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ELECTROMOBILITY IN POLAND AND SLOVAKIA. BENCHMARKING OF ELECTRIC VEHICLES FOR 2019

Since the entry into force of the Paris Agreement in 2015, and with the publication of the Intergovernmental Panel on Climate Change report on the consequences of 1.5 degrees of global warming, the issue of reducing greenhouse gas emissions in a cost-effective manner and within the timeframe outlined has become a matter of urgency. The transport sector, which accounts for a quarter of total GHG (Greenhouse Gas) emissions in the 28 EU Member States, is no exception. Due to the serious environmental impacts of transport, new mobility concepts are being implemented at both national and international levels. One of these is the large-scale deployment of electric vehicles, including those powered exclusively by Battery Electric Vehicle (BEV) batteries. They are quiet and virtually emission-free and, in terms of safety, have the feature that, in the event of an accident, they reduce the risk of detonating the vehicle and of burning or burning out the passengers. This article presents the current state of electromobility in Poland and Slovakia with an indication of light electric cars BEV and the most important factors stimulating its development.

Keywords: *electromobility, electric car, charging station, noise*

1 Introduction

The framework established by the European Union in the field of climate and energy for 2030 sets targets for reducing greenhouse gas emissions (carbon dioxide emissions by 20%), increasing the share of renewable energy by 20% and increasing energy efficiency by 20%. It is assumed that by 2030 the emission of greenhouse gases should be reduced by 40% compared to 1990 and at least 32% of energy should come from renewable sources [1-2]. In order to achieve these assumptions, the European Parliament noted that efforts will have to be made in all the sectors, as well as the introduction of many different solutions with a converging target [3-4]. Currently, among the sectors of the economy, the largest source of emissions is transport, which accounts for a quarter of the greenhouse gases emitted in the EU, and its share has been still growing in recent years. As a result, significant progress has been made in recent years in reducing the environmental impact of vehicles. This progress mainly concerns the reduction of pollutant emissions through development of the power trains and use of alternative fuels, reduction of consumption of natural resources and reduction of waste through recycling of the end-of-life vehicles or reduction of the noise emissions. However, on a sectoral basis, this impact still remains significant, due, inter alia, to the steadily increasing number of vehicles on the road and increasing mileage. The European Environment Agency forecasts that demand for mobility in the EU will increase by around 60% in 2050. The continuous increase in demand for transport therefore requires further steps to reduce its negative effects so that carbon dioxide emissions are reduced by 80 to 90% by 2025 [5-8]. One of them is the intensively implemented strategy of using alternative vehicles, including those powered exclusively by Battery Electric Vehicle (BEV), in the European Union transport sector. The scale of changes to be made in this respect in the coming years is best illustrated by one of the assumptions of the White Paper entitled "The European Union's transport policy for alternative vehicles". "A Roadmap to a Single European Transport Area - Towards a Single European Transport Area a competitive and resource-efficient transport system" - halving the number of conventionally propelled cars in urban transport by 2030 and eliminating them from cities by 2050, and according to the EU, all the new passenger cars sold at that time are to be fully electric by 2035 [9]. The goal, which from today's point of view seems unrealistic to meet due to many economic, technological and social barriers, may be achieved within the next few decades, taking into account the continuous development and technical progress [10]. Electromobility, is currently considered to be the best possible solution to solve the problems discussed above [11]. The manufacturers point out that with limited possibilities of modification of internal combustion engines, electric cars may be not only one of the ways to improve the local air quality but also affect development of the dispersed renewable sources, lower dependence on the import of fossil fuels and, thus, a higher level of energy security. These favorable features make battery-powered cars a serious candidate for the mitigation of greenhouse gas emissions and air pollution from transport [12-14]. This publication discusses the current state of electromobility

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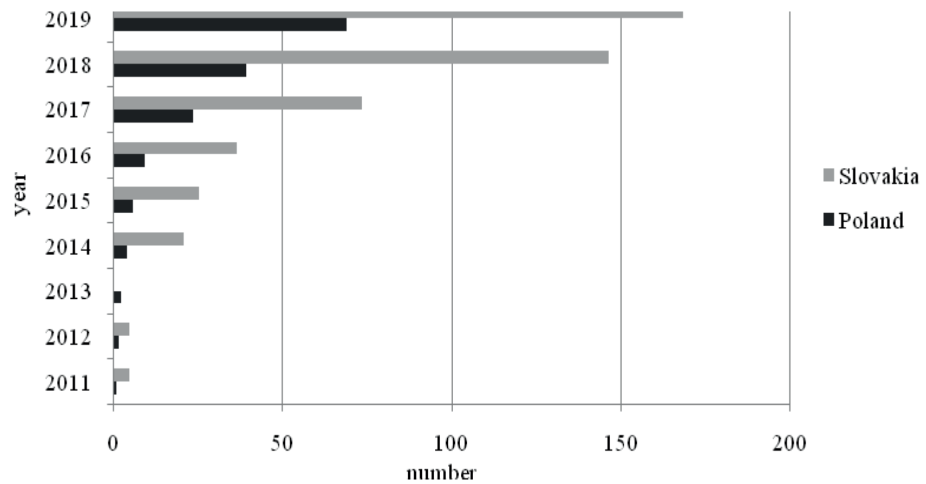

Figure 1 *Number of BEVs in Poland and Slovakia per 1 million inhabitants [15]*

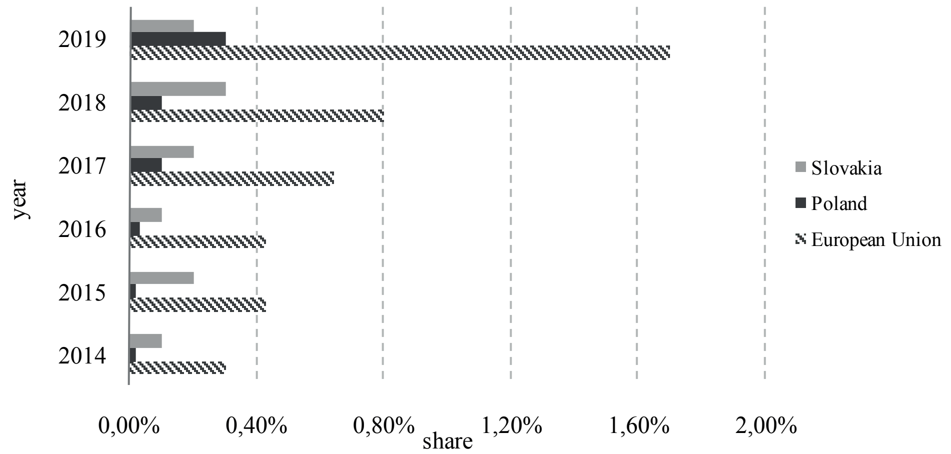

Figure 2 *Share of BEV electric cars in the automotive market in 2014-2019 [15]*

in Poland and Slovakia, paying special attention to M1 passenger cars of the BEV type.

2 Current electric car market in Poland and Slovakia

Analyzing the global statistics on the rate of growth of electric cars and realizing EU requirements concerning, among others, the improvement of air quality, also Poland and Slovakia are facing the electricity age. In 2019, 68 such vehicles were registered in Poland per 1 million inhabitants, while 169 in Slovakia (Figure 1), which represents 0.3% (Poland) and 0.2% (Slovakia) of the automotive market in the analyzed countries (Figure 2).

In the years 2011-2019, the number of registrations of the new BEVs in Poland grew on average by 56% year on year, while in Slovakia by 24% (Figure 3, Table 1). The greatest increase in the number of newly registered BEVs, as compared to the previous year, was recorded in Poland in 2017. The number of new registrations increased there by 244%. In Slovakia, the biggest growth year by year was in 2013 - 433%. In 2019 the number of the new BEV registrations, compared to 2018, increased by 91% in Poland and decreased by 55% in Slovakia. In 2019, the number of electric cars has increased since 2011 - by 3560% in Slovakia and twice as many in Poland - by 7349%.

Number of the new BEVs registered in 2019 per 1 million inhabitants in Poland was 69 and 168 in Slovakia, which makes them ranked 22 and 26 among the European Union countries (Figure 4).

In January 2018 the Parliament (Sejm) of the Republic of Poland passed the Act on Electromobility and alternative fuels, in which it obliged municipalities and districts of over 50000 inhabitants to assure a minimum 10% share of electric vehicles in their fleet by 1 January 2022. The sanction for failure to implement the regulations will be the expiration on 31 December 2021 of contracts for the performance of public tasks with entities that do not comply with the requirements (except for public mass transport). The provision is to apply not only to local government offices themselves, but also to all companies performing public tasks commissioned by the local government. Such units deal, inter alia, with public transport, waste management or fire protection. Additionally, from 2028, local governments will be able to outsource the performance of services only to such entities, which will be able to provide a fleet with a 30% share of low-emission vehicles in a given area. A challenge may be to ensure that an appropriate percentage of the fleet of electric refuse collectors, snow

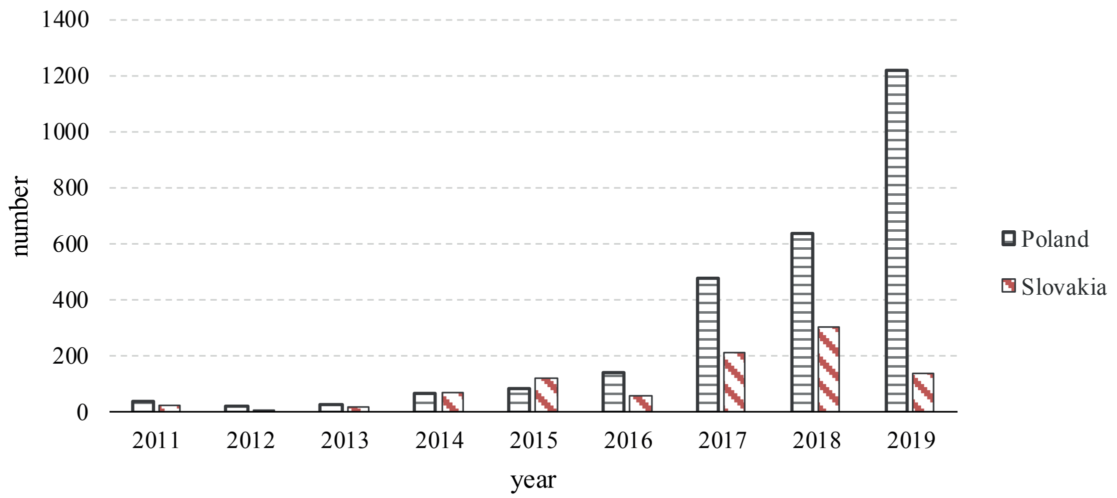

Figure 3 *Number of new registrations of the BEV electric cars in Poland and Slovakia in the years 2011-2019 [15]*

Table 1 *Number of new BEV registrations in 2011-2019 (growth, dynamics)*

Year	Number of BEV registrations		Absolute growth (compared to the previous year)		Increase Relative (compared to the previous year)		Growth rate in %		Individual Chain Indices	
	Poland	Slovakia	Poland	Slovakia	Poland	Slovakia	Poland	Slovakia	Poland	Slovakia
2011	35	25								
2012	19	3	-16	-22	-0.46	-0.88	-46%	-88%	0.54	0.12
2013	27	16	8	13	0.42	4.33	42%	433%	1.42	5.33
2014	68	69	41	53	1.52	3.31	152%	331%	2.52	4.31
2015	86	123	18	54	0.26	0.78	26%	78%	1.26	1.78
2016	138	55	52	-68	0.60	-0.55	60%	-55%	1.60	0.45
2017	475	209	337	154	2,44	2.80	244%	280%	3.44	3.80
2018	639	302	164	93	0.35	0.44	35%	44%	1.35	1.44
2019	1221	136	582	-166	0.91	-0.55	91%	-55%	1.91	0.45
			average rate of change						1.56	1.24
			medium-term pace of change						56%	24%

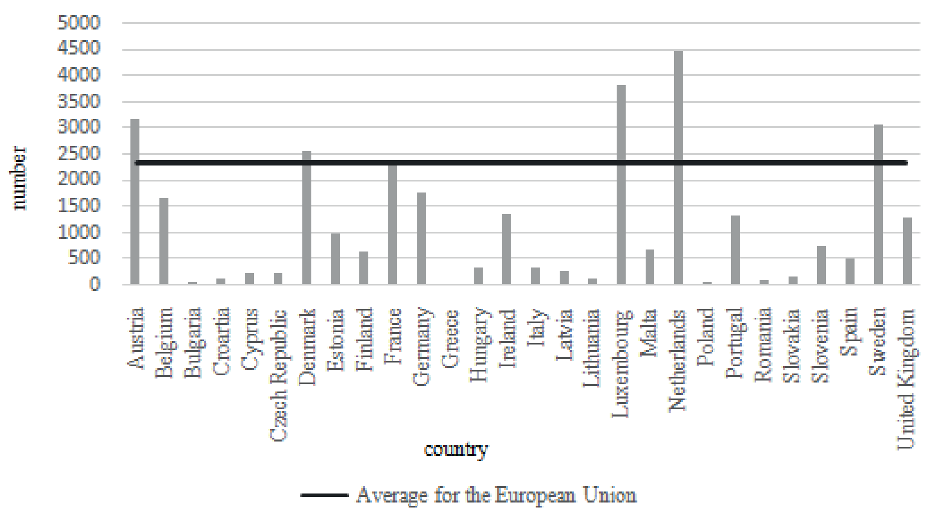

Figure 4 *Number of the new BEVs registered in the European Union in 2019 per 1 million inhabitants [15]*

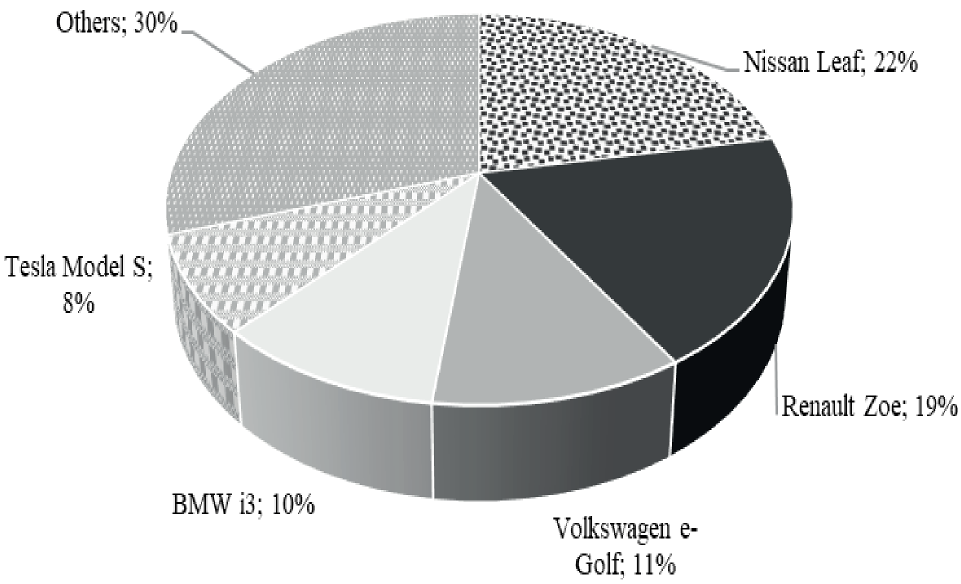

Figure 5 *The five most frequently purchased electric cars in the European Union in 2018 [15]*

Table 2 *BEV car prices [20-27]*

Mark	Model	Price (euro)		Difference in value (%)
		Poland	Slovakia	
1	2	3	4	5
Renault	Zoe R110	29251.64	31900	-8%
Volkswagen	e-UP!	22532.34	19900	13%
Volkswagen	e-Golf	33202.97	37270	-11%
Nissan	Leaf	36387.78	34250	6%
Kia	e-Soul	36972.79	31790	16%
Hyundai	Kona Electric	38836.69	38490	1%
Hyundai	Ioniq	38508.95	37290	3%
BMW	i3	39538.98	55258	-28%
BMW	i3s	42933.38	55258	-22%
Audi	e-Tron 50 Quatro	70207.50	79900	-12%
Tesla	M Model 3 Long Range RWD	60968.43	56700	8%

shovels or sweepers is available. Such vehicles are difficult to access on the market - it was only in 2018 that the first electric garbage truck in Europe took to the streets of Amsterdam. In addition, the cost of such equipment can be high for a long time, which will translate into the price of services that residents will have to pay. In turn, the central and central governments have been obliged to increase the share of the BEVs in their fleet to a minimum of 10% by the end of 2021, to min. 20% by the end of 2022 and until min. Exemption from this obligation is provided for vehicles used by the Ministry of Foreign Affairs, SW (Prison Service), KGP (Chief of Police), ITD (Road Transport Inspection), ABW (Internal Security Agency), KGPSP (State Fire Service Headquarters), AW (Intelligence Agency), KAS (National Revenue Administration), KGSG (Border Guard Headquarters), CBA (Central Anti-Corruption Bureau), SWW (Military Intelligence Service), GDDKiA (General Directorate for National Roads and Motorways) and State Protection Services. The sanction for non-compliance is the same as in the case of local government units - termination of the contract with the entity providing business services in the field of transport.

3 Barriers to electromobility development in Poland and Slovakia

The marginal number of the BEVs in use today proves that the market for electric mobility in both Poland and Slovakia is still in its infancy. Today, having an electric car - although it has many advantages - is still quite burdensome for the owner. The first difficulty, already when buying such a car is limited choice and then their price. In 2018 (as of 06/2018), consumers had only fifty-two BEV models

***Table 3** Price of selected new passenger cars with different engines in Poland [euro]*

Mark	Model EV	Price	Model whit ZS	Price	Model whit ZI	Price
1	2	3	4	5	6	7
Nissan	Leaf	30 184.64-38 909.89	Juke	16 980.73-19 808.67	Juke	16 980.73-20 990.07
Renault	Zoe	28 746.15-33 725.62	Clio	13 323.69-14 856.50	Twingo	10 848.80-14 620.68
Volkswagen	e-golf	33 202.97	golf	20 280.30-27 826.46	golf	18 865.40-22 166.84
Volkswagen	e-Up!	22 532.34	-	-	Up!	9 432.70

***Table 4** Price of selected new passenger cars with different engines in Slovakia [euro]*

Mark	Model EV	Price	Model whit ZS	Price	Model whit ZI	Price
1	2	3	4	5	6	7
Nissan	Leaf	34 250	Juke	-	Juke	16590
Renault	Zoe	31 900	Clio	15 400	Clio	9850
Volkswagen	e-golf	37 270	golf	16990	golf	21050
Volkswagen	e-Up!	19 900	-	-	Up!	22 170

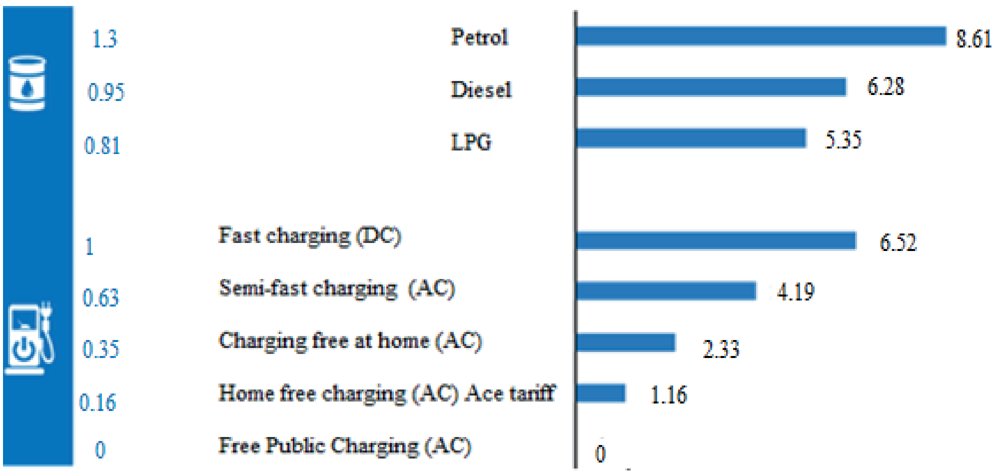

***Figure 6** Costs of refueling combustion cars and charging electric cars in Poland [euro] [32]*

to choose from with over four hundred of the Internal Combustions Engines (ICE) models. The lion's share at that time belonged to five models, as shown in Figure 5.

Often, both in Poland and Slovakia, the BEV models cannot be seen in the dealership and after one buys it, he/she has to wait long to collect it. Almost all the consumer studies have shown that one of the main obstacles to the implementation of e-mobility is the higher price of battery-powered electric cars compared to similar models with conventional internal combustion engines [16- 19]. In Table 2, the ratings of new the BEVs in Poland and Slovakia are presented and for the selected ones, in Tables 3 and 4, they are compared to prices of cars with conventional drive of similar power and equipment.

Meanwhile, already today, from the economic point of view, the total costs of ownership (TCO = costs of purchasing a car (CAPEX) + costs of its use in a specific time (OPEX) of an electric car are lower than that of a vehicle with a conventional engine [28]. This is primarily due to significant differences in electricity prices vs. other fuel, lower maintenance, service and repair costs due to their simpler construction. Compared to the ICE vehicles prices, they may be even for 30% lower [29]. According to the research, consumers rarely make a purchase decision based on a rational financial analysis [30]. Most of them even think so that the costs related to the operation of an electric car are much higher than in the case of vehicles with conventional drive [31]. Taking into account the current prices of energy (antismog tariff) and fuel, the costs of driving 100 km through the BEV in Poland is at least five times lower than in the case of vehicles with classic propulsion. The costs of fueling combustion cars and charging electric cars, presented in Figures 6 and 7, were developed for a B-segment car, normal driving (15000 km/year) in a mixed cycle, according to fuel prices, of a network of chargers and average energy prices for individual consumers. The consumption per 100 km is assumed: 15 kWh, 61 diesel, 81 unleaded petrol (95), 111 LPG. Table 5 shows the costs of driving 100 km by electric vehicle in Poland and Slovakia in 2018.

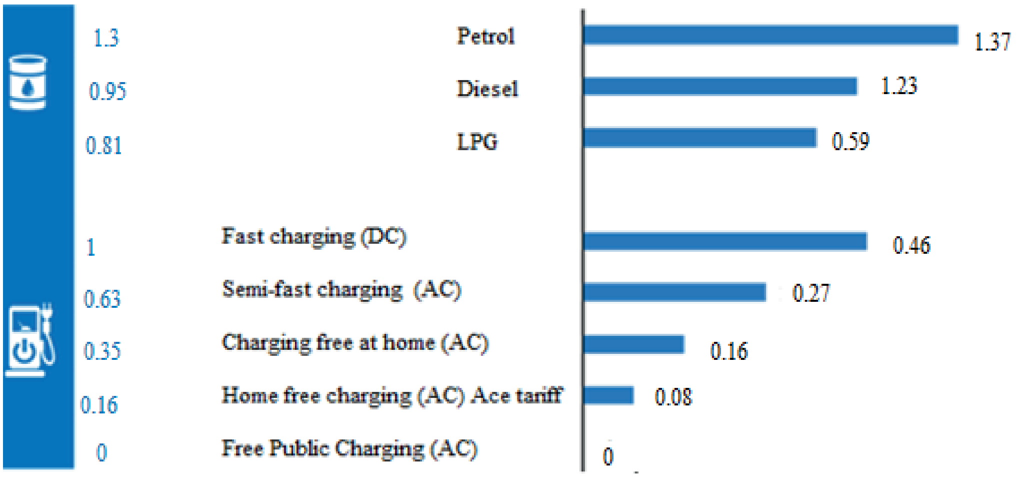

Figure 7 *Costs of refueling combustion cars and charging electric cars in Slovakia [euro] [32]*

Table 5 *Costs of driving 100 km by electric car in Poland and Slovakia in 2018 [33]*

Mark	Model	Cost of Driving 100 km (euro)	
		Poland*	Slovakia**
1	2	3	4
Hyundai	Ioniqelectric	1.98	2.32
Nissan	Leaf	2.75	3.23
BMW	I3	2.34	2.74
Tesla	Model S P90D	3.22	3.78
TeTesla	X 100D	3.22	3.79
Renault	Zoe	2.73	3.20
Volkswagen	e-golf	2.32	2.73
Volkswagen	e-up!	1.96	2.30

**0.13 euro/kWh*
***0.16 euro/kWh*

Problems related to the spread of battery cars in Poland and Slovakia should be considered not only in financial terms, but in terms of their efficiency, long charging time and infrastructure barriers, as well. The infrastructure in this market relates mainly to the network of charging stations, on which the mobility of electric vehicles depends and appears to be a key barrier to market diffusion, as well as a major source of consumer concern about changing their preferences. In the case of early stage markets, which is undoubtedly the market for electric cars BEV in Poland and Slovakia, it is important to adapt the pace of infrastructure development to increase in the number of its users. Too many vehicles with a shortage of charging stations may discourage future users. On the other hand, building a large number of stations in the absence of charging demand will make investments in stations scarce. It can be expected that barriers related to charging infrastructure will gradually disappear in Poland and Slovakia.

Development of infrastructure is driven by government regulations and subsidies, but also by the strategies of energy companies and companies from the automotive sector. Directive 2014/94/EU of the European Parliament and of the Council, "Clean energy for transport", recommends that by 2020 there should be one public charging point for every 10 registered plug-in electric and plug-in hybrid cars [34]. Figure 8 shows the number of the PEV (electric and plug-in hybrid cars) per charging point in the European Union in 2019.

At present (as of 12/2019), there are 247 public charging stations in Poland, located mainly in large cities (the largest number of stations is in Warsaw, followed by the most important examples of the type of chargers (for example in Krakow, Wroclaw, Katowice and Poznan), which provide a total of 582 plugs, of which only 64% allow for charging to 22 kW, 38% belong to the category of fast chargers (> 22 kW) (Figure 9). In Slovakia, 65% are slow chargers and 35% are fast chargers (Figure 9) [15].

In order to increase the number of public chargers for electric vehicles, the Polish legislator imposed an obligation on municipalities to put the relevant technical infrastructure into operation by 31 December 2020. The minimum number of charging points in publicly available charging stations was determined based on the number of inhabitants and registered vehicles in a given municipality. In the first years, the infrastructure is to be developed on a commercial basis. This means that the possibility of

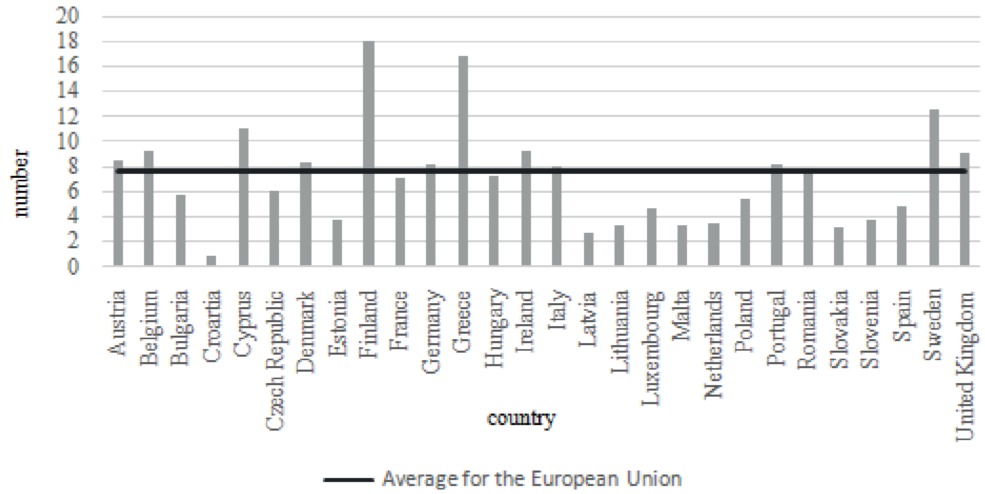

***Figure 8** The number of PEV (BEV + PHEV) per one charging point in 2019 in EU countries [15]*

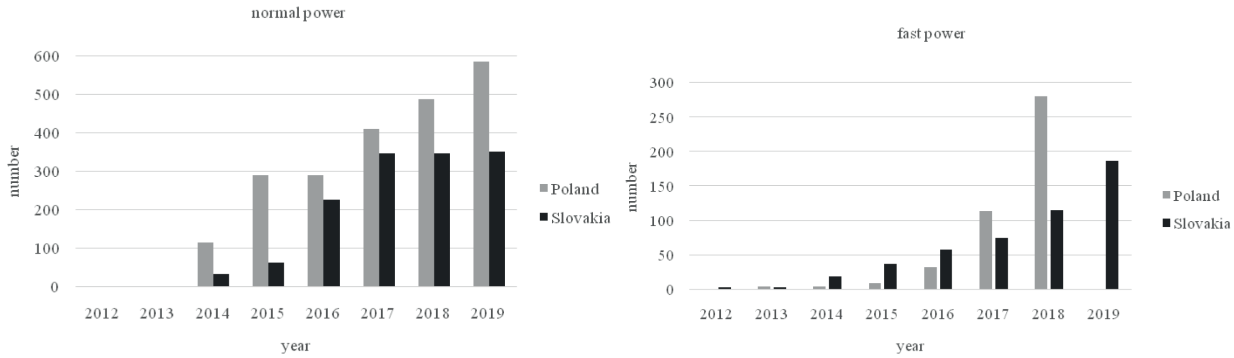

***Figure 9** Number of publicly available electric vehicle charging points in Poland and Slovakia [15]*

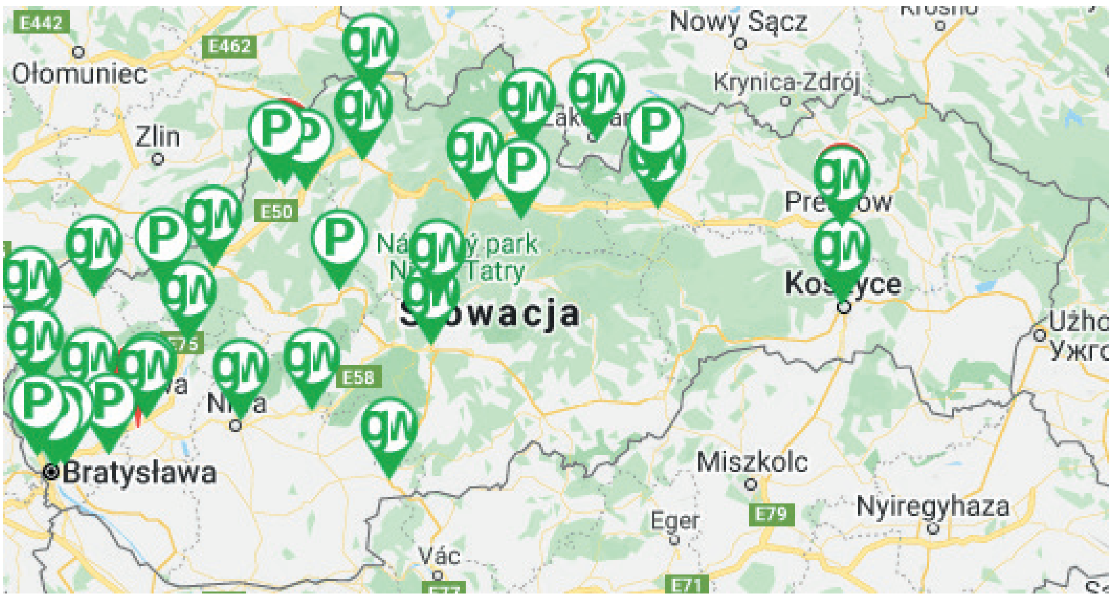

***Figure 10** Charging stations in Slovakia Greenway [37]*

building publicly available stations will be open to all the entrepreneurs through the public tenders. If the minimum number indicated in the Act is not reached by 15 January 2020, the burden of network development will lie with the distribution network operators (DSOs). In such a case, the executive bodies of local governments will be obliged to draw up a schedule for station construction, consulted with the DSO. However, no discounts are foreseen for the construction of the charging infrastructure or its financing from the central budget. Moreover, the legal procedures for obtaining a station construction permit may take up to 18 months. According to the concept of the Ministry of Energy of the Republic of Poland, 6000 publicly available charging points of normal power and 400 of high power will be built in Poland by 2020. Electric vehicle charging stations in Slovakia are located in every region (Figure 10).

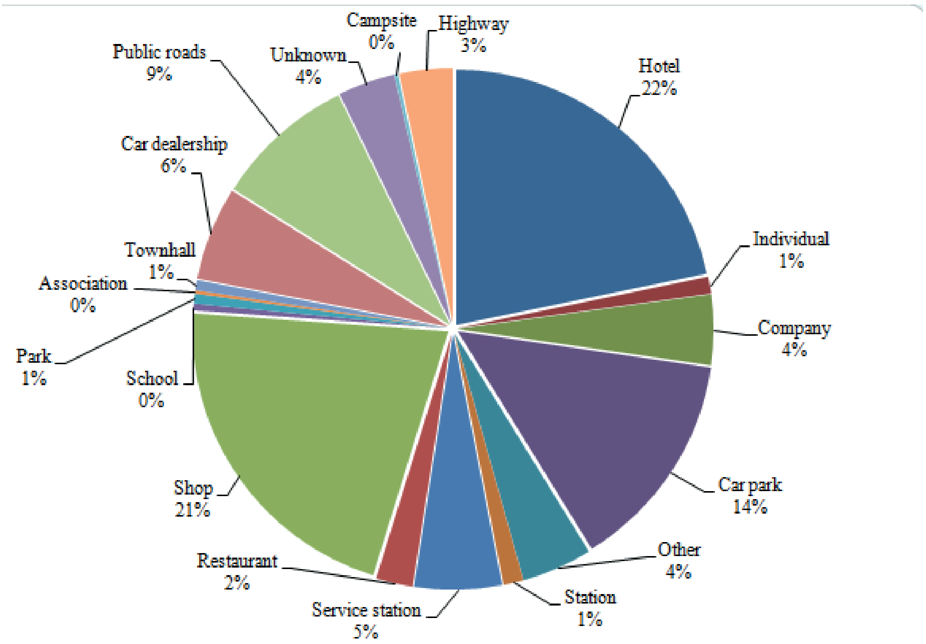

Figure 11 *Location of charging points in Poland [38]*

Additionally, another 80 new stations are planned to be built near motorways, first class roads and cities [35]. In Budca, the first 350 kW ultra-fast station was built in 2018 and two 175 kW stations in the Next-E project. The location of the charging point is near the R1 motorway and it is equipped with all the typical connections [36]. It belongs to the WEEE (*Waste of Electrical and Electronic Equipment)*, which built another 9 Budca stations this time at McDonald's car park. They are planning 13 new stations in Bratislava, Trnava, Nitra, Trencin, Zilina, Zvolen, Banska Bystrica, Prievidza, Liptovsky Mikulas, Martin, Kosice and Presov. The Next-E project, which is financed by a fund from the CEF of the European Union and in the Slovakian training area, provides for the construction of 25 stations 18 fast and 7 ultra-fast chargers [20].

However, the problem of the number of charging points is not the only problem related to the infrastructure of electric cars in Poland. It is very often difficult to access them (Figure 11).

One often needs to call and make an appointment in advance to benefit from charging. One may also find that he/she cannot use the charger as there is no suitably qualified person to start the charger. It happens that the free charging at the car wash can be used only after buying the most expensive package [39].

4 Proposed incentives in Poland and Slovakia

In order to encourage the potential car buyers to buy the BEV electric cars, several incentives have been introduced in Poland and Slovakia to encourage them to buy this type of vehicle. In Poland, the Ministry of Energy has in recent months presented plans to introduce subsidies of up to 30% of the cost of purchasing an electric vehicle. In the latest version of the draft, this amount is expected to be a maximum of EUR 8 658.56 for passenger cars, whose purchase price must not exceed EUR 29 237.68. This means that only a few models available on the Polish market will be able to count on surcharges (Skoda CITIGOeiV- 20 265.36 euro, Volkswagen E-UP! - 22 532.34 euro, Seat MII electric - 18 720.40 euro, Peugeot E-208 - 29 222.47 euro, Renault ZOE - 29 237.68 euro, Opel E-Corsa - 29 231.62 euro and Smart EV For two - 22 116.80, EV For four - 22 467.86 euro), none of which belongs to the bestselling vehicles on the European market. Support for commercial vehicles, for which subsidies may amount to as much as EUR 47 163.50 regardless of the price of the vehicle, may prove much more beneficial. An important stimulation of development and at the same time benefit for users of electric cars is to be the application of the so-called soft support instruments. In Poland, drivers of the BEV electric vehicles, thanks to the Act on Electromobility, were given the opportunity to drive from February 2018 to 2026 on bus pass. In addition, the road manager may make the driving of such vehicles on the designated lanes dependent on the number of people travelling together in such vehicles [40]. In 2018, there were 276.9 km of bus lanes in Poland as a whole (an increase of 7.2% y/y), more than half of which were designated in only four cities: Warsaw, Krakow, Wroclaw and Lodz [41]. Over the last six years in some cities, the length of bus lanes has been reduced, for example in Torun as much as 13 times (from 17 km in 2013 to 1.3 km in 2018). Electric car drivers will therefore be able to use from the privilege, as long as they move in the four largest cities. In order to help identify vehicles entitled to use the BEV's bus ports for electric vehicle users, blue stickers with the indication "EE" are issued in Poland and from 2020 they can apply for green license plates. Another privilege granted to BEV electric vehicle users is the possibility of free parking in the paid parking zone in cities. Additionally, as is apparent from the above law, in addition to hydrogen and natural gas cars, electric cars will be able to drive in the low-emission zones, which can be designated by the municipality.

The Ministry of Economy of the Slovak Republic, on the other hand, introduced Act No. 71/2013 in accordance with § 11 Section 6, introduced electronic registration for granting of subsidies for the purchase of an electric vehicle for 2019. The Ministry of Economy of the Slovak Republic will co-finance the purchase of an electric vehicle in the amount of EUR 8000. This is the second version of the grant. The first one from the middle of 2016 provided for the co-financing in the amount of 5000 euro and it covered 800 BEVs, which was 70% of the e-vehicles. The Act aims to encourage Slovak drivers to purchase alternative powered vehicles including the BEVs. Private persons are entitled to receive such a subsidy, as well as The Legal entities: entrepreneurs and business entities without public participation. It is also available to the public administration of the commune and higher units, budget organizations supported by the commune and economic entities, which are partially owned by the commune. Private persons are persons who are not entrepreneurs and are the registered as tax-payers. Only the new cars not previously registered without the first owner are subsidized [36, 42]. In 2017, the Slovak government encouraged the purchase of electric cars by granting benefits from the registration tax, and other financial benefits [43]. In 2019, the Slovak government is considering an electromobility development plan. This plan consists of 16 measures to encourage drivers to buy electric vehicles. The measures are to be: financial assistance for the purchase of zero-emission vehicle, investments in charging stations, green procurement, license plates for electric vehicles not used in Slovakia, use of the zero-emission zone and lanes, simplification of administrative procedures for the construction of infrastructure [20, 44].

5 Discussion and conclusions

Currently, the BEV electric car market both in Poland and Slovakia is in the early stages of development, as evidenced by the small share of such vehicles in the automotive market and the lack of a sufficiently developed network of public charging points. Undoubtedly, an important factor in the intensification of e-mobility in Poland and Slovakia will be the proposed financial incentives, so that the purchase of an electric car will not deviate significantly from prices of similar models equipped by the conventional internal combustion engines. It is because that is currently the biggest barrier to the development of electric cars. For example, the electric version of the popular VW Golf costs at least 40 088.97 euro and its petrol-fueled equivalent 24 053.38 euro (with similar engine power and equipment) while with a diesel engine 25 235.25 euro [45].

It is also important on the part of the principals, to launch a set of non-financial incentives, as well as financial support for expansion of the charging infrastructure. This is all the more important since nowadays a mid-range fully charged electric car can cover a distance of 100-200 km, depending on the year of production, which, with a daily mileage of 25 km in the city, requires recharging every few days [46]. If the vehicle is used for commuting to work and shopping, in most cases it will need free charging points at owner's home or workplace. A challenge arises when it is necessary to go out of town or move between distant towns [47]. The car will travel exactly as much as the capacity of the battery, whose charging cycle is up to several hours. In practice, it makes it impossible to travel more than 200 km, which is a significant concern for drivers. When travelling in such a car, drivers are afraid that the battery in their car will run out in a place far away from the charging station. In conclusion, if the legislators of the analyzed countries implement the announced BEV measures, this will undoubtedly affect development of the electromobility market. One of the attributes of electromobility is its quiet vehicle operation. The low level of noise emitted by the vehicle has less impact on the environment - other road users - and also on the vehicle crew [48]. Often, this aspect is in the assessment and comparison of an electric vehicle as an alternative to its other advantages, such as emission production. Governments and municipalities should also take into consideration the fact - how the environmental friendly electricity is available for charging the vehicle in a specific country. The mix of energy sources used for electricity production influences the GHG emissions from electromobilty. Each country reaches different values of the GHG production during the electricity production [49], thus the specific country needs specific sensible solutions in the problem of the future of mobility. Not everywhere is supporting electromobility really eco-friendly and brings decreasing of the GHG production of the country or region. This fact is also noticeable in the comparison of Poland and Slovakia.

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