Assessing the Deployment of Electric Mobility: a Review

Sarah B. Gruetzmacher[1][0000−0002−1193−4461], Clara B. Vaz[1,2][0000−0001−9862−6068] and Ângela P. Ferreira[1][0000−0002−1912−2556]

[1] Research Centre in Digitalization and Intelligent Robotics (CeDRI), Instituto Politécnico de Bragança (IPB), Campus Santa Apolónia, 5300-253 Bragança, Portugal
[2] Centre for Management and Industrial Engineering (CEGI/INESC TEC)
`sarah.gruetz@gmail.com`
`{clvaz,apf}@ipb.pt`

Abstract. The transport sector of the European Union is the only sector of the economy that has been increasing its emissions since 2014. To reduce the use of fossil fuels and achieve the greenhouse gas emissions mitigation target, many countries are focusing on the deployment of electric vehicles. This paper aims at analysing recent literature on the deployment of electric vehicles (EV) and typifying objectives, methods and indicators generally exploited, to better understand the state of the art on this topic. The Web of Science database was used and the results showed that the interest in the topic of electric vehicles has been increasing exponentially since 2010. The main significant indicators and the assessment methodologies were analysed. The indicators identified were aggregated in four main clusters: environmental, economic, social and technical indicators. Although the factors that contribute to EV deployment can vary depending on the regions specific characteristics, most of the research studies pointed out that the main contributors are the high density of recharging points, the existence of government monetary incentives and the lower operational cost of EV.

Keywords: Electric vehicles · Deployment · GHG emissions.

1 Introduction

To meet the climate goal set in the Paris Agreement and achieve climate neutrality by 2050, the European Union (EU) set in 2014 a target of 40% reduction in the domestic greenhouse gas (GHG) emissions by 2030 when compared to 1990 levels [1, 2]. All Member States should contribute to the overall reduction with the efforts allocated among them on a basis of relative Gross Domestic Product (GDP) per capita. Regulation (EU) 2018/842 [3] presents the targeted percentage reduction for each country to achieve by 2030 calculated using 2005 GHG emissions levels. Figure 1 shows these targets as red dots, in addition to the GHG emissions evaluated in 2018 in blue, both compared to 2005 levels (i.e., 100%).

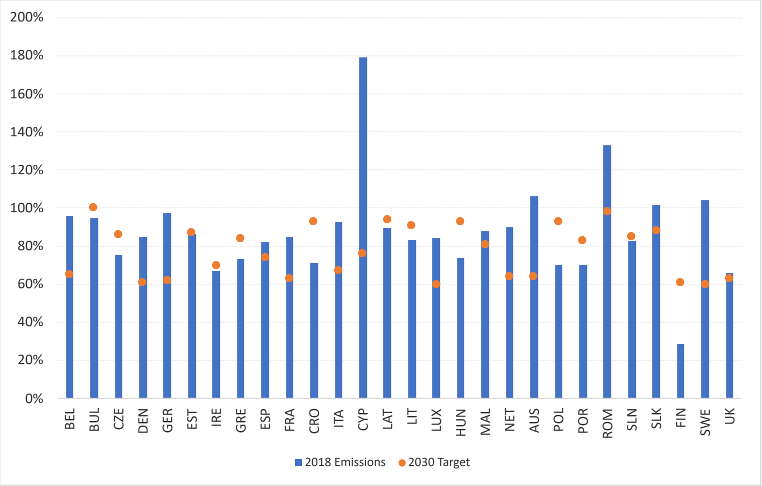


Fig. 1: 2018 GHG emissions and 2030 targets for EU countries, compared to 2005 levels. Adapted from [3, 4].

Half the EU countries have already achieved their target, but some work still needs to be done, especially since the EU pursues a GHG emissions reduction of 55% and will come with a new proposal by June 2021 [5]. The contributions to reduce the emissions should be made by all sectors of the economy, i.e., industry, transport, electric energy production, residential and commercial and also agriculture [3]. However, despite technological improvements, the GHG emissions from Europe's transport sector have increased since 1990, as shown in Fig. 2 [2, 6]. In 2018, this sector was responsible for 28% of the EU's total GHG emissions or 21% when excluding international aviation and shipping [8].

Passenger cars largely dominate the inland passenger transport, accounting for 83% of the total volume. Unfortunately, this mode of transport remains very oil dependent. In 2019, the sales of petrol passenger cars in the EU maintained their best sellers position with almost 60% of the total sales of the year and over 73% of the transport related GHG emissions in Europe came from road transportation, as shown in Fig. 3(a) [2]. Under this transportation mode, passenger cars are the main contributors, accounting for more than 60% of the total GHG emissions from road transport (Fig. 3(b)) [8–10].

To reduce the emissions from the transport sector some important changes were proposed in the White paper on transport strategy from 2011 [11]. One of these changes aims at a drastic reduction in the utilization of petrol vehicles, by halving their number by 2030 and phasing them out of the cities by 2050. Another paradigm shift is to use cleaner energies on road transport which is fundamental for a low carbon transition where the electrification of the transport sector has a fundamental role.

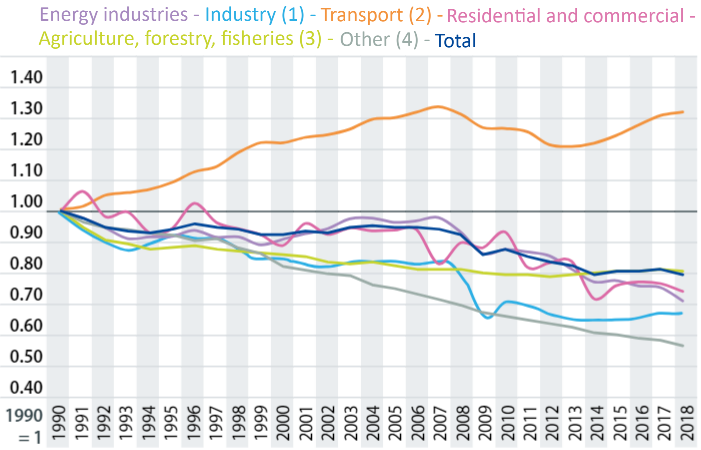
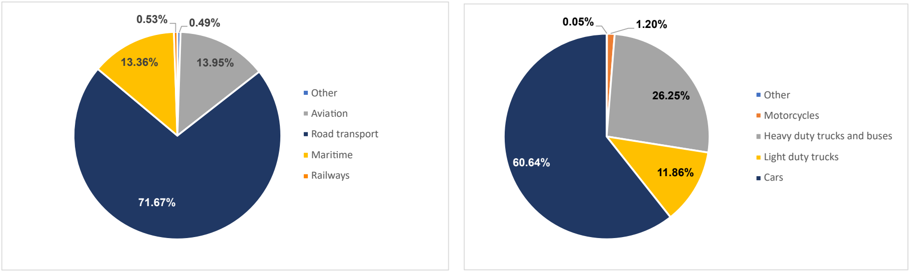


Fig. 2: Variation of GHG emissions by sector from EU-27 [7]. (1) Emissions from manufacturing and construction, industrial processes and product use. (2) Excluding international maritime, but including international aviation. (3) Emissions from fuel combustion and other emissions from agriculture. (4) Emissions from fuel combustion in other (not elsewhere specified), fugitive emissions from fuels, waste, indirect CO_2.



(a)

(b)

Fig. 3: Share of GHG emissions from transport in the EU (a) by transport mode and (b) by road transport mode. Adapted from [10].

From the above, it is clear why the electric mobility area has been receiving much attention and significance in recent years, and the electric vehicle fleet is expanding at a rapid pace. Worldwide, the number of passenger cars sold in 2020 has decreased by 15.3% when compared to 2019 values, and in the EU market this decline was of 23.7% [12]. The registrations of new passenger cars have fallen significantly across the globe due to the outbreak of the COVID-19 pandemic in the beginning of 2020. In the same period, the electric vehicles (EV) sales have increased due to a raised awareness on environmental issues and also tax/fiscal incentives: 3,24 million electric vehicles were sold worldwide, which is 43% more than the previous year. Europe registered 1,4 million new EV during 2020, a growth of more than 137% from 2019 [13].

The deployment of EV is a strategy used by many countries to reduce the use of fossil fuels and further mitigate GHG emissions [1]. The aim of this paper is to exploit and analyse recent literature on the deployment of electric vehicles regarding their environmental and energy sustainability, aiming at typifying objectives, methods and indicators to better understand the state of the art on this topic.

This paper is organized as follows: Sect. 2 gives some context into the electric propulsion-based vehicle, introducing the existing EV types and the EU policies related to their deployment; Sect. 3 presents the literature review on electric vehicles deployment, the indicators identified, the methodologies and main results from the source papers. Finally, Sect. 4 rounds off the paper, drawing the conclusions of this work.

2 Electric Propulsion-based Vehicles Context

Electric vehicles were among the first vehicles introduced in the 1800s and by 1900 they represented a third of all road vehicles [14]. However, limitations on the battery technology and the scarce grid electrification, combined with cheap oil prices and technological development of the internal combustion engine (ICE) vehicles, drove the interest away from EV. Nowadays, climate change, concerns on the environment and the forthcoming end of the oil age due to depletion of world reserves, have brought the interest back to the EV in the last decades.

2.1 Existing Types of Electric Propulsion-based Vehicles

Currently, there are a few different types of powertrain configurations for electric vehicles, as stated hereinafter.

The battery electric vehicles (BEV) are fully electric vehicles that rely on one or more electric motors for propulsion. The energy is obtained from electrical charging points and stored in the batteries [15]. The battery is also charged through regenerative braking. BEV have zero tailpipe emissions, however, as will be discussed later in this paper, their actual emissions depend on the carbon intensity of the primary energy source, from which is obtained the electricity.

Another type of EV are the plug-in hybrid electric vehicles (PHEV). PHEV are primarily powered by an electric motor with a plug-in battery and uses an ICE to extend the cruising range. The battery can be charged using the plug-in, by the ICE or through regenerative braking [14].

Hybrid electric vehicles (HEV) are powered by a combination of a conventional ICE and an electric motor, to improve its fuel efficiency. The battery cannot be plugged in for charging, it is replenished by energy generated by the ICE and regenerative braking [16].

Finally, electric vehicle can be powered through a fuel-cell, named fuel-cell electric vehicles (FCEV). Their typology is similar to BEV, by using an electric powertrain, but, it uses a full cell stack device to produce electric energy [17]. The fuel cell is an electrochemical device that converts the chemical energy of hydrogen into electrical energy and heat. The hydrogen is combined with an oxidizing element (often oxygen) inside the fuel cell stack and the reaction produces water, heat and electricity, the later powering the electric motor [18]. The electric energy generated by a fuel cell can directly power the traction motor of the vehicle or it can be stored in a battery or a ultra-capacitor. Most FCEV have a battery for recapturing braking energy, providing extra power during short acceleration moments and to smooth out the power delivered from the fuel cell [19].

Figure 4 summarizes the main differences between EV powertrains types. For petrol and diesel cars, the local and method for refuelling is well-established and straightforward. However, for plug-in electric vehicles (PEV), i.e. BEV and PHEV, the recharging process can be accomplished in different locations, at different charging rates, depending on the vehicle model and/or the electric power available. A learning curve will be necessary in the transition to PEV and should focus on enabling a behaviour shift to electric mobility by addressing issues such as lack of infrastructure related to EV, preconceptions and doubts from the general public and lack of awareness among public administrations and citizens concerning electric mobility [20, 21].

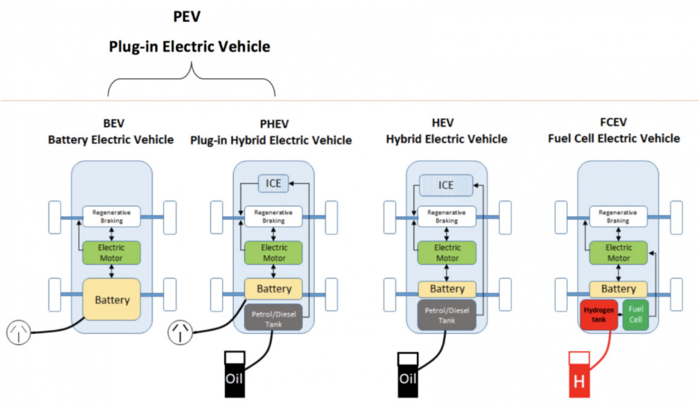


Fig. 4: Differences between the types of EV available [22].

2.2 Policies Related to Electric Vehicles

To foster the deployment of electric vehicles, governments worldwide have introduced an increasing number of incentives at the consumer-level, such as purchase subsidies and parking privileges [23]. By 2020, in the EU, 26 out of the 27 countries have applied some kind of fiscal measure to stimulate EV purchase. Twenty countries offer incentives to buyers and 6 countries only offer tax reductions or exemptions for electric cars. The monetary value of these incentives varies greatly across the EU. Table 1 presents a summary of the countries that provide tax exemptions or reductions for the acquisition and/or ownership of EV. It also shows the countries that offer monetary purchase incentives and the values applied. A more detailed overview of these benefits can be seen in [24].

Concerning to car manufacturers, one of the policies set by the EU to push the electrification of road transportation forward is to limit CO_2 emissions of their fleet [25]. Regulation (EU) 2019/631 sets a mandatory target for the average emission of the manufacturer's overall fleet of new passenger cars of 95 grams of CO_2 per kilometer by 2021 [26]. To reach this limit, a great market introduction of partially and full EV is required [25]. Mathieu et al. [8] mention that although the CO_2 emission standards were created as a climate regulation, they can also be seen as a great industrial policy since it propels the car industry to invest and supply the zero emissions technologies in Europe for the near future.

The growing sales of electric cars across Europe in the last years have resulted in a significant drop in new car CO2 emissions. In 2020, they reached 111g/km, 9% bellow the 2019 levels of over 122g/km, which is the largest drop since the standards came into effect in 2008 [8]. Figure 5 shows the market share of plug-in electric vehicles (BEV and PHEV) in the EU and the 5 countries with the highest market share by 2020. Ten of the 28 countries (EU-27 + UK) have surpassed 10% market share for PEV.

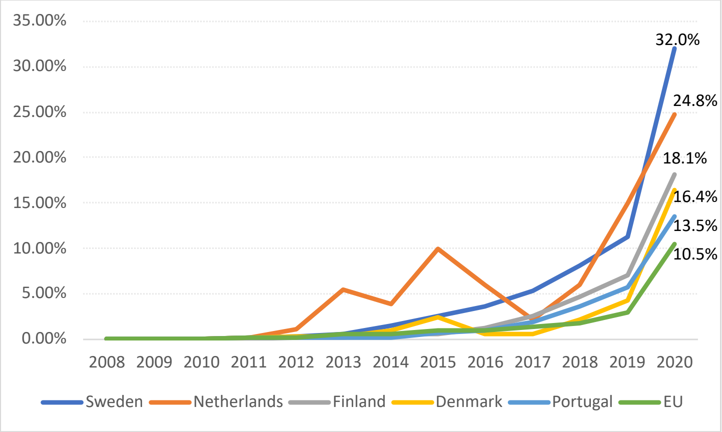


Fig. 5: PEV market share of the top 5 EU countries and the EU. Adapted from [27].

Furthermore, the GHG emissions reduction potential from EV is heavily dependent on its energy efficiency and the carbon intensity of the primary source for electricity generation. Nevertheless, an average EV using electricity characterised by the current global carbon intensity (518 g CO2-eq/kWh), over their life cycle, emits less GHG than the average ICE vehicle using gasoline [28]. The

Table 1: Summary of countries that have tax benefits and purchase incentive (values in Euro) for passenger EV. Adapted from [24].

Country	Tax benefits		Purchase incentive		
	Acquisition	Ownership	BEV	PHEV	FCEV
Austria	x	x	3000	1250	3000
Belgium	x	x	-	-	-
Bulgaria	-	x	-	-	-
Croatia	x	x	9200	4600	-
Cyprus	x	x	-	-	-
Czech Republic	x	x	-	-	-
Denmark	x	x	-	-	-
Estonia	-	-	5000	-	-
Finland	x	x	2000	-	-
France	x	-	3000-7000	3000-7000	3000-7000
Germany	x	x	7500-9000	5625-6750	7500-9000
Greece	x	x	15% cashback (up to 5500)	-	-
Hungary	x	x	1500-7350	1500-7350	1500-7350
Ireland	x	x	up to 5000	up to 5000	-
Italy		x	up to 6000	up to 6000	up to 6000
Latvia	x	x	-	-	-
Lithuania	-	-	-	-	-
Luxembourg	-	x	5000	2500	5000
Malta	x	x	-	-	-
Netherlands	x	x	-	-	-
Poland	x	-	8300*	-	20000*
Portugal	x	x	3000	-	-
Romania	-	x	10000	4250	-
Slovakia	x	x	8000	5000	-
Slovenia	x	-	7500	4500	-
Spain	x	x	4000-5000	1900-2600	-
Sweden	-	x	6000*	1000*	-
United Kingdom	x	x	up to 3000	-	-

(*) Values given in local currency and converted to Euro.

avoided emissions in road transport outbalance the higher emissions from the electricity generation and, according to the European Commission projection, by 2050, a 10% reduction of the total emissions from all sectors could be achieved [6]. From a technological point of view, the fleet electrification, combined with the penetration of renewable energy sources to generate electricity and the advances in energy storage, such as green hydrogen systems, are the best approaches for for further reducing GHG emissions.

3 Review Methodology on Assessing the Electric Vehicles Deployment

3.1 Systematic Approach

A review on the literature was performed to analyse the methodologies used to assess the deployment of electric vehicles through a set of indicators. A search was made for articles between 2010 and 2021, evaluating the deployment of electric vehicles. Only articles published on journals were chosen from the Web of Science (WoS) database.

The first search for the term "electric vehicles" on the WoS database, in the 2010 to 2021 period, returns more than 16 thousand articles. Only in the first quarter of 2021, 742 articles on this theme have already been published. Figure 6 shows the growing interest in this subject in the past ten years.

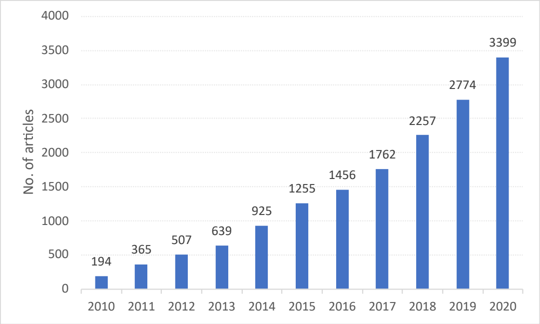


Fig. 6: Number of articles on electric vehicles published by year.

A keyword analysis using the VOSviewer software [29] divided these articles into four clusters, enabling to identify the main areas of study in this theme. The first cluster relates to batteries development, modeling and performance, as well as their degradation and recycling potential. Another cluster is defined with works related to the EV design, such as system, motor and energy management. The third cluster is composed by works analysing the EV impacts on the energy system and generation. These works deal with demand response, smart grids, renewable energy and power quality. Finally, the last cluster includes works in the area of interest of this paper, that are related to EV deployment and adoption, government policies and incentives and sustainable mobility.

To reduce the search for relevant papers in the subject under analysis, relevant keywords from the selected cluster were selected and applied in the search engine: “electric vehicles”, “sustainab*” and “deployment” OR “adoption”. From this search, it was possible to identify several indicators that have been used to assess the deployment of EV through quantitative methodologies. Table 2 summarizes the main significant indicators under use, the paper source and also the assessment methodology. The objectives, indicators and methodologies from the selected works, as well as their main conclusions are presented hereinafter.

3.2 Analysis and Discussion

Onat et al. [30] explore the suitability of BEV in the United States and identifies the policy strategies that are necessary to increase their competitiveness in each state. A novel multi-criteria decision-support framework is proposed based on Data Envelopment Analysis (DEA) and Agent-based modeling (ABM). DEA is used to assess the efficiency of using BEV in each state using the inputs operation cost and environmental impact (GHG emissions, energy consumption, water withdrawal and consumption) and the output data (the service provided per vehicle-miles travelled); ABM estimates the future market share using as inputs the government subsidies, social acceptability and the availability of charging infrastructure in each state. By coupling the relative performances from DEA and the possible market share from ABM the relative policy inefficiencies are revealed. DEA is a non-parametric technique that assesses the efficiency of a set of homogeneous decision making units (DMU) in using a multiple inputs to produce multiple outputs. It identifies the efficient DMU, which define the efficient frontier, enabling to quantify the inefficiency of the remaining DMU [31]. DEA uses mathematical linear programming to derive weights for inputs and outputs of each DMU, avoiding the subjectivity observed in others methods or expert-based weights assignment [30]. ABM is a discrete-event simulation approach in which the system under analysis is modeled as a collection of autonomous decision-making entities called agents [32]. ABM enables to simulate the interactions among different agents in a virtual environment. Each agent individually assesses its situation and makes decisions on the basis of a set of rules [30]. The work divides the states into four groups regarding their utilization score and efficiency score in order to suggest prioritization on investment in electric power generation or in policies for BEV adoption. Each state requires its own set of policy recommendations, however, this work helps to narrow down the main targets for future policies.

The authors Wang et al. [33] assess the city readiness for EV adoption through the analysis of 25 demonstration cities using a Partial Least Square (PLS) path model and a clustering analysis approach. A PLS path model with five factors (latent variables) was used in the analysis. These factors consist of government policies and investments, charging infrastructure construction and operation, business models and maintenance service system, consumer awareness

Table 2: Reviewed literature summarized.

Reference Region	**Objective**	**Methodology**	**Indicators**
Onat et al. (2017) [30] US states	Analyse the suitability of BEV	Data Envelopment Analysis (DEA) and Agent Based Modeling (ABM)	– GHG emissions – energy and water consumption – operation cost – government incentives – social acceptability – charging infrastructure
Wang et al. (2015) [33] Chinese cities	Assess the city readiness for EV adoption	Partial Least Square (PLS) path model	– government incentives – charging infrastructure – maintenance services – consumer awareness education – environmental benefits
Thiel et al. (2019) [34] EU countries	Analyse the impacts of EV policies in different areas	DIONE and SHERPA models	– EV/recharging point ratio – EV market share – charging infrastructure – job creation – GHG emissions – energy demand
Neves et al. (2019) [38] 24 EU countries	Analyse factors supporting the transition EV	Panel-Corrected Standard Errors (PCSE)	– No. of policies on EV – employment rate – education level – Industrial Production Index – GDP per capita – fuel and electricity prices – GHG emissions – charging infrastructure – battery price, range and capacity – renewable electricity generation – patents in the transport sector
Wang et al. (2019) [40] 30 countries	Identify factors that promote EV adoption	Multiple linear regression method	– EV market share – government incentive – charging infrastructure – environmental performance index – fuel and electricity price – income – vehicles per capita
Javid et al. (2017) [41] California counties	Explore factors related to PEV purchasing and estimate their penetration	Multiple Logit Regression Analysis	– car sharing – income and education – charging infrastructure – fuel price
Neves et al. (2020) [31] 20 European countries	Calculate the efficiency scores for BEV adoption and EV policies and examine their determinants	DEA and fractional regression	– EV market share – No. of policies – industrial production index – Brent crude oil prices – electricity intensity – No. of BEV models in top 10 sellers – renewable electricity generation – charging infrastructure – services added value – imports/exports rate – government incentives – socioeconomic indicators
Yong et al. (2017) [44] 24 countries	Analyse the factors affecting the deployment of EV	Fuzzy-set qualitative comparative analysis	– EV penetration rate – charging infrastructure – GDP per capita – government incentives – free charging points

education, operation scope and environmental benefits. Each latent variable is measured by a set of manifest variables collected from the summary report for each city. PLS Path Model is a method of structural equation which allows to estimate complex cause-effect relationship models with latent variables. Thus, the PLS path model consists of two parts, the measurement model, describing the relationships between latent variables and manifest variables, and the structural model, which describes the relationships among the latent variables [33]. The results in [33] show that the latent factors that most affect the city readiness of EV adoption are the charging infrastructure, government policies and investment. Based on the scores derived from the PLS path model, the clustering analysis is used to classify the 25 cities in terms of city assessment of EV adoption.

Thiel et al. [34] develop a holistic assessment of the impact of the EV deployment plans of the European Union. To assess the recharging point sufficiency, the ratio of EV per recharging point was calculated and maps with infrastructure density were produced for each member state. A new model is proposed to calculate job impact, using as input the infrastructure deployment, value added and productivity to estimate the gross job creation. The DIONE model is used to project pollutant emissions from the future EV shares. DIONE is a fleet impact model owned by the European Commission that is used to analyse fleet composition scenarios of European road transport up to 2050, including the projection of vehicle fleet composition, fuel consumption, pollutant emissions and energy consumption [35]. The pollutant emissions results from the DIONE are then employed in the SHERPA model. The SHERPA (Screening for High Emission Reduction Potentials for Air quality) is an air quality model with open access owned by the European Commission which produces air pollutant concentrations for each region. By assuming a linear relationship between concentration and emission changes, SHERPA allows the identification of regions where the pollution originates, the ranking of the sources of air pollution and also the simulation of the impact of air quality plans scenarios [34, 37]. This work concludes that the EU needs to take further actions in the deployment of publicly accessible recharging points by, for example, implementing incentives for their build-up.

Neves et al. [38] analyse factors that promote the EV adoption, including BEV and PHEV using data from 2010 to 2016 for a panel of 24 EU countries. A Panel-Corrected Standard Errors (PCSE) model is used to analyse the factors driving the market share of BEV and PHEV individually, and all EV together. The factors analysed include several areas, such as government policies (number of policies on EV), social aspects (employment rate and education level), economic indicators (Industrial Production Index, GDP per capita, fuel price and electricity price), environmental indicators (GHG emissions) and technical aspects (number of charging stations per 100 thousand inhabitants, battery cost, battery range, battery capacity, renewable electricity per capita, patents in the transport sector). PCSE is a panel regression model used to deal with the presence of contemporaneous correlation in time-series data. This model accounts for the deviations from spherical errors, allowing for better inference from linear models [39]. The results show that policies should be focused on BEV or PHEV, instead of EV as a whole, since factors that support BEV are different from the ones for PHEV.

Wang et al. [40] also identify the key factors that promote EV adoption. The relationship between these factors and the EV market share for the year 2015 in 30 countries is explored using multiple linear regression method. This method assesses the linear relationship between one dependent variable and several independent variables using ordinary least squares. This study shows that chargers' density, fuel price and road priority are significantly positive factors correlated with a country's electric vehicle market share.

Javid et al. [41] explore the potential factors that can be attributed to the purchasing of PEV, in order to estimate their penetration in 58 California counties. Data from demographic and travel-related characteristics, socioeconomic variables, infrastructural and regional specifications were used to estimate the PEV penetration rate using Multiple Logistic Regression applied to a 2012 California Household Travel Survey dataset which includes both PEV and conventional car buyers' information. The logit regression model enables to predict a dichotomous dependent variable based on a set of independent variables, being the log odds of the dependent variable modeled as a linear combination of the independent variables. This study identifies that household income, maximum level of education in the household, car sharing status, charging stations density, and gas price in the region are the significant factors for PEV adoption.

In Neves et al. [31], DEA is used in a first stage to calculate the efficiency scores for 20 European countries of BEV adoption and policies supporting electric mobility. In a second stage, using the efficiency scores previously calculated, the Fractional Regression Model (FRM) enable to identify the significant determinants of electric mobility. FRM is a regression method used wherein the dependent variable is within the interval $[0, 1]$, being the estimation based on Quasi Maximum Likelihood method suggested by Papke and Wooldrige (1996) [42]. Since the DEA efficiency corresponds to the dependent variable, FRM is used in the second stage to identify their significant determinants [43]. This paper finds that few countries are performing on the efficiency frontier. Additionally, renewable electricity generation and the existence of peak periods of demand during the day decreases the efficiency scores.

Yong et al. (2017) [44] employ a fuzzy-set qualitative comparative analysis (fsQCA) to analyse the factors affecting the EV deployment and draw policy implications for EV promotion. The fsQCA is a form of succession of qualitative comparative analysis (QCA) since variables can get all the values within the range of 0 and 1. The fsQCA is a social science method that combines qualitative (case-oriented research) and quantitative (variable-oriented research) analysis. The study concludes that to promote electric vehicles countries should focus on tax exemptions, purchase subsidies and spreading charging infrastructure.

3.3 Main Results

From the performed survey, it is possible to grade the indicators into four main groups: environmental, economic, social and technical indicators. Thus, the environmental indicators include the GHG emissions, energy and water consumption, renewable electricity generation, environmental benefits and the Environmental Performance Index. The economic indicators encompass the government incentives, GDP per capita, fuel and electricity prices, operational costs, maintenance services, battery prices, import/export rate and the Industrial Production Index. The social indicators comprehend job creation, income, EV social acceptability, consumer awareness education, number of policies on EV, employment rate, vehicles per capita, car sharing and service added value. Finally, the technical indicators include the charging infrastructure, free charging points, EV typology market share and penetration rate, number of BEV models on the top 10 sellers maintenance services, battery range and capacity, patents in the transport sector, energy demand and electricity intensity.

A general analysis of these indicators showed that the ones related to the charging infrastructure were the most frequently used in the assessment approaches, followed by the EV market share and government incentives. The methodologies employed are diverse, depending on the type of data used and the various possible approaches to explore the EV deployment or adoption.

From this research analysis, it is possible to identify a trend on policy plans being region specific, since the characteristics and necessities can vary significantly. Nevertheless, most authors pointed out that the main contributors to the deployment of electric vehicles are a high density of recharging points, the existence of government monetary incentives, such as tax exemptions and purchase subsides, and the lower operational cost of EV (electricity vs. fuel prices).

4 Conclusions

Although most sectors of the EU economy have been reducing their GHG emissions, the transportation sector has been increasing their emissions since 2014. Since most of these emissions are related to the road transport and specifically passenger cars transport, the EU countries strategy is focused on the electrification of the sector. Even though EV are not yet commercially competitive with ICE vehicles, namely in terms of driving range, EV sales have been increasing, with some countries recently reaching a 10% market share. In 2020, registrations of electric vehicles in the EU have increased 137%, when compared to 2019, mainly caused by the promotion of different scheme of incentives, tax exemptions or reductions for the acquisition and/or ownership of EV in European countries.

The objective of this paper was to analyse existing literature on the deployment of electric vehicles and typifying objectives, methods and identify relevant indicators for assessing the deployment of electric vehicles. This issue is included in one of the main clusters of papers published in the literature related to EV deployment and adoption, government policies, incentives and sustainable mobility. Using the Web of Science database, a search was made for articles evaluating the deployment of EV that applied various methodologies to a set of indicators. The main significant indicators and the assessment methodologies were analysed, and the first ones were aggregated in four main clusters: environmental, economic, social and technical indicators.

Although the factors that contribute to EV deployment can vary depending on the regions specific characteristics, most of the research studies pointed out that the main contributors are a high density of recharging points, the existence of government monetary incentives and a lower operational cost of EV.

As the EV market deploys, research directions should be updated to include for instance driving range, fostered by improved storage systems, and green electricity availability. Also, new electricity market frameworks, on a two-way grid edge concept towards a decentralized and transactive electric grid, have the potential to affect the transition to electrified road transportation.

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