These scenarios are aligned with the policies established in the PNEC [96], which in turn is aligned with the RNC 2050 [97].These governmental guidelines establish important energy demand targets when it comes to carbon-free energy sources. As an example, the evolution of BEV and PHEV (in the progressive scenario) is coherent with the targets of 20% incorporation of renewable energies in the final energy consumption in transportation by 2030.

The electricity demand aimed at the transportation sector takes into consideration three main factors: the number of EVs in the fleet, the average energy efficiency, and the average travelled distance per vehicle. The first two factors are already foreseen in the previous sections, being the number of electric vehicles depicted in Figure 6.9 to Figure 6.14. The following assumptions are taken into account:

- Light duty: currently 25 kWh/ 100 km improves to 19 kWh/ 100 km in 2050.
- Heavy passenger: currently 100 kWh/ 100 km improves to 90 kWh/ 100 km in 2050.
- Heavy duty: 150 kWh/ 100 km until 2050.

The latter reflects the mobility behaviour of the Portuguese population. The conservative scenario strengthens the current paradigm of individual mobility, while the progressive and disruptive scenarios have a growing role in shared mobility. This effect is considered in the average annual distance per vehicle. This information is based on the forecast performed by RMSA [98] , which is a tool that evaluates the system requirements in the energy sector for mid/long-term horizons taking into consideration the previously mentioned guidelines of Portuguese policymakers. The predicted distance per vehicle by an electric powertrain is presented in Table 6.2.

Table 6.2: Average distance travelled by each type of electric vehicle in km

Year	Light					Heavy	
	Passenger				Duty	Passenger	Duty
	BEV		PHEV		BEV	BEV	BEV
	Conserv.	Progress. & Disrupt.	Conserv.	Progress. & Disrupt.	Conserv. & Progress. & Disrupt.	Conserv. & Progress. & Disrupt.	Conserv. & Progress. & Disrupt.
2020	10 000	10 000	5 000	5 000	10 000	-	-
2030	13 800	14 200	6 000	6 500	17 500	32 200	30 000
2040	15 100	15 900	6 000	6 500	17 500	32 700	40 000
2050	15 900	16 300	6 000	6 500	17 500	33 000	45 000

With these premises, it is possible to predict the electricity demand for the mid/ long-term in Portugal and Azores (São Miguel Island in particular), as shown in Figure 6.21 and Figure 6.22.

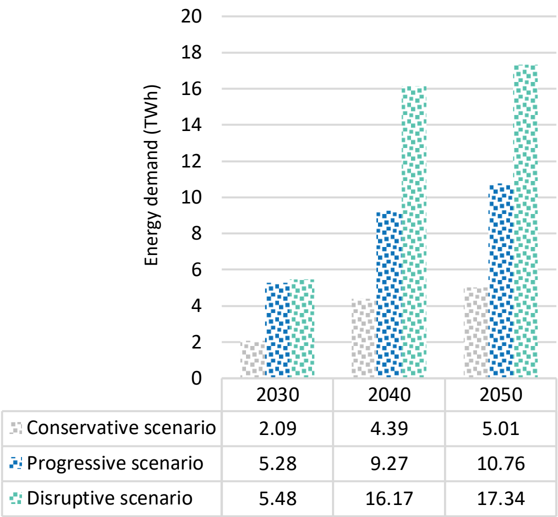


Figure 6.21 – Electricity demand evolution required for electric mobility in Portugal

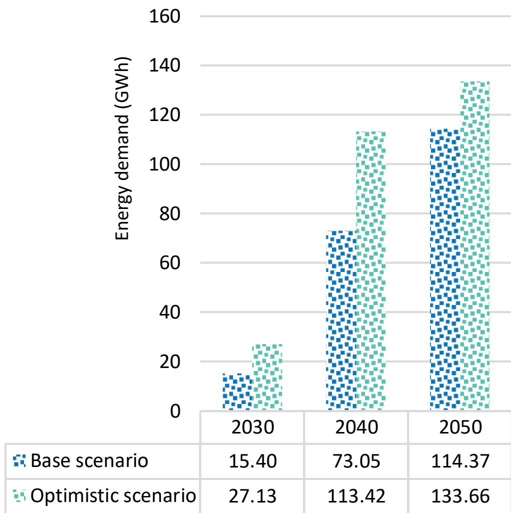


Figure 6.22 – Electricity demand evolution required for electric mobility in the Azores (São Miguel Island)

The energy demand in every scenario is aligned with the predictions made in RCN 2050, with 4.4, 9.3 and 16.17 TWh by 2040 for the conservative, progressive and disruptive scenarios, respectively. The energy demand strongly correlates with the number of EVs in circulation, with a substantial growth until 2030 which then slows down due to deceleration in the growth rate of sales and more efficient vehicles. In the case of the disruptive scenario, in which mobility needs are significantly higher than the remaining scenarios, the energy demand continues to rise at the same pace even after 2030, stabilizing around 2045 when the total fleet is almost electric. In this scenario, about 20% of the total electricity demand of Portugal is due to electric mobility, which is following the guidelines provided by the government [97], [103].

In the Azores case, the total energy demand of São Miguel Island is around 500 GWh [103], being the electricity demand for mobility is around 25% for the optimistic scenario. This value is slightly higher when compared with the mainland but is coherent with the demographic characteristics of the island.

7 Electric Vehicles Evolution Scenarios and Targets in Slovenia

In this chapter a summary of the current state of electric mobility in Slovenia will be presented, focusing on EV sales (Section 7.1.1), charging stations (Section 7.1.2) and electricity demand (Section 7.1.3). Afterwards, predictions regarding the evolution of the EV market on the same topics will be presented, depending on the different scenarios considered (Section 7.2).

7.1 Electric Vehicles: Slovenian Market

In Slovenia, following European trends, there is the ambition for transition to a low-carbon circular economy, which will increase the quality of life. One of the sectors that are experiencing a lot of changes in that regard is the Energy sector. Following European Union's decisions, Slovenia has adopted numerous new laws or has changed laws in the field of energy, led research activities, conducted studies, and more. Furthermore, like all member states, Slovenia has prepared an extensive national energy and climate plan (NECP) [104]. NECP can be considered a guideline and one of the most important documents for a climate-neutral Slovenia. The document describes the current situation, presents projections with already existing policies and measures, and assesses the impact of planned policies and measures.

For energy consumption NECP [104] predicts that Slovenia will meet the goals set by European Union if policies and measures presented in NECP are to be followed. One of the changes expected in the energy mix is the increase in the utilization of RES. More precisely, RES should represent at least 27% of total energy consumption until 2035.

Not just changes in the production of energy, and increment of the percentage of RES, but also changes in energy consumption are needed to achieve established goals. Slovenia has drawn out a path to reduce GHG emissions in different sectors as presented in Table 7.1.

Table 7.1: Targets for the reduction of GHG per sector in Slovenia (Source: [104]**)**

	Annual GHG Emissions [kt CO2 eq]		Annual GHG Emissions [kt CO2 eq]		Reduction Compared to 2007
Sectors	**2005**	**2017**	**2020 OP-GHG**	**2030 NEPN**	**2030 NEPN**
Transport	4 416	5 541	27%	+12%	-10%
General consumption	2 661	1 456	-53%	-76%	-57%
Agriculture	1 709	1 688	+5%	-1%	0%
Waste Management	848	557	-44%	-65%	-47%
Industry*	1 542	1 132	-42%	-43%	-23%
Energy*	591	509	+6%	-34%	-23%

* Only part of the sector not covered by the ETS

From the previous table, we can see, that the most significant contributor to GHG is the domain of Transport. To lower emissions on the side of production, Slovenia demands an increase of RES in all final energy sold for use in transport. More precisely, distributors must gradually increase the percentage of RES to 20.8% in the year 2030, in accordance with Decree on renewable energy sources in transport [105].

7.1.1 Electric Vehicles Sales and Stock in Slovenia

Like all regions of the European Union, Slovenia is also marking an increase in the number of EVs, both BEV and PHEV types. Country wise increase of EVs last year (2021) was 65 %. This is the biggest increase since 2014 (data collected by the Statistical Office of the Republic of Slovenia, Table 7.2 and Figure 7.1) [106]. Table 7.2 presents the number of EVs that were registered in Slovenia until 2021, as well as the percentage of the change in the number of all EVs.

Table 7.2: Sales and stock of EVs in Slovenia (Source: [106])

Year	2014	2015	2016	2017	2018	2019	2020	2021
EVs Stock								
BEV	133	288	457	780	1 309	2 001	3 677	5 423
PHEV	1 107	1 363	1 913	3 042	4 617	6 816	9 434	16 151
all	**1 240**	**1 651**	**2 370**	**3 822**	**5 926**	**8 817**	**13 111**	**21 574**
EVs Sales								
first registration[9]	170	452	780	1 674	2 471	3 467	5 223	11 255
new EVs	126	359	582	1 459	2 242	3 156	4 741	9 938
Increase (%)		**33%**	**44%**	**61%**	**55%**	**49%**	**49%**	**65%**

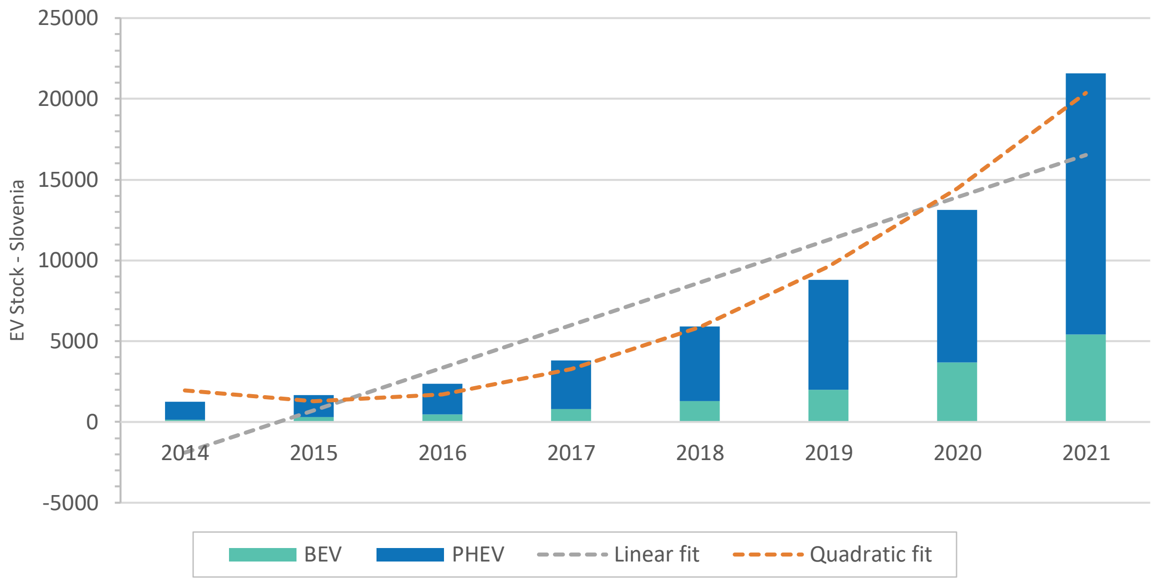


Figure 7.1 – EVs stock in Slovenia (Source: [106])

In Table 7.2 can be observed that the increase in the number of all EVs last year was 65% and the increase in average sales observed over the years was 51%. But even more satisfying is the increase in the number of new EVs bought per year corresponding to an average of 93% in the same period.

Beyond the EVs stock, Figure 7.1 also has information concerning the linear and quadratic trends of the EV stock evolution. These trends can be used to define some evolution scenarios described in Section 7.2.1. The data of sold EVs gives just a part of the whole picture. To have the global vision we must compare it with the number of all vehicles sold. This comparison is presented in Table 7.3.

[9] Includes new EVs and imported ones

Table 7.3: Vehicles registration and EVs share in Slovenia (Source: [106]**)**

Year	2014	2015	2016	2017	2018	2019	2020
new cars	54 699	60 976	65 446	73 320	75 071	73 471	53 880
Variation (%)	4.7%	11.5%	7.3%	12.0%	2.4%	-2.1%	-26.7%
EVs Share (%)	0.31%	0.74%	1.19%	2.28%	3.29%	4.72%	9.69%

As we can see the numbers of cars sold per year are oscillating, with some negative trends in the last years, while EVs mark a constant increase in sales. The car registration for 2021 is not yet available. However, considering the sales of EVs, the positive trend should continue. Another interesting statistic that can be obtained in [106], is the number of vehicles per 1000 citizens and the average car age. The number of vehicles per citizen increased from 442 vehicles per 1000 citizens in 2001 to 555 vehicles per 1000 citizens in 2020 and the average age of the vehicles increased from 6.9 to 10.4 years. This means that an important part of the new vehicle sales is not replacing existing ones but mainly increasing the global number of vehicles.

7.1.2 Charging Stations in Slovenia

Based on the analysis presented in Section 7.1.1, it is possible to conclude that more and more people are deciding to switch from ICE to EV since the number of sold EVs are on a constant rise and the number of total sold cars has been decreased. But the number of people that buy ICE cars is still too high. Some of the concerns why people do not switch to EVs, are not having enough charging stations and low milage of EVs. In Slovenia, there are currently around 700 charging stations [107]. This number is estimated since in Slovenia there is no centralized authority that collects such information. One of the actions to increase the number of charging stations is a new law (Act on Energy Efficiency [108]) imposing that every new build or renovated parking lot, with more than 10 parking spaces, must have charging stations installed.

Out of those estimated 700 charging stations, there are 26 fast charging stations, that were built in agreement with the European project Central European Green Corridors (CEGC) as part of the programme Trans-European Transport Network (TEN-T) [109].

7.1.3 Electricity Demand in Slovenia

Information concerning the usage of slow charging stations is not available in Slovenia. Concerning fast charging stations, according to [106], their usage is rising, which is not surprising considering the increasing number of EVs. Data collected from fast charging stations are presented in Table 7.4. Data for the year 2022 is incomplete as it is available only before the 31st of July.

Table 7.4: Energy consumption for fast charging stations per year (Source: [106]**)**

	2016	2017	2018	2019	2020	2021	2022
Energy consumption [kWh]	78 152	83 605	108 072	138 459	122 323	188 786	178 659
Number of usages	9 280	8 945	10 656	12 522	10 775	15 822	13 488
Time of charging [h]	4 093	2 636	3 260	3 950	3 622	5 419	4 962
Energy per usage [kWh]	8.4	9.3	10.1	11.1	11.4	11.9	13.2
Energy per hour [kW]	19.1	31.7	33.2	35.1	33.8	34.8	36.0
Time per usage [min]	26.5	17.7	18.4	18.9	20.2	20.5	22.1

7.2 Electric Vehicles Evolution Scenarios in Slovenia

In 2017 Slovenia adopted "*A strategy in the field of market development for the establishment of appropriate infrastructure related to alternative fuels in the transport sector in the Republic of Slovenia*" [110]. Some of the measures proposed by the strategy include the provision of adequate charging infrastructure for EVs, financial stimulations, and co-financing of the construction of appropriate infrastructure for alternative fuels, financial incentives for the purchase of BEV and PHEV, exemptions from paying certain duties, free parking and other similar measures.

Since the field of transport and energy is very dynamic, it is necessary to update the goals and methods of their achievement on an ongoing basis according to the real situation. Thus, according to the "Action program for alternative fuels in transport [111]" the goals and methods are updated every two years. This document also presents a projection of the situation until 2030.

To implement the measures of the action program [111], it is planned to prepare a review of the implemented measures for each year. "*The report on the implementation of the action program for alternative fuels in traffic*" [112] includes an overview of the measures implemented by the action program, the implementation of other activities of the ministry necessary to achieve the goals of the strategy, a description of the problems that inhibit the implementation of the measures and an overview of the achievement of the goals of the strategy.

7.2.1 Electric Vehicles Sales and Stock Evolution in Slovenia

Table 7.5 shows the actual figures for 2020 and the projected numbers for 2020, 2025 and 2030 as envisaged in the strategy from 2017 [113]. Additionally, percentages of ICE and EV cars out of all vehicles are presented.

As we can see from the table, the predictions from 2017 were a bit too optimistic. The actual numbers for 2020 are lower than predicted within the strategy. However, the total car stock was also lower than expected in 2017.

Table 7.5: Actual and predicted numbers of EVs (Source: [113]**)**

	Actual numbers		Predicted numbers based on strategy					
	on 31. 12. 2020		2020		2025		2030	
Year	number	percent	number	percent	number	percent	number	Percent
ICE	1 230 810	98.2%	1 097 286	95.0%	1 044 513	88.7%	911 879	76.6%
EVs total	13 111	1.0%	11 344	1.0%	66 687	5.7%	201 354	16.9%
BEV	3 677		5 311		40 096		129 690	
PHEV	9 434		6 033		26 591		71 664	
All	1 253 985		1 154 479		1 177 619		1 191 161	

Considering that strategy's projections proposed in [113] are only for 2030, we developed two scenarios (pessimistic and optimistic) to predict the future number of EVs. The pessimistic scenario uses a linear function, illustrated in Figure 7.1, to estimate the EVs' evolution until 2050. The optimistic scenario considers the quadratic function also illustrated in Figure 7.1. The functions were adjusted to the data from 2018 to 2021 after the strategy was adopted. The EVs' evolution predictions until 2050 are presented in Table 7.6.

Table 7.6: Predicted numbers of EVs in Slovenia until 2050

Year	2025	2030	2035	2040	2045	2050
Actual Projection	66 687	201 354				
Pessimistic	40 537	66 156	91 775	117 394	143 013	168 632
Optimistic	80 934	217 993	424 702	701 061	1 047 070	1 462 729

Analysing the values presented in Table 7.5 and Table 7.6 for 2030, we see that the predicted EV evolution under the existing strategy and the optimistic scenario are comparable, while the pessimistic scenario is much lower. Table 7.6 also shows that the number of all EVs in 2050 regarding an optimistic scenario exceeds the number of all cars in 2020 by approximately 17%. Depending on the vehicle stock evolution in Slovenia, the values obtained in the optimistic scenario for EVs stock can represent around 100% of total vehicles.

7.2.2 Charging Infrastructure Evolution in Slovenia

Due to the increase of EVs, it will also be necessary to increase the number of charging points. Slovenia has installed high-power chargers on its highways. Some with the European TEN-T programme. With the expected growth of EVs, we will need 7 000 charging stations in 2025 and 22 300 in 2030. Table 7.7 shows the projected numbers of charging stations for 2020, 2025 and 2030 as envisaged in the strategy from 2017 and the number of charging locations [110]–[112]. Table 7.7 also presents the change in numbers per year as a percentage.

Table 7.7: Charging sites evolution in Slovenia (Source: [110]–[112]**)**

	Actual numbers of charging locations					Predicted numbers		
Year	2016	2017	2018	2019	2020	2020	2025	2030
Charging locations	228	295	328	319	545	1 200	7 000	22 300
Yearly increase (%)		29.4%	11.2%	-2.7%	70.8%		96.7%	43.7%

The values presented in the table correspond to the number of sites where the charging stations are placed. However, there can be one or multiple charging points at that site. As already mentioned, the total number of charging points is not available in Slovenia, because there is no centralized authority that would collect such information.

Table 7.8 shows the estimated number of charging sites under the pessimistic and optimistic scenarios. We followed the same logic as in Section 4.2.2 to calculate these numbers. For the pessimistic scenario, we have assumed a ratio of 40 EVs per charging point and for an optimistic scenario, we have assumed an ideal ratio of 10 EVs per charging point by 2050.

Table 7.8: Charging sites evolution in Slovenia until 2050

Year	2025	2030	2035	2040	2045	2050
Actual Projection	7 000	22 300				
pessimistic	1 013	1 653	2 294	2 934	3 575	4 215
optimistic	8 093	21 799	42 470	70 106	104 707	146 273

7.2.3 Electricity Demand Evolution in Slovenia

Another important document regarding e-mobility in Slovenia is the "Audit report of Implementation of e-mobility" of the Court of Audit [114]. The audit aimed to express an opinion on the effectiveness of the Ministry of Infrastructure in implementing e-mobility in the period from 1 January 2016 to 30 June 2019. In the audit report, the Court of Audit also assesses the impact of these measures on the future, estimating the impact of EVs on electricity consumption for the period from 2019 to 2028. In this point, the Court of Audit relies on the study from 2018 "*The impact of mass electrification of personal transport and heating on the development of the distribution network*" [115]. The predicted electricity consumption in Slovenia is presented in Figure 7.2.

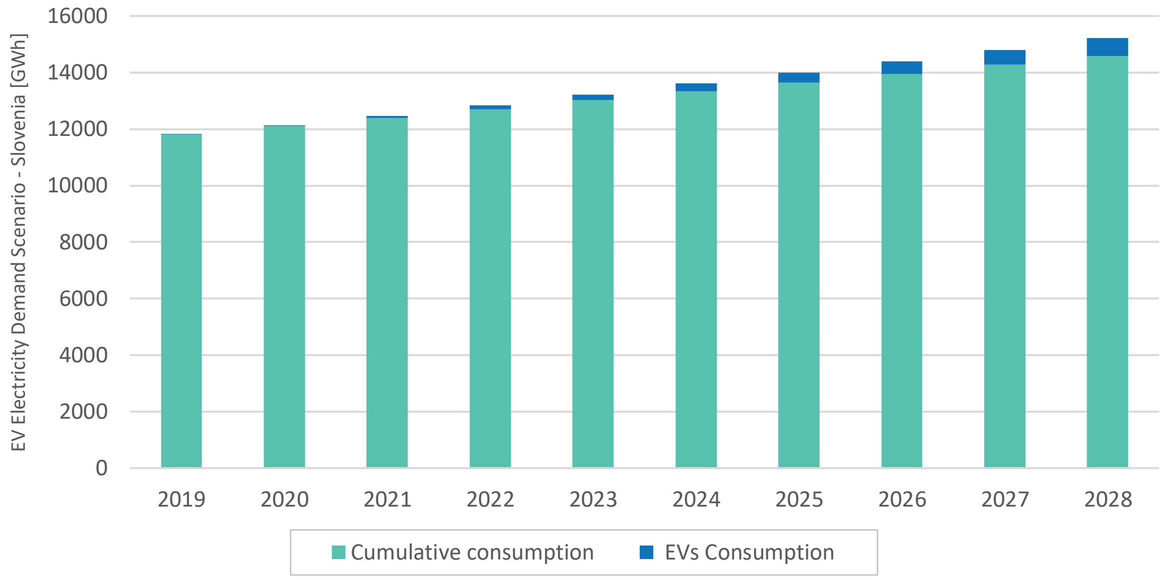


Figure 7.2 – Predicted electricity consumption in Slovenia (Source: [114]**)**

The following Table 7.9 shows the estimated electricity consumption for EV under pessimistic and optimistic scenarios. The values were calculated using the assumption for light passenger vehicles from Section 6.2.3. The current consumption is 19 kWh/100 km. A gradual improvement to 15 kWh/100 km in 2050 is assumed. We also considered an average mileage of 10 000 kilometres per year.

Table 7.9: Electricity consumption of EVs in Slovenia predicted by pessimistic and optimistic scenarios

Year	2025	2030	2035	2040	2045	2050
Pessimistic [GWh]	77	125	174	223	271	320
Optimistic [GWh]	153	414	806	1 332	1 989	2 779

8 Key Factors Impacting the Electric Vehicles Evolution

Several factors can impact the evolution of EVs and their massive adoption by the citizens. In this section, an analysis of the most important factors is presented. These factors are presented following a Political, Economic, Social, Technological, Environmental and Legal (PESTEL) analysis. Additionally, behavioural aspects can also be identified as important factors in EV adoption leading to a PESTEL+B analysis. Some publications such as [116]–[120] have been used as references.

8.1 Political Analysis

Governments can create incentives or taxes reduction to promote the development of EVs. Some examples can be mentioned such as the Danish government exempting people willing to buy EVs from paying a share or the total amount of this tax [121]. Research showed that a more stable policy regarding EV subsidizing would help people to decide on EV purchases. In Portugal and Greece buying incentives are also in place in the acquisition as well as in the annual tax.

Another way to indirectly subsidise the EVs is by eliminating or reducing the taxes or tariffs paid for each consumed kWh. For example, in Denmark EV users can pay a reduced tax on electricity consumed for EV charging [122].

8.2 Economic Analysis

Factors related to vehicle costs, including initial investment, maintenance and use costs (fuel) are also significant for EV adoption. According to [123], parity between EVs and ICEs will happen during this decade mainly depending on the battery costs. However, incentives and taxes reduction can balance the difference. Additionally, the utilization cost is much more volatile in ICE vehicles than in EVs. Less tangible factors such as the need to buy a new vehicle or a replacement strategy can also be mentioned. In some companies, the fleet is replaced every 3 / 4 years.

Macroeconomic factors can also affect EV adoption namely the Gross Domestic Product (GDP) of the country.

8.3 Social Analysis

Change from ICEs to EVs can be different depending on social factors such as gender or age. However, factors such as individual income, and the number of children seem much more important for EV adoption. The country and the place (rural or non-rural areas) can also be mentioned as social factors. A general understanding of EVs among the citizens is needed for their large-scale deployment. Additionally, governmental policies change frequently, making it difficult for car owners to keep up with the information. This implies that clear information should be available. The introduction of more EV models in the market that cover more diverse needs and offer more options to users, e.g., wider ranges of battery sizes and prices, faster-charging capabilities etc., can help in the EV adoption for different purposes and lifestyles.

The perception of the origin of the energy can also be identified as an adoption factor mainly in countries where renewables have high penetration allowing the reduction of the energetic dependence.

8.4 Technological Analysis

Factors related to technologies can be split into the ones related to vehicles and the ones related to the charging infrastructure.

Vehicles:
The main challenges are the driving range, the battery lifetime and the efficiency (electricity consumption). Afterwards, general aspects such as the facility in the operation, reliability and design can also influence the selection of the vehicles.
Another externality that can impact EV adoption is the maturity of other technologies such as the FCEVs and biofuels. Nowadays, EVs have higher maturity compared to the mentioned technologies. However, a significant research effort is expected in the development of these technologies.
Charging Infrastructure
Drivers are still afraid of taking cross-country trips due to uncertain charging capabilities. Another challenge is that different charger connectors exist (see Chademo vs Combined Charging System – CCS), which are not compatible with each other. Payment methods are not unified, e.g., some charging stations still require an APP or dedicated Radio Frequency identification (RFID), or credit cards are not always accepted. An example is Tesla car owners who show less concern in this regard, thanks to the availability of Tesla fast-charging stations. Systems interoperability in different countries (EVs roaming) can also be an important aspect that can limit the EVs adoption. Time of charging, including queue for charging, is another important aspect that should be addressed to improve EVs experience. Finally, the possibility of V2X can be an important factor soon.

8.5 Environmental Analysis

Environmental conscientiousness is guiding energy transition and changing the values of society. Factors such as energy efficiency, the lifecycle of the materials, recycling and re-utilization are very important aspects in the selection of products and particular vehicles. Concerning EVs, energy efficiency is a clear advantage compared with ICEs. However, lifecycle, recycling and re-use of batteries can be identified as blocking factors due to the negative environment impact. Another important aspect that can impact the adoption is the coordination between EVs and renewables, mainly photovoltaics (PV). PV systems can be installed on a small scale in houses, buildings, parking lots and companies. The marginal cost of this technology is zero and the environmental impact during the production period is negligible. Because of that, the coordination between EVs and PVs will decrease the environmental impact of EVs, the operating costs and the impact on the power networks (reduce power flow and losses).

8.6 Legal Analysis

Legal factors are important factors in the adoption of EVs. A first initiative was made by some municipalities limiting the access of pollutant vehicles to the cities. These rules can be more restricted in the future limiting access only to ZEVs. These initiatives will have an impact on the reduction of local pollution (smoke), increase the air quality, reduce the degradation of the building and increase the quality of life and most important the health of the citizens. Another legal measurement that has been published recently in Europe, is the one defining that in 2035 all new vehicle registrations should be ZEVs.

8.7 Behavioural (vehicles use) Analysis

Considering the characteristics of the EVs and the perception of their limitations, some behavioural aspects can be identified. One of the main concerns of the users is the range anxiety and the charging process. These aspects are already identified in previous factors. However, when the user buys a vehicle some aspects such as frequency of use, average travel distance and the number of cars owned by the user can be important factors. Users that use the car frequently and do long distances can be induced not to buy EVs. On the contrary, users with more than one vehicle are more likely to have an

EV. Other factors such as driver's licence time or EVs' previous experience can influence the users' decision. Last but not least, the “image” that the use of an EV can have also a conscious factor.

9 Conclusions

This deliverable presents a vision of the EVs situation Worldwide, in Europe, Denmark, Greece, Portugal and Slovenia. The first conclusion is that the adoption of EVs is different in the four analysed countries. Comparing the EVs in Europe and worldwide it is possible to verify a higher share of PHEVs and a lower share of EVs. This can be due to the increase in global vehicle stock worldwide. In the case of Europe, the stock is relatively stable and the EVs are replacing existing ICE vehicles.

Another important factor that can be stated is the faster evolution of the EVs stock compared with charging infrastructure development. In most of the analyses, the ratio of the number of EVs with the number of charging points increased in 2021.

Evolution scenarios are also analysed concerning the EV stock, charging infrastructure and electricity needed to supply EVs demand. Several reports are mentioned mainly for Europe. Some work is already done at a country level but deeper analyses are needed in some of the analyzed countries. Looking into the presented scenarios, it is clear the impact of recent events such as the war in Ukraine and the energy crisis as well as the rule to achieve 100% ZEV sales by 2035. The reports proposing scenarios after these events normally have more ambitious scenarios.

A point of divergence between the reports concerns the total vehicle stock. In some cases, it is assumed that shared mobility will increase, reducing the total number of vehicles. However, in other reports, it is expected that the stock will increase. Another aspect that in most cases is not completely reported is the evolution of FCEVs and their impact on the stock share.

The scenarios described in the present report will be used in the next deliverables of Work Package 1 such as in the definition of business models and business use cases. Afterwards, the models that will be developed in Work Package 2 will be tested considering the mass deployment of EVs following the scenarios presented in this report.

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