Electric Vehicle Infrastructure – Concepts and Challenges for Greece

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Abstract— Electric Vehicles (EVs) represent a self-evident solution to environmental issues. Particularly in urban areas, the inhabitants must cope with increasing air pollution from industry and traffic. Promoting the electrification of individual transport can be part of the solution not only to slow down climate change but also to improve the quality of life of city dwellers. Athens has one of the highest emission rates in Europe due to traffic. The Greek Government published the National Plan for Energy and Climate in late 2019. A key message of this plan is that by 2030, one in three vehicles sold in Greece should be equipped with an electric drive. Additionally, Renewable Energy Sources (RES) are about to be promoted, which shall lead to a more environmentally friendly electricity mix (29.2 % share of RES in 2020, aiming for 61 % share of RES in 2030). This is necessary for EVs to achieve a reasonably well-to-wheel CO2 and NOx balance, not only a reasonable tank-to-wheel balance. Government subsidies are intended to create incentives to buy an electric vehicle. Including tax benefits, these subsidies can support the purchase of an electric vehicle for up to 10,000 €. Considering the comparatively low purchasing power in Europe and the lacking Charging Infrastructure, this is an ambitious target. Declining prices for EVs and charging facilities also enable countries with lower GDP per capita to electrify their mobility. This paper's purpose is to examine whether Greece's above objective of transport electrification is achievable and in addition to highlighting the strategies and methods that must be utilized to electrify Greece's private transport. Therefore, the methodology followed includes the calculation of the minimum number of Public Charging Points (PCPs) required and subsequent analysis of pioneer countries regarding EV Infrastructure that Greece should be adapt to electrify its private transport appropriately. Concluding this paper's results show, that Greece's objective is achievable.

Keywords— Electric Vehicle; Greece Infrastructure; Charging Points; Charging Infrastructure

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1. Introduction

In 2019 the Greek Government published the National Plan for Energy and Climate with the plan one in three vehicles that will be sold in 2030 in Greece to be equipped with an electric drive. Additionally, Greece's RES shall lead to a more environmentally friendly electricity mix (29.2 % share of RES in 2020, aiming for 61 % share of RES in 2030) [1]. To achieve this goal government subsidy would intend to create incentives to buy an electric vehicle, including tax benefits, and can support the purchase of an electric vehicle with up to 10,000 € [2].

In the following research, only Plug-In Electric Vehicles (PEVs) are considered, as they matter the most for the charging infrastructure. They will also be referred to as EVs. The following Figure 1 shows the very low market share of 0.4 % in sales of EVs in Greece compared to other European countries in 2019 [4]. If one considers that only 75 Charging Points (several Charging Points can be included in one charging station) were installed in Greece by April 2020, it becomes clear that there is also a need for action regarding the charging infrastructure [5]. On the other hand, the automotive industry is reporting steadily rising sales figures and major strategic decisions regarding the electrification of the vehicle fleet. As part of VW's 2025 strategy, for example, VW does not intend to build cars equipped with combustion engines from 2026 onwards [6]. A customer thinking about an EV will notice that the obstacle to electromobility is not a lack of vehicles, but an underdeveloped charging infrastructure. At the same time, consumers need to rethink their behavior. Charging an EV is in not comparable to refueling a conventional vehicle. This is due to the different charging speeds and the technology required. The main matter of interest regarding a charging point to the consumer is: How long does it take to charge an EV? Contrary to the petrol station infrastructure the EV charging infrastructure is much more complex and technical. Charging concepts can be divided by the charging speed. The charging speed depends on the charging power of the car, the cable, and the charging point. The weakest component defines the general charging power. Therefore no general assumption about charging speeds for EVs can be made. Table 1 presents the IEC Standard Categories European Charging modes [7].

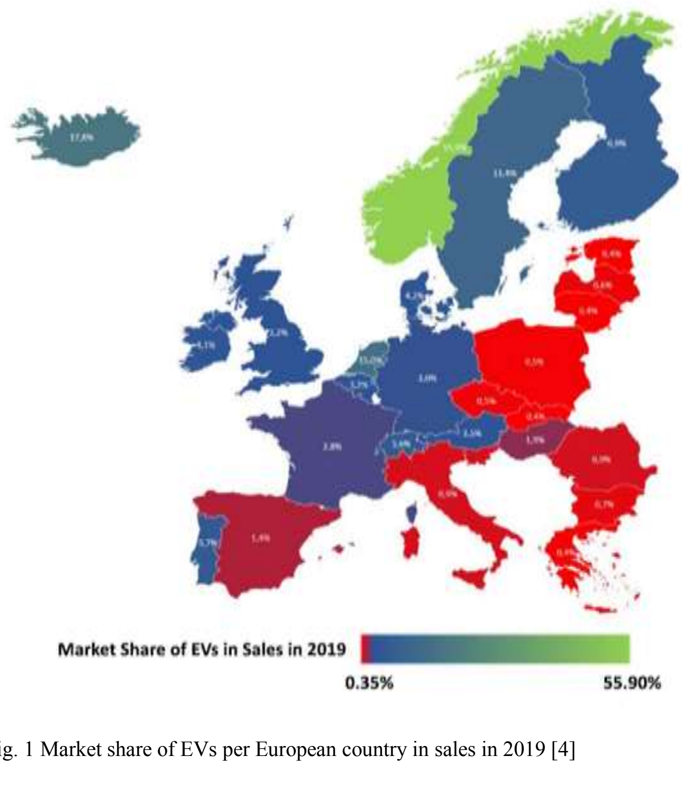

Fig. 1 Market share of EVs per European country in sales in 2019 [4]

TABLE 1 IEC 61851 Standard Charging Modes [7]

Mode	Voltage	Charging Power	Current Transformer
Mode 1 (AC)	250 V single phase	max. 4 KW (16 A) 2.3 KW (10 A 230 V EU domestic Socket)	no communication
	480 V three phases	max. 13.3 KW (16 A)	
Mode 2 (AC)	250 V single phase	max. 8 KW (32 A)	In-Cable-Control-and-Protective-Device (ICCPD)
	480 V three phases	22 KW 11 KW (domestic three-phase)	
Mode 3 (AC)	480 V three phases	30 KW	AC Charging Box
Mode 4 (DC)	DC	up to 250 KW (400 KW with cooling)	DC Charging Box

This paper is dedicated to determining the relevance of the different charging con-cepts for an EV infrastructure. The study is one of the first approaches to answer those questions by using the daily usage profile of vehicles as a database. The reason for this is that the charging behavior of EVs is not determined by the annual travel distance and range, but by the daily travel distance as well as the required charging time. Based on the elaborated findings this paper includes the attempt to adopt a concept of an EV charging infrastructure to the needs and objectives of Greece and Athens in particular.

2. Methodology

2.1 Analysis of Charging Concepts)

Basic charging concepts can be defined based on IEC modes and EV charging capacities. But not every car can charge with all IEC charging modes. Besides this limitation, the capability of the Charging Point depends on the given power supply and the capability of the car. To evaluate the Charging capability, the charging speed is defined and calculated with the following formula in which [h] represents the charging speed while [KWh] represents the energy consumed per hour and [KW] the power correspondingly:

$$[h] = \frac{[KWh]}{[KW]} \tag{1}$$

The Smart Fortwo, the Renault Zoe, and the Tesla Model 3 are considered in this comparison. The Smart represents the small car series with short-range. The Renault Zoe represents a group of small cars with a medium range. Renault is the second most sold EV in Europe. The best-selling EV in Europe is Tesla. It represents a cost-wise mid-range car with a long driving range [9].

Based on the IEC standard and the charging possibilities of the vehicles, the following charging concepts can be set up:

Home charging makes it possible to charge the car at the home's power socket. Since the maximum power is limited by the power supply company, a maximum of 2.3 KW can be charged with a one phase-supply and 11 KW with a three-phase supply. Depending on the model, charging speeds of 7 h/100km single-phase and 1.5 h/100 km three-phase are possible. An advantage is that the relatively slow charging speed is only of secondary importance, as the vehicles can be charged at night. However, this requires a parking space on the owners' property. This is rarely the case in densely populated urban areas.

Street charging is based on the assumption that an EV owner uses a publicly accessible charging station for his vehicle. This can be done mainly in connection with parking the vehicle. In residential areas, for example, charging can be done overnight or during a long shopping trip in the supermarket parking lot. Depending on the model, up to 22 KW charging power can be achieved, which results in a charging speed of about 45 min/100km. An advantage here is that free parking around the Charging Stations in densely populated areas can serve as a pull factor for the electrification of passenger traffic.

Employee charging allows employees to charge their vehicle on the employer's premises using a single-phase or three-phase charging point.

With fast charging 46 - 163 KW charging power can be achieved under DC voltage. Short charging times of 9 – 20 minutes/100 km make it possible to cover longer distances by stopping for charging at service stations. A conversion in urban areas places a heavy load on the power grid but can be used by private investors in shopping facilities as a customer offer. There is also the possibility of controlling the load on the power grid through smart charging. In this case, the charging power is adapted to the load of the network by a control system connected to the network provider. This can be used especially for charging during the night.

2.2 Definition of Usage Profiles of Passenger Cars

To define the minimum requirements of the EV charging infrastructure, which is necessary to ensure the most extensive electrification of personal mobility, especially in urban areas, it is necessary to analyze the usage profiles of passenger cars. For this purpose, the data from the world's largest mobility study "Mobility in Germany" from 2017 will be evaluated.

In the study, households in Germany are asked about their mobility behavior on a certain key date. The evaluation results in a cross-section of individual mobility, which can be used to map normal, regular mobility behavior. The used raw data basis relates to the use of the car on the key date and covers 11,876 cars. A weighting factor [11] assesses the relevance of the votes of the individual passenger cars regarding their representativeness resulting in an extrapolated data basis of 29,285 passenger cars [12]. Based on the effect of weighting the votes and a comparison with other mobility studies [13] it is assumed that the data basis and the resulting results can be used across countries. Initially, the characteristic values "Total Distance traveled by Car on the Deadline Day (in Groups of km)" and the "Number of Cars per Group" contained in the following profile groups are evaluated. This results in the cumulated histogram shown in Figure 2. Daily Usage Profiles are derived from this. The definition of these profiles is based on the current possible ranges of EVs (cf. Table 2) and a categorization based on an ABC analysis.

TABLE 2 Car Market Data [10]

Car	Battery KWh (km)	Power consumption KWh/100 km	Charging Power KW	Charging Speed h/100 km
Smart Fortwo 453 Electric Drive	17.6 (100)	16.7	2.3 domestic	7.26h
			max.22 11 domestic	46 min 1.52h (11KW)
Renault ZOE	55 (320)	16,3	2.3 domestic	7.45h
			max. 22 11 domestic	45min 1.48h
			46DC	21min
Tesla Model 3	50 - 75 (315 - 445)	15,1-16,3	2.3 domestic	6.57h
			11	1.37h
			45 - 100 KW (DC CCS Fastcharger) 163KW (Tesla Supercharger)	9-20 min 6 min (Tesla Supercharge r)

The categorization is used to prioritize the charging concepts regarding their fit to the proportion of cars contained in the respective daily usage profiles.

To gain a better understanding of the individual Daily Usage Profiles, the percentage distribution of the factors "Number of Trips on Deadline Day" and "Average Distance per Trip on Deadline Day" will be included in the detailed analysis.

The Daily Usage Profile A (regular, daily total mileage >0 km to <100 km, including 89.2% (of all cars) is shown in Figure 3. The focus of this usage profile lies on two trips per day, each with an average single trip length of 2 km to <50 km. The average total daily mileage is 30.7 km.

The Daily Usage Profile B (regular, daily total mileage 100 km to <200 km, including 7.1% of all cars is shown in Figure 4. The focus of this usage profile lies on two trips per day, each with an average single trip length of 50 km to <100 km. The average total daily mileage is 135.9 km.

The Daily Usage Profile C (regular, daily total mileage ⩾ 200 km, including 3.7% of all cars) is shown in Figure 5. The focus of this usage profile lies on one to three trips per day, each with an average single trip length of ⩾100 km. The average total daily mileage is 377.5 km.

To determine the average daily mileage of the profiles and their combinations, the vehicles that were not moved on the deadline day must also be considered. This adds 5,018 or 11,952 vehicles to the data basis by weighting [12]. This group is referred to in the following as "Daily Usage Profile 0". It is assumed that when these vehicles are moved, they are used according to the prevailing profiles. Thus, the percentage distribution of the vehicles moved remains the same regarding the Daily Usage Profiles. The daily mileage of the usage profiles, which can be covered by an average battery charge (cf. Table 2), is summarized for the calculation of the average daily mileage. According to the distribution, the combination of 96.3% of Profile 0 with Profile A/B results in an average daily mileage of 22.6 km/day, as shown in Table 3. When considering a group of vehicles this realistic average daily mileage is decisive for later use of the results (cf. Table 3).

TABLE 3 Average Daily Mileage (own representation)

Profile 0	Profile A	Profile B	Profile C
0 km/day	Ø 30.7 km/day	Ø 135.9 km/day	Ø 377.5 km/day
Ø 22.6 km/day			

All these cross-section considerations only reflect the usual usage profile of the vehicles. However, no conclusion can be drawn for all journeys that take place over a longer period with the respective vehicle. Exceptions (such as longer journeys) are not considered or represented. For example, in an observation period of one year, approximately 50% of the vehicles cover about 400 km on at least one day [13]. This irregularity in the usage profile of all vehicles on at least one day of the year correlates approximately with the driving performance which is regularly managed by vehicles of Usage Profile C. For all following results, the longitudinal section on mobility must therefore always be considered as a qualitative influencing factor.

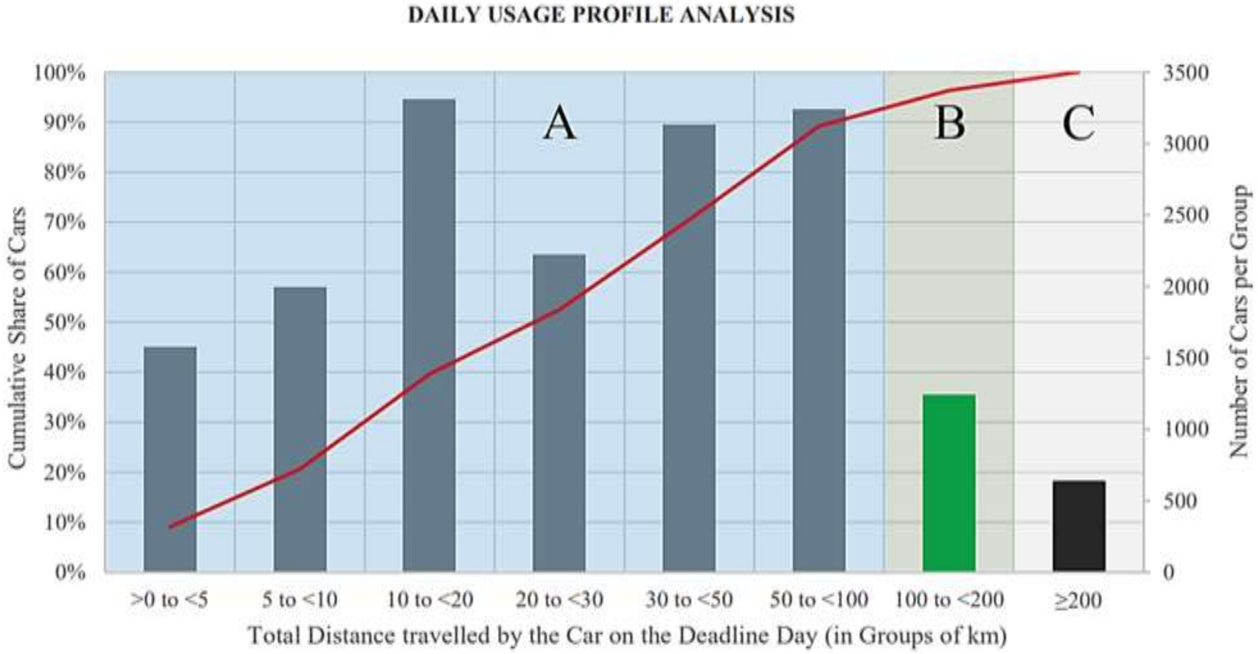

Fig. 2 Daily Usage Profile Analysis (own representation, based on [12])

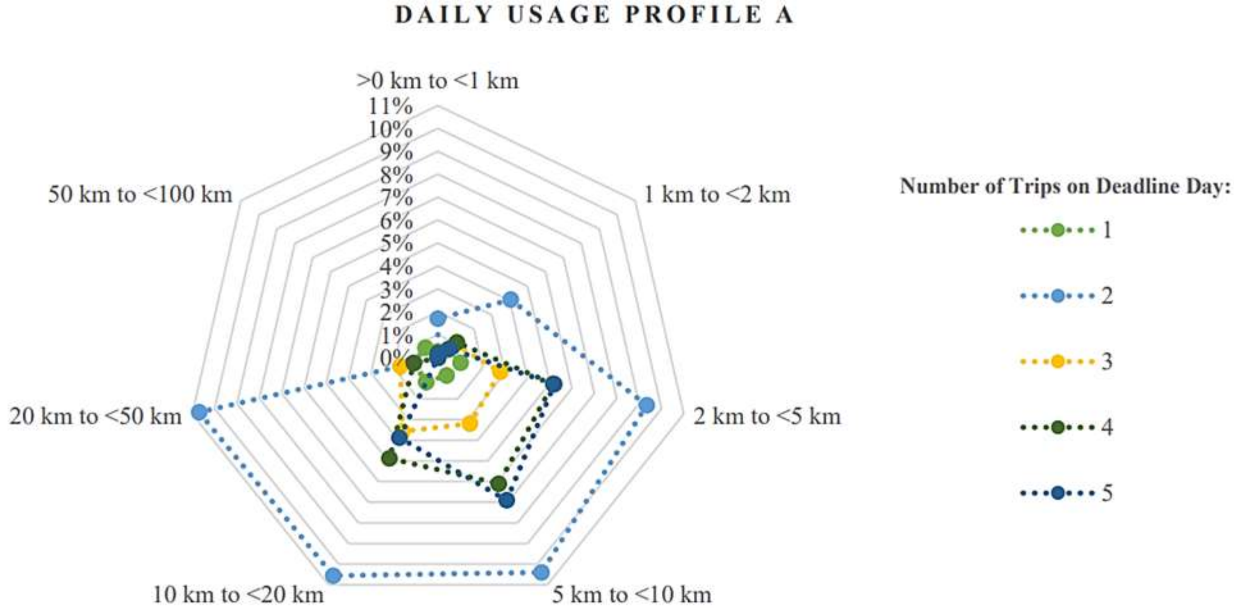

Fig. 3 Daily Usage Profile A Analysis (own representation based on [12])

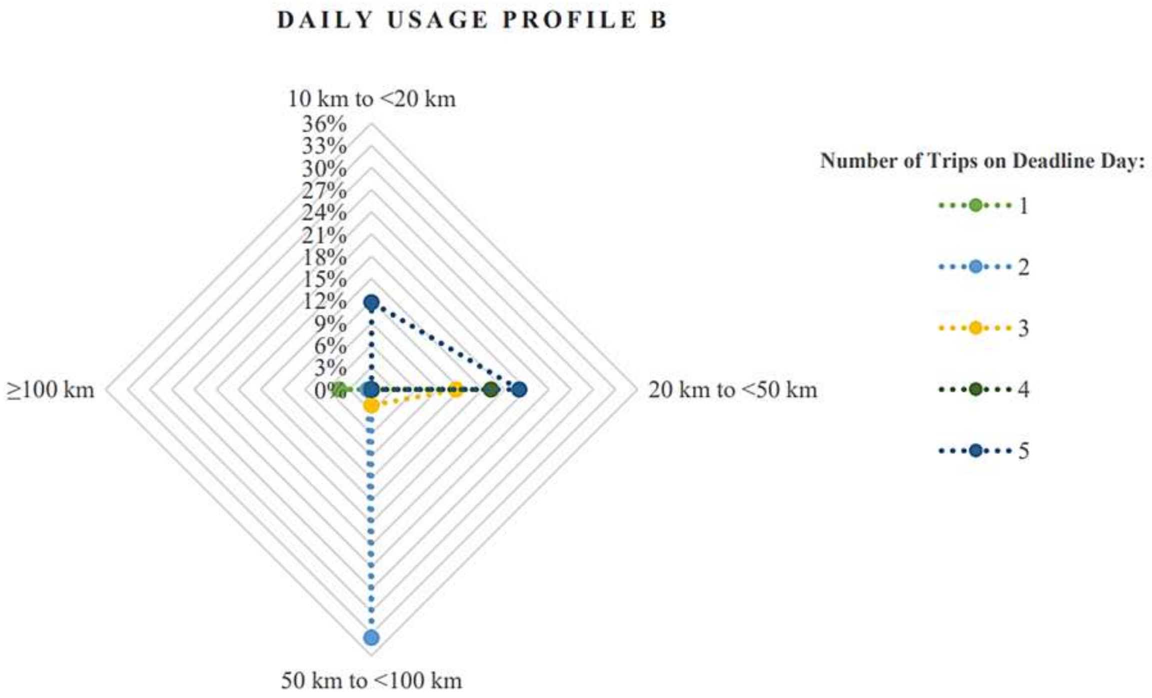

Fig. 4 Daily Usage Profile B Analysis (own representation based on [12])

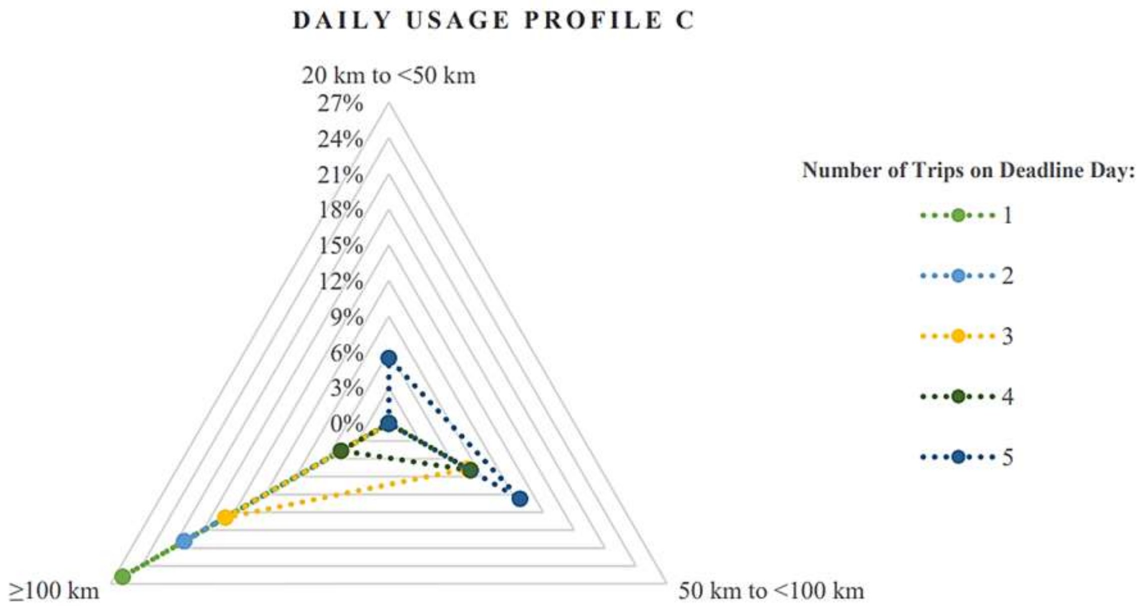

Fig. 5 Daily Usage Profile C Analysis (own representation, based on [12])

2.3 Determination of the Required Charging Infrastructure in Urban Living Areas

With knowledge of Daily Usage Profiles, EV energy consumption and charging possibilities, the required amount in residential areas can be estimated. In the following, electricity consumption of 16.3 KWh is assumed for a medium-sized EV as shown in Table 2.

Usage Profile C shows an average daily distance of about 380 km. As this group of drives only accounts for 3.7% of all trips and has a total range of about 320 km, it can be assumed that an EV is not predestined for these trips. Since the range of the EV is also not enough to reach the destination with one battery charge, it is assumed that these vehicles are not only charged within a residential area and are therefore not considered in the following calculation for now. As seen in the longitudinal section on mobility [13], however, an expansion of quick-charging facilities along the long-distance routes is not only necessary for vehicles with Usage Profile C. Since vehicles of Daily Usage Profile A and B also occasionally have to cover distances that cannot be covered by one battery charge, the expansion of fast-charging facilities along highways is indispensable for comprehensive electrification [14].

Most vehicles fall into Usage Profiles A and B. If the vehicles that are not moved daily are also considered, the evaluation shows an average daily distance traveled of

22.6 km. This results in an average daily charging need of 3.7 KWh. The daily charging time at a domestic socket is therefore 1.6 hours. Charging at a three-phase connection takes 10 to 20 minutes, depending on an 11 KW or 22 KW supply. The weekly charging time is 70 to 140 minutes. The duration of charging via fast charging is 5 minutes daily or 35 minutes weekly.

To determine the number of Charging Points required from the pure charging time, several additional factors must be considered as shown in Table 4. A port at which one EV can be charged is referred to as a charging point. Several Charging points can be integrated into one charging station. The following formula calculates the number of Charging Points in a residential area. It is assumed that charging is carried out mainly by the street charging concept. Partial out-of-town charging and charging in domestic stations are met as described below by a real measurement of the Dutch study in a representative residential area.

TABLE 4 Parameters for Calculating CP (own representation)

CP	[-]	Charging Points Ratio
$k_{utility}$	[%]	Utility Rate
$k_{charging}$	[%]	Charging Rate
d_{daily}	[km]	Daily Distance (average)
E_{car}	[KWh]	Energy Consumption Car
E_{point}	[KWh]	Energy Capacity Charging Point

$$CP = \frac{ddaily * ECar}{kUtility * kCharging * EPoint} \tag{2}$$

The utility rate describes the degree of occupation of a charging point (CP). This is intentionally not 100%, as the availability of free Charging Points for the consumer must be guaranteed. According to a study on the developed charging infrastructure in the Netherlands, a utility rate of 50% can be considered very high while a utility rate of 30% is considered realistic. Since these are real values, the factor that vehicles in a residential area are not only charged exclusively in that area but also by street charging or at the employer's premises, for example, also plays a role [15]. The utility rate is strongly dependent on the expansion of the entire charging infrastructure and the availability granted to the consumer.

The charging rate is defined by the charging time divided by connection time. The real measurement of the Dutch study of the charging rate showed a value of only 15% to 22%. This is partly because fully charged vehicles are not moved at night and the places around Charging Stations are used as parking spaces during the day [15]. A regulation that allows overnight parking of 14 hours but prohibits daytime manning of the station without charging would be possible. Assuming a full charge within 2.5 hours at night and a charging rate of 100% during the day, the total charging rate is theoretically 52%. The following values (cf. Table 5) are used to calculate an absolute minimum requirement of Charging Points, which is significantly influenced by local infrastructure policy.

TABLE 5 Parameters for Calculating CPmin,theor. (own representation)

$k_{utility,measured}$	50 %
$k_{charging,theoretically}$	52 %
d_{daily}	22.6 km
E_{car}	0.163 KWh/km
E_{point}	528 KWh (24 h *22 kW)

$$CPmin,theor. = \frac{22{,}6km * 0.163 \frac{KWh}{km}}{0.5 * 0.52 * 528KWh} \approx 0.03 \frac{Points}{EV} \tag{3}$$

According to the Dutch study, the measured average combined value of the Utility Rate and charging rate is 5 to 10 percent [15]. According to the formula, this means an amount of Charging Points from 0.14 to 0.07 per EV (cf. Table 6).

TABLE 6 : Parameters for Calculating $CPmin, meas.$ (own representation)

$(k_{utility}+k_{charging})$measured	5 % - 10 %
d_{daily}	22.6 km
E_{car}	0.163 KWh/km
E_{point}	528 KWh

$$CPmin,meas1. = \frac{22{,}6km * 0.163 \frac{KWh}{km}}{0.05 * 24 * 22KW} \approx 0.14 \frac{Points}{EV} \tag{4}$$

$$CPmin,meas2. = \frac{22{,}6km * 0.163 \frac{KWh}{km}}{0.1 * 24 * 22KW} \approx 0.07 \frac{Points}{EV} \tag{5}$$

Another approach is from the consumer's point of view. It can be assumed that in the residential area charging is only done overnight. It can also be assumed in this analysis that the consumer wants to charge his car on the same day of the week out of habit. With an average driving distance of 22.6 km per day, or approx. 160 km per week, a maximum vehicle range of 320 km is enough to charge the car only once a week at night. This considers that the maximum range is nearly never exploited in practice [16]. This means that 7 vehicles can be charged per week, or 0.14 Charging Points per vehicle are required.

Since the Charging Point Ratio of 0.14 Charging Points per Vehicle is verified with both approaches, this value can be considered plausible for a minimum requirement.

To include the Daily Usage Profile C, which has been excluded in the calculation of the Charging Point Ratio, these vehicles must be considered for calculating the required amount of Charging Points in an area. This assumes that the distribution of long-distance drivers is the same in all urban areas and is therefore also applicable to residential areas. To add this group to the calculation, it is assumed that each long-distance driver needs his Charging Point to be able to charge every night. Therefore, the factor $klong$is introduced. $klong$

describes the share of long-distance drivers according to the Usage Profile C (cf. Figure 5).

TABLE 7 Parameters for Calculating Total Points (own representation)

$CPmin,verified$	0.14 $Points/EV$
NV	Number of Vehicles (in the area)
$klong$	3.7 %

$$\text{Total Points} = CP_{min,verified}*N_V+N_V*k_{long} \quad (6)$$

With a CP ratio of 0.14 and a share of 3.7% of long-distance drivers (cf. Figure 2), the formula calculates the number of 18 Street Charging Points per 100 vehicles (NV) for residential areas.

In summary, it can be said that the calculation of the CP Ratio is strongly dependent on the composition of the resident clientele. In addition, factors of local infrastructure policy play a major role in keeping the capacity utilization of Charging Points as high as possible. To capture these uncertainties, a customer-oriented expansion of the infrastructure is recommended. Regarding the Daily Usage Profiles, the number of trips is a decisive factor. For example, Section A2 shows an accumulation of two trips per day, which indicates a return trip. A loading option in between these two trips significantly reduces the number of Street Charging Points required in residential areas. The possibility of Domestic Charging, which depends largely on the urban morphology, also influences the required Street Charging Infrastructure. For this purpose, it is necessary to record the number of EVs and their charging behavior. This can be done automatically or manually by the vehicle owner. Furthermore, the real CP Ratio needs to be constantly checked.

3. Implementing Electro mobility in Greece

The obstacles to implementing electromobility can be compared to the chicken or egg dilemma. To figure out if there first must be a comprehensive Charging Infrastructure or a widespread usage of EVs, best practices are analyzed.

According to these two criteria, the most advanced markets regarding electromobility are Norway and the Netherlands [17]. Because of that, they are referred to as best practices. As seen in Figure 6 the market share of EVs among newly sold cars in 2019 was 56% in Norway [18], 15% in the Netherlands [19], and 0.42% in Greece [4]. The absolute market share of EVs amongst passenger cars is 13.5% in Norway [18], 2.3% in the Netherlands [20], and 0.3% in Greece [2]. The ratio of Charging Points can be described per 100 EVs (Norway: 3.6 [18], Netherlands: 18.7 [21], Greece: 10.9 [2]) or per 1000 capitals (Norway: 2.55 [18], Netherlands: 2.14 [3], Greece: 0.01 [22]), also displayed in Figure 6.

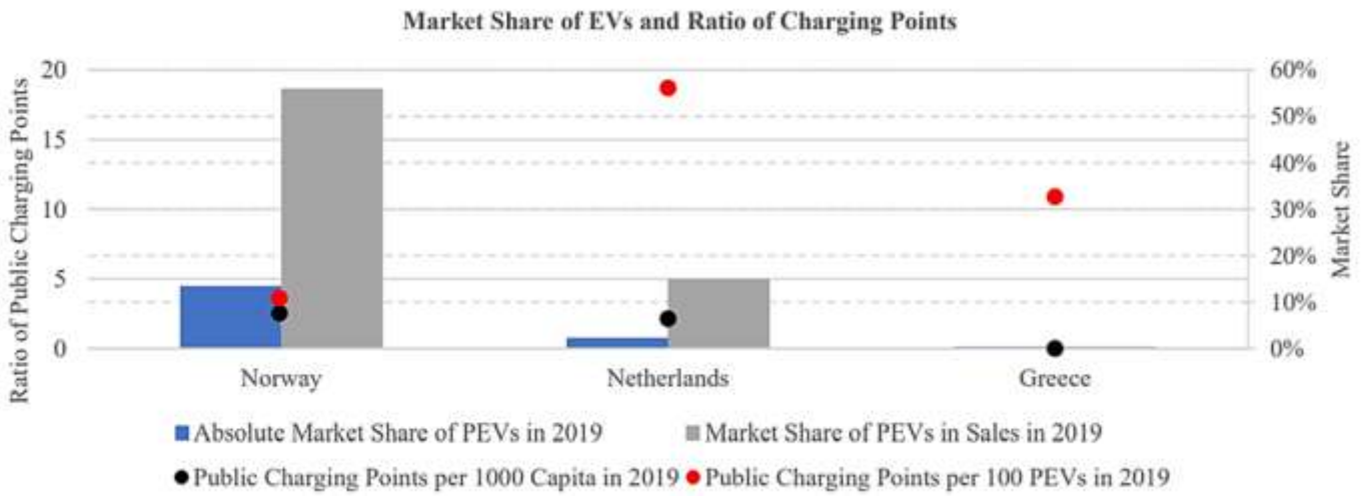

Fig. 6 Market Share of EVs and Ratio of Charging Points (own representation)

By looking at the total market share of EVs in Norway (which is the highest in the world), one can say that in 2019 Norway is in the “Early Adopters” phase of the diffusion of innovations. Despite being also one of the most advanced EV markets, the Netherlands is still in the “Innovators” phase (cf Figure 7).

Therefore, one must be aware that even amongst best practice countries there is still no proven model which has established electric mobility up to and beyond the majority phase. However, this also implies that it is not too late for countries like Greece to join the electrification of their individual mobility. To undergo that process as efficiently, fast, and sustainable as possible it is necessary to analyze what Norway and the Netherlands did do until now.

The main reason for electrifying mobility is to lower the emissions emitted by vehicles and thereby reduce the pollution of the environment. Therefore, it is important to take not only the tank-to-wheel balance but also the well-to-wheel balance into account. To achieve a reasonable well-to-wheel balance in terms of CO_2 and NOx emissions, RES must be promoted. According to the National Energy and Climate Plan the share of RES for the production of electric energy shall be improved from 29.2% in 2020 to 61% in 2030 [1]. Considering the huge potential of RES in Greece [24], the goals set are essential for environmentally friendly electrification of mobility.

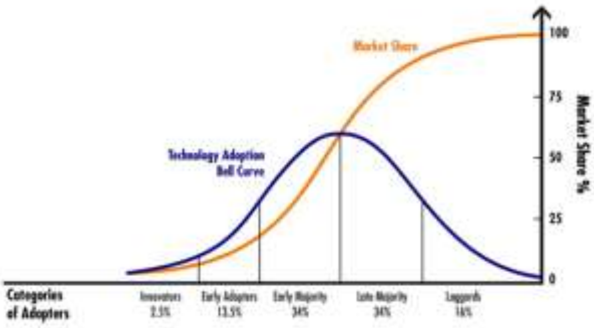

Fig. 7 Diffusion of Innovations according to Rogers [23]

4. Best Practice Governmental EV Purchasing Incentives

4.1 Netherlands

The experience of the last decade in the Netherlands regarding the acceptance of EVs by the consumer market shows that with the same financial support of PHEVs (Plug-in Hybrid Electric Vehicles) and BEVs (Battery Electric Vehicles), PHEVs were preferred sales-wise. This is mainly due to range anxiety, although analyses show that electrically driven kilometers were far below expectations. Nevertheless, charging data show that BHEVs are responsible for half of the charging power used and are therefore a major contributor to the reduction of air pollution. Regarding the subsidization of EVs, registration costs and taxation have been partially suspended. It is assumed that the elimination of registration costs has a minor factor in purchasing behavior. Rather, it is the tax relief, the direct financial support, which provides an incentive to purchase an EV. [25]

Recently subsidization of 4.000 Euro for EV with purchasing costs below 45,000 Euro and a minimum range of 120 km has been introduced in the Netherlands. A promotion of leasing contracts and the purchase of used vehicles is also supported. This should open the EV market for the cheaper market segment, to achieve a wide area coverage of EVs [26].

Another buying incentive is a free parking policy. The free parking strategy, as applied in the Netherlands means that EV vehicles can park for free around Charging Stations as long as they are connected to the Charging Point. The experiences show that this policy is a very effective tool for purchasing EVs in areas with high parking needs. However, this results in increased pressure on non-EV drivers to find a parking space and further increases the discrepancy between the effective charging time and the Utilization Rate. If the actual charged KWh is charged and not the occupation time, this strategy reduces the financial profitability of the stations. Thus, the sales of EVs are promoted but not the investment attractiveness of the Charging Stations for the city or the electricity supplier [15].

4.2 Norway

In the main, the Norwegian EV policy aims to ensure that the choice of a zero-emission vehicle over a high-emission equivalent is always economically beneficial. This is achieved by the "polluter pays" principle of the tax system. Due to high taxes for high-emission cars, low- or zero-emission vehicles can be charged with lower taxes and even promoted without loss in revenues.

The incentives for promoting electromobility in Norway already started in the early 1990s, even though the EV market barely existed back then. To purchase EVs palatable, approaches have been taken at different economic levels. To reduce the acquisition costs, the purchase and import taxes have been abolished for BEVs (1990-). A high proportion of these taxes is based on the CO2 emissions of the car. The other part of that tax is based on the weight of the car. For the calculation of the tax for PHEVs, the weight is reduced by 26% since 2015. In that way, PHEVs are still promoted compared to cars with internal combustion engines, but not as strong as BEVs. Additionally, all EVs are excluded from the Value Added Tax (VAT) of 25% (2001-). Since 2015 leased EVs are also excluded from the VAT. To encourage the conversion of company fleets to zero-emission vehicles, the company car tax has been reduced by 50% from 2000 – to 2018. From 2018 on, financial compensation for the scrapping of vans with internal combustion engines is granted, if it is replaced by a zero-emission van. The company car tax reduction has been reduced to 40% in 2018.

To lower the total cost of ownership, no annual road tax must be paid for EVs (1996-). From 1996 until 2017 EVs were completely excluded from tolls for roads and fares for ferries. From 2018 on, a maximum of 50% of the full price can be charged for the usage of ferries. Since 2019 50% of the normal road tolls must be paid for EVs. Municipal parking was free from 1999 to 2017 and now is locally a maximum of 50% of the full price.

Incentives have also been introduced at the non-monetary level. Therefore, the usage of bus lanes for EVs is allowed (2005-). However, local authorities may limit the access to bus lanes to EVs that carry at least one passenger [27] [28].

5. Best Practice Governmental Infrastructural Measures

The majority of EV owners rely on domestic and work charging [29]. This is because the majority of EV owners have a relatively high income and therefore live in real estate that provides access to private charging [17]. However, to promote the widespread use of EVs, the implementation of Public Charging is necessary. Regarding the Public Charging Infrastructure, the main difficulty is the balance between underutilization, overutilization, and the maximum possible Charging Time Ratio. The balance of these parameters reflects the conflict between sufficient available charging capacity and overcapacity, which strongly influences the financial profitability of Charging Stations. Also, the (connector) type, as well as the placement of the Charging Station, are decisive for its workload. Even though a functioning Charging Infrastructure itself is no direct economical funding, it is indispensable for promoting electromobility. Without a proper Charging Infrastructure, it is impossible to comprehensively use EVs daily. Independently of all other incentives, there is no way to reach a high market share of EVs with an incomplete Charging Infrastructure.

5.1 Netherlands

In the Netherlands, the Charging Infrastructure is initiated by the Government and financed by investors with state support. The rollout of a Charging Infrastructure took place by installing 480 strategic Charging Points all over the Netherlands before even the first EV was introduced to the Netherland market back in 2012. By 2015 more strategic Charging Stations and 673 demand-driven Charging Points were installed. The demand-driven Charging Stations are a typical placement strategy in high-density lining areas. This method has been approved to be the most efficient policy to fulfill the customers' needs. In addition, an initiative installation of strategic Charging Stations was done to increase the popularity and acceptance of EVs [30]. Fast Charging Stations are mainly placed alongside motorways. Fast Charging Stations have been set up at suitable locations such as supermarket parking lots. As a result, 750 Fast Charging Points were already available at the beginning of 2018 [31].

To optimize the utilization and financial profitability of Charging Stations, for instance, the Daytime Charging policy was applied. Daytime Charging is based on the principle that during the day, only EVs may park in parking spaces with Charging Stations, while at night all vehicles may park in the parking spaces. This strategy aims to increase the attractiveness of EVs by providing free parking spaces during the day without increasing the pressure on the more precarious parking situation in densely populated residential areas at night. Experience shows that during the day, only a slightly larger amount of EVs is used at the Charging Station, while at night the Charging Station is increasingly occupied by non-EV. Thus, the pressure can be successfully removed from the parking situation at night, but there is no sign of increasing attractiveness for EV users. This strategy therefore only serves to avoid unnecessary vacancies when there is a high demand for parking space [15].

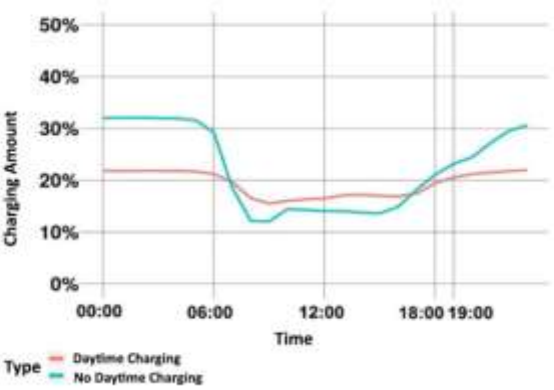

Fig. 8 Daytime vs No Daytime charging (own representation)

Looking to the future the Ministry of Economic Affairs declares, that furthermore the demand-driven strategy will be applied. To reduce the pressure on the public parking situation, more emphasis will be placed on Semi-Public Charging Stations. This refers to shopping centers, railway stations, and private business car parks. Furthermore, the stress on the electricity grid is to be reduced by Smart Charging methods [32].

5.2 Norway

Even though the promotion of EVs began in 1990, the governmental support of the Charging Infrastructure started in 2009 first. The National Transport Plan of Norway pursues the credo that all charging or fuel supply facilities for zero-emission vehicles must be easily available and accessible. This strategy shall minimize waiting times in urban areas and make delay-free long-distance driving possible [17] [27] [29].

In 2009 Enova (a Norwegian agency founded with money from petroleum and natural gas sales to promote the reduction of greenhouse gas emissions and to improve energy efficiency) invested initially 50,000,000 NOK on the “normal” EV Charging Infrastructure. Thus 100% of the installation costs of normal Charging Points (up to 30,000 NOK) were funded. Thereof around 1,800 household sockets (schuko) have been created all over the country. As federal funding continued, and many municipal subsidies were introduced (e.g. 16,000,000 NOK by the city of Olso from 2008-to 2011) [33], more Charging Points with Type 2 connectors were installed. As household sockets have proven themselves as not practicable for charging EVs, many of them have been upgraded to Type 2 connectors or were taken out of service, due to high maintenance costs [17] [27] [29]. The first Public Charging Stations were mostly placed by a market-driven approach. Therefore, the principle “first ask, first served” was used [33]. Additionally, the responsible Agency surveyed the streets to look for places with a high density of parked (electric) vehicles and no Charging Stations [34].

Experience in Norway has shown that although most EV owners use Home Charging, it is essential for them to be able to rely on a functioning Fast Charging Infrastructure. This allows users on longer journeys to recharge if necessary, without excessive waiting times. In the favor of a functioning market economy, users are also prepared to pay up to three times the normal price of electricity at Fast Charging Points [27]. Particularly for Fast Charging Stations, an initial support program was established by the government from 2010 to 2014. The volume of funding amounted to 50,000,000 NOK. The scheme funded up to 100 % of the costs for the installation of Fast Chargers. There was no support for the operating costs, which had to be borne by the operator. Also, there was no national payment system. Hence every operator had to provide its own, functioning payment solution by the deadline. In 2015 Enova presented a plan aimed to cover all Norwegian main roads with Fast Charging Stations every 50 km. To provide a Charging Infrastructure with state-of-the-art technology, the operators must install at least two Fast Charging Points (ChAdeMO and CCS) and two normal 22 KW Type 2 Charging Points per Charging Station. The potential operators could compete for public

funding by applying for smaller segments into which the roads were split.
Besides this procedure, the Norwegian authorities can observe a tendency, that operators to build Fast Charging Stations without governmental support. This is evidence that Norway is on the threshold of a functioning market economy, where Charging Stations are built for economic reasons [27] [29].

6. Adapting Best Practice to Greece

So, what's the best rollout strategy for Greece? As Unni Berge, Head of Communication and PR at the Norwegian EV Association breaks down the results of a survey among Norwegian EV users [28], "Really it's all about the money […] EVs are simply more financially efficient." In terms of a rollout plan, there are two overarching issues to consider which represent the chicken or egg dilemma. In the following, the distribution of vehicles and the development of the infrastructure will be treated.

6.1 Increasing the Market Share of EVs

From the experience of Netherlands subsidies, it is clear that general subsidization of EVs does not necessarily lead to a reduction in air pollution. This is since BHEVs were purchased in the majority of cases, but they were mainly used in combustion mode. From this, it can be concluded that subsidies should specifically support the sale of pure BEVs. This can be done through minimum range limits or direct subsidies. To counter this problem, Norway is pursuing a strategy of linking EV tax advantages to the CO2 emissions of the respective vehicle. These subsidizing measures must be maintained until the EV market offers cheaper vehicles, or EV vehicles are offered which are cheaper than their Internal Combustion Engines equivalents. In general, monetary subsidies are most important to increase the market share of EVs. Both the reduction of the initial purchase costs (elimination of VAT and purchase tax) and the reduction of current costs (road tolls and road tax) are the decisive purchase incentives. Non-financial support such as free parking or access to the bus lane are cost-effective measures but are usually not a key purchasing factor [29].
This funding could be financed by the "polluter pays" principle. The Greek tax system is predestined for this kind of approach, as the road tax for vehicles is already scaled based on CO2 emissions and additionally there is a luxury tax for vehicles with large-volume ICEs [35]. Following the Norwegian example this revenue can be used for zero- and low-emission vehicles. The targeted use of these revenues has been shown to increase public acceptance of EVs and their funding. As Greece is still in the "Innovators" phase, the support must be maintained until technological progress has developed the market to a point where, through the economics of scale, choosing an EV is always the economically sound decision, even without subsidies [28].

6.2 Raising an adequate Charging Infrastructure

Regarding the Charging Infrastructure, by comparing the EV markets of the Netherlands and Norway, it is clear that an exclusive focus on the development of a Street Charging Infrastructure is not the ideal way to promote the establishment of EVs. Especially in the "Innovators" phase, vehicle owners mostly do not depend on a Street Charging Infrastructure, as they rely on Home Charging. For this target group, the development of a Fast Charging Infrastructure at strategic motorway junctions is much more decisive as a buying incentive. Considering Greece's relatively unstable electricity grid, the promotion of Home Charging should also be considered. This is best done by promoting Type 2 connectors to provide a state-of-the-art Home Charging Infrastructure and to be prepared for the future (increasing battery capacities) in the form of adequate charging times [17]. However, especially in Greece, it is still necessary to build a Street Charging Infrastructure in densely populated residential areas in a relatively early stage of electrification compared to Norway. That is because in countries like Greece with lower accessibility of private parking spaces it is more likely that EV users will have to rely on Street Charging overnight in the "Early Adopters" phase already [36] [37]. The evaluation of the Usage Profiles in Section AA.2 shows that most vehicles cover the daily distance in two or more separate trips. Charging possibilities between these journeys (e.g. Employee Charging) can reduce the need for Street Charging Stations and should also be taken into account when establishing a support program for electromobility.
The approved approach for the placement of Charging Stations in an urban or residential area is the demand-driven one. The nationwide Fast Charging Infrastructure along highways should be established at regular distances, and the number of Charging Points itself should correlate with the traffic volume along the individual sections of the highway. As the CCS and Type 2 connectors have largely established themselves as the standard in Europe, they should be used mainly. Subsidies should be maintained until a functioning market economy is established (through an increased market share of EVs) among the operators of the charging stations [38].

7. Results

The result of the analysis of the charging infrastructure in this paper is that an average daily driving distance of 22.6 km can be covered by charging through public Charging Stations. An expansion of the fast charging infrastructure at strategic points along the highway is still necessary to increase the practicability of EVs and to overcome range anxiety. Based on the results of a study and own calculations, it can be concluded that 0.14 street Charging Points per vehicle can cover the demand for Charging Points in a residential area. Due to the low required charging power resulting from the low distance traveled, it can be concluded that purely fast-charging infrastructure is not necessary. Furthermore, not all car models have the possibility to use this charging concept. Also, the power supply system is not designed for this.

The findings of the research can help solve the chicken or egg dilemma of promoting electromobility in Greece. A clear conclusion can be drawn: It is not chicken or egg, but chicken and egg. Greece is currently in the “Innovators” phase, which means a functioning and nationwide fast-charging infrastructure must be established. Furthermore, due to the dimensioning of the Greek electricity grid and domestic installations, the promotion of home charging should be considered in this phase. Because of the housing and private parking conditions in Greece, more attention will probably have to be paid to public street charging in residential areas already in the “Early Adopters” phase D.

The experience of the Norwegian and Dutch EV markets proves, that a highly developed charging infrastructure alone won’t promote the market share of EVs in the desired way. Therefore, buying incentives for EVs must be created, especially ones of a financial nature. For reasons of economy and acceptance among the population, the promotion of EVs and charging infrastructure should be financed by the "polluter pays" tax principle. Measures to regulate parking policy serve no more than to fine-tune the capacity utilization of individual staging areas to increase profitability.

If one projects the results of this paper onto the Greek Plan for Energy and Climate, good approaches for reaching the set goal of 33% market share of EVs in 2030 can already be seen in it. Summing up, it remains to be constantly evaluated in which phase the expansion of the Greek EV market is to adjust and specify measures in time for the future according to the proposals shown. The overall objective must be to establish a functioning market economy through the economics of scale, to be able to discontinue subsidies.

8. Discussion

It should be noted that the mentioned measures only apply to the “Early Adopters” phase. Concepts already exist for all but there are still no reliable examples of use. Therefore, it is necessary to continue observing the pioneer countries to adopt suitable measures. With growing amounts of data, a strategy can be chosen in the future using simulation-based approaches. To verify these approaches, the studies should be carried out in already well-developed infrastructures to extrapolate the validated results to other countries. It remains to be observed how technical developments change the charging infrastructure. For example, smart charging is one way to effectively use the capacity of the Charging Infrastructure without overloading the electricity grid. An often-underestimated factor regarding the acceptance of new technologies, such as EVs, is their practicability. Simple handling for the user of infrastructure is therefore important. It has been shown that both the various payment platforms for charging power and the diversity of charging cables and connectors require standardization to increase convenience. The advantage of building infrastructure in Greece is that there is no strong automotive lobby, as is the case in Western European countries, for example, that can block development. In countries such as Greece, which do not have an economically significant automotive industry, the promotion of electromobility can take place without harming their own economy. Instead, electrification can be an opportunity to take advantage of the great potential of renewable energy in Greece. Considering the current state of the world economy, caused by the COVID-19 pandemic, there is a unique opportunity for Greece. If the country acts on the model of the Norwegian subsidies following the 2008 global economic crisis, which not only stimulated its own economy but also gave the starting signal for the massive promotion of electric mobility [29], an enormous boost for the electrification of Greek mobility could result. In addition, the expansion of the charging infrastructure could boost the associated branch of the economy. The money thus gained in the energy sector could flow directly back into the expansion of RES. This makes it financially easier to achieve the goals stated in the National Plan for Energy and Climate. In addition, this energy mix would improve the ecological footprint of electro mobility in Greece enormously.

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