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PROSPECTS FOR THE DEVELOPMENT OF ELECTRIC VEHICLE CHARGING INFRASTRUCTURE IN POLAND IN THE LIGHT OF THE REGULATIONS IN FORCE

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Abstract:

The Polish electric mobility market, presently at a relatively early development stage, cannot compete with traditional means of transport in relation to the number of locations enabling drivers to "refuel" their vehicles. Simultaneously, extension of the network of publicly available EV charging stations constitutes a vital prerequisite for electric vehicle industry development. The feeling of range anxiety connected with limited access to suitable EV charging outlets, in particular during longer trips, discourages potential buyers from purchasing electric vehicles, and, as a result, limited demand hinders development of this industry. In January 2018, the Polish Parliament (the Sejm) passed the Act on electromobility and alternative fuels which establishes a certain system and provides a number of objectives vital for electric vehicle market development. Being aware of the fact that, at least for the first few years, infrastructure development is a key factor, the legislator, in Art. 60, section 1 of the Act, establishes a minimum number of EV charging outlets to be installed in Polish communes, by 31 December 2020. However, no detailed guidelines as to their location were given. It only indicates a minimum number of them, which should be established in communes with a given demographic and transport characteristics of the commune ie the number of inhabitants and motor vehicles and the number of cars per 1000 inhabitants of the commune. The purpose of this article is to indicate in which, specifically, municipalities, according to the act, electric vehicles charging outlets are to be located. Based on the analysis performed it was determined that publicly available EV charging outlets must be installed only in 32 of 2477 communes in Poland and and these are municipalities. Identification of such communes made it possible to determine the distances between them, which made it possible to verify whether the network of EV charging infrastructure planned on the basis of the guidelines in the Act will enable efficient route travel in the future without experiencing any range anxiety. In addition, the existing market conditions were presented and discussed, with an indication of whether they are conducive to meeting the minimum set in the Act regarding the number of charging points. The conducted analysis is an introduction to further research on determining the optimal distribution of charging outlet in Poland.

Keywords: *electromobility, EV charging outlet, infrastructure, EV charging station, electric vehicle*

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1. Introduction

The acceleration of civilisational development observed since the end of the 18th century, in addition to a number of achievements, has resulted in gradual depletion of natural resources, impoverishment of the biosphere, ecological imbalance as well as lot of destruction, disasters and threats (Hiwaki, K., 2019; Khvatova, M.A., Magomedov, R.M., and Magomedrasulov. M.N. et al., 2019; Kochneva, L.V., Kurakin, A.V., and Be-Lov, V.E. et al., 2019; Ledwith, M., 2020; Sztumski, W., 2019). Thus the previous assumption stating that social development stems from the drive to satisfy people's material needs has been revised and rendered as incomplete (Jodkowska, L., 2001). The necessity to take into account the role of social and environmental factors, in addition to the economic dimension, in economic activity, with a view to satisfying the needs not only of the current generation but also the future ones, in line with the concept of sustainable development, has started being recognised (Fig. 1).

The European Union has been promoting the sustainable development concept for many years now. In particular, this refers to the transport sector which, among various anthropology divisions, is responsible for over a quarter of greenhouse gas (GHG) emissions, which makes it the second largest source of such emissions (Fig. 2) (COM, 2016).

The Community's objective is to create such an organised transport system that will adhere to the sustainable development rules, i.e. a system making transport and mobility services available to all inhabitants in a safe and environmentally-friendly manner, this contributing to economic development and society's prosperity enhancement (Correa, D.F., Beyer, H.L., Fargionec, J.E. et al., 2019; Nikołajewka, A., Adey, P., Cresswell, T. et al., 2019; Pisonia, E., Christidis, P., Thunis, P., and Trombetti, M., 2019; Standing, C., Standing, S., and Biermann, S., 2019; Zhao, X., Ke, Y., and Zuo, J. et al., 2020). Despite the fact that a sustainable transport system should integrate various modes of transport, taking into account the fact that road transport, in particular passenger vehicles (Fig. 3) whose numbers still increase in the European Union (Fig. 4), is responsible for most emissions (i.e. 73%), this sector requires altering the mobility paradigm, in the short-time perspective.

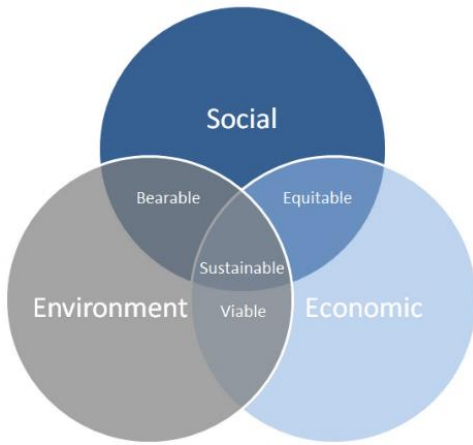

Fig. 1. Three pillars of sustainable development

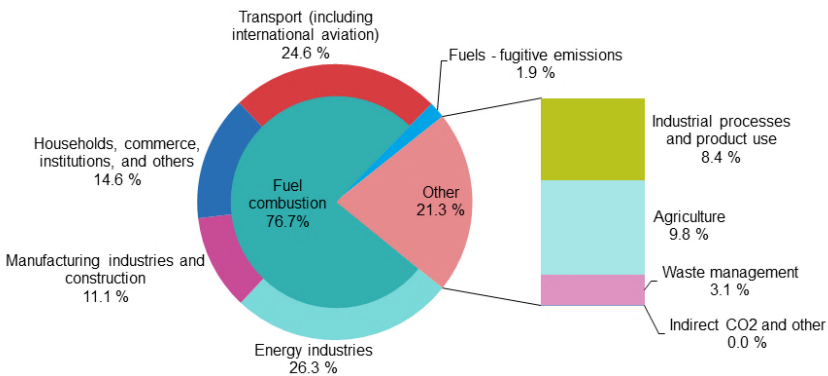

Fig. 2. Greenhouse gas emissions by IPCC (The Intergovernmental Panel on Climate Change) source sector, EU-28, 2017 (ESE, 2017)

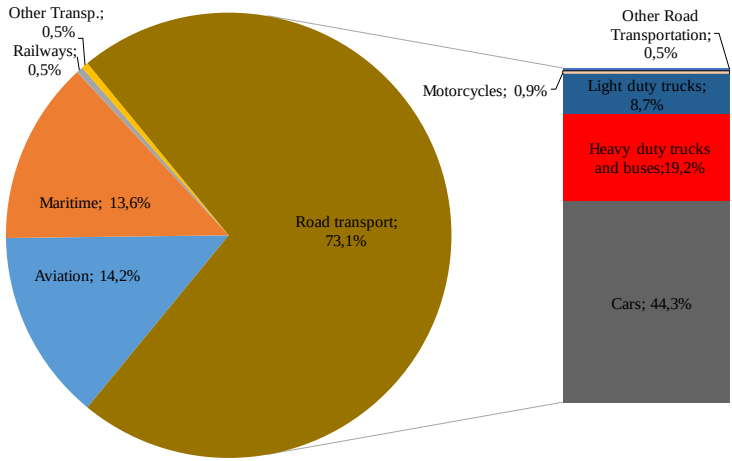

Fig. 3 Greenhouse gas emissions in the European Union transport sector, in 2017 (proprietary compilation based on (EUROSTAT))

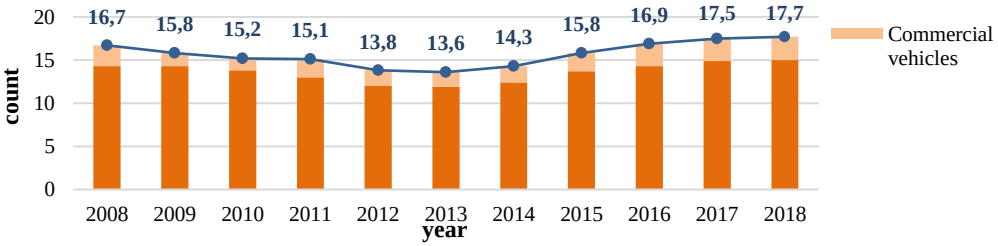

Fig. 4. Sales of vehicles in the European Union (million) (proprietary compilation based on (EAMA))

The method for bringing about this transformation is defined in the strategy developed in the White Paper, i.e. "Roadmap to a Single European Transport Area-Towards a competitive and resource efficient transport system" applicable in the European Union. The strategy encompasses ten extremely ambitious objectives simultaneously constituting guidelines for future actions and means for measuring development in the process of ensuring low-emission and zero-emission transport. The objectives include the goal of halving the use of conventionally-fuelled cars in urban transport by 2030, and phasing them out in cities by 2050 (EUWP, 2011).

Electromobility is a serious alternative for conventional mobility systems which has been gaining in popularity in the entire EU area (Milojević, S., Skrucany, T.H., and Stanojević, D. et al., 2018).

In 2011-2018, the number of new ECVs (Electric Commercial Vehicles) increased by 84% on average, on the year-to-year basis (Table 1).

In 2018, electrically-chargeable vehicles accounted for 2.0% of new cars registered across the EU, which is demonstrated in Figure 5. Such development is expected to continue over the next several years with special subsidy packages, as addressed in references (Babić, D., Bajor, I., and Babić, M.I., 2010; Hoerstebrock, T., Hahn, and A., Sauer, J., 2014), and especially in reference (Carbon, C.C., and Gebauer, F., 2017).

2. Current electromobility status in Poland

In Poland, the general acceptance of electricity-fuelled vehicles is much less significant. The share of such vehicles in the total number of vehicles on the automotive market registered in 2019 was only - 0.5% (Fig. 6). In that period, 8637 passenger electric vehicles were registered, including 5091 (i.e. 59%) Battery Electric Vehicles (BEV) and 3546 Plug-in Hybrid Electric Vehicles (PEHV).

Table 1. Number of electric vehicles in the European Union, in 2011-2019 (growth, dynamics) (proprietary compilation based on (EAFO))

Year	Number of ECVs registrations	Absolute increase (in relation to the previous year)	Growth rate in %
2011	35	-	-
2012	66	31	89%
2013	103	37	56%
2014	257	154	150%
2015	489	232	90%
2016	773	284	58%
2017	1712	939	121%
2018	3079	1367	80%
2019	4688	1609	52%
average change rate			1.84
medium-term change rate			84%

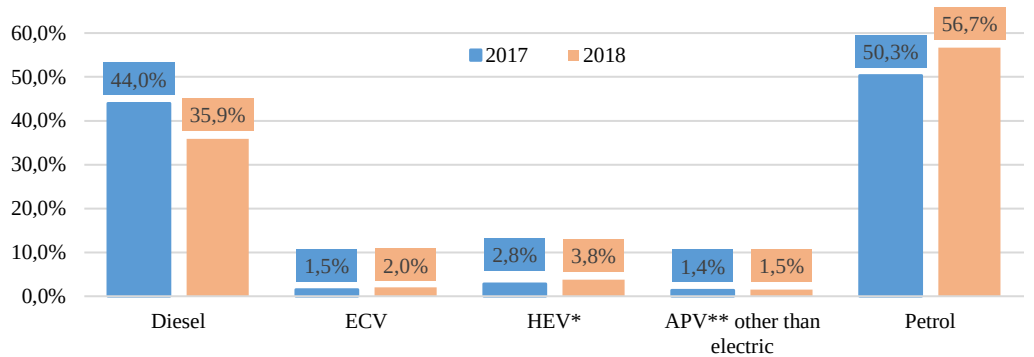

Fig. 5. New passenger cars in the EU by fuel type, % share (proprietary compilation based on (EAMA))

The negligible number of currently operated electric vehicles shows that the electric mobility market in Poland is still in its initial development phase. According results of research conducted among Polish drivers, the reason for marginal interest in ECVs is mostly their high prices and technical constraints, e.g. lack of sufficiently developed, publicly available charging infrastructure (Table 2), despite the fact that approx. 70 - 80% electric vehicle charging operations are performed in domestic facilities, and the average route (approx. 23 km, according to the Motor Transport Institute) can be driven without recharging. Also, recent literature has investigated the variety of barriers that EVs face, and generally found that typical barriers include range, and charging infrastructure (Krawiec, S., and Krawiec, K., 2017; Sendek-Matysiak, E., and Szumska, E., 2018; Wierzbowski. P., 2019; Zaniewska-Zielińska, D., 2018; Sendek-Matysiak, E., 2020). In (Sovacool, B.K, and Hirsh, R.F., 2009), implementing a qualitative literature review, found that EVs faced a variety of barriers, including price, conflicting social and cultural values, and charging infrastructure. Secondly many transport economists have attempted to quantify the barriers in choice experiments, typically finding that price, range, and charging infrastructure/time are the most costly barriers (Hidrue, M.K., Parsons, G.R., Kempton, W., and Gardner. M.P., 2011; Schuitema, G, Anable, J, Skippon, S, and Kinnear, N., 2013). Other more recent literature have also consistently found similar yet varied barriers. For example, in (Graham-Rowe, E., Gardner, B., Abraham, C.,) utilizing test drives and interviews, found that range, price, aesthetics and symbolic value were the primary barriers to EV adoption.

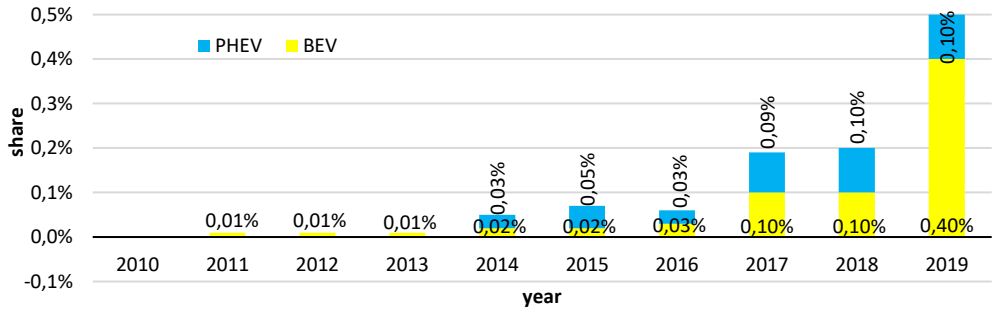

Fig. 6. Share of electric vehicles in the total number of new AF type vehicles registered in Poland (proprietary compilation based on (EAFO))

Finally, in (Rezvani, Z, Jansson, J, and Bodin, J., 2015) an extensive literature review was carried out and it was found that price, range, charging infrastructure, and consumer perceptions and knowledge to be central and consistent barriers, among various others. Thus, range and range anxiety is a prominent fixture in the literature as one of the more substantial barriers to EV adoption. A litany of studies articulate how range poses a barrier to EV adoption, firstly by investigating the technical requirements of an EV (Pearre, N.S, Kempton, W., Guensler, R.L, and Elango, V.V., 2011), or based on the psychology and inexperience of the consumer (Franke, T., and Krems, J.F., 2013). Curiously, however, the understanding of range anxiety is still nebulous, especially as it continues to persist as a barrier despite the increasing range of EVs, the development of public charging infrastructure, and more consumer education and experience.

According to (CROV; PAFA; PAIA), in 2019, there were 1011 EV charging stations available in Poland (1815 publicly available charging outlets, including 28% of direct current (DC) chargers).

In that period, one publicly available EV charging outlet was provided per 5 electric vehicles (in line with Directive 2014/94/EU of the European Parliament and of the Council, i.e. "Clean Power for Transport", it is recommended that, by 2020, in Member States, there should be one publicly available EV charging outlet per 10 registered vehicles of this type (PAFA)) (Fig. 7).

Table 2. Answers to the "What, in your opinion, are the largest barriers for electric vehicle development in Poland?" question given by respondents surveyed

Source	Poorly developed EV charging station infrastructure (%)
(EMP)	48.0
(PAFA)	47.4
(INNOGY)	41.0
(KPMG)	21.0

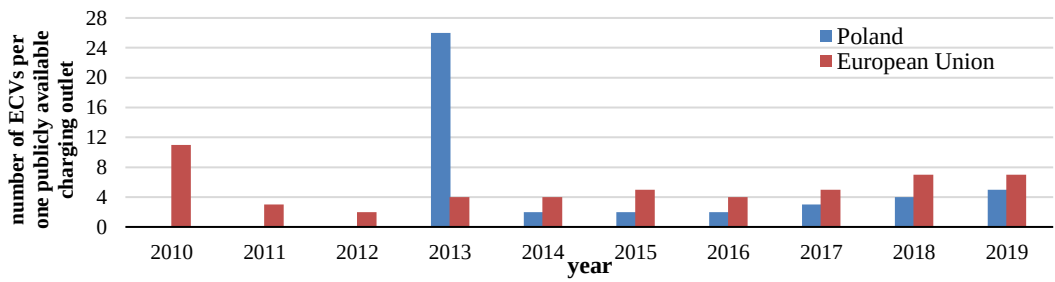

Fig. 7. Number of electric vehicles per one publicly accessible EV charging outlet (proprietary compilation based on (EAFO))

However, this indicator does not reflect the correct level of the EV charging infrastructure development in Poland. Apart from the quantitative value, a network of EV chargers should also be characterised by their optimum distribution in a given country. A network of EV charging stations must facilitate efficient driving within a given route, without experiencing the range anxiety resulting from the fear that a vehicle may run out of charge within a given section of the route, failing to reach its destination (JAKOBSSON, N., GNANN, T., PLÖTZ, P. et al., 2016). Thus a parameter more effectively demonstrating the EV charging infrastructure development condition is the density of charger distribution. In Poland, there are 3 EV charging stations per 1000 km^2. In comparison, there are 990 charging stations per the same area in the Netherlands, which are the leader among all European countries within this scope (Fig. 8).

Figure 9 shows that, in Poland, EV charging stations are located mostly in large cities (48% (Fig. 10)) and along main traffic routes. This is one of the factors contributing to the fact that, presently, the electromobility development in Poland is limited mostly to largest cities.

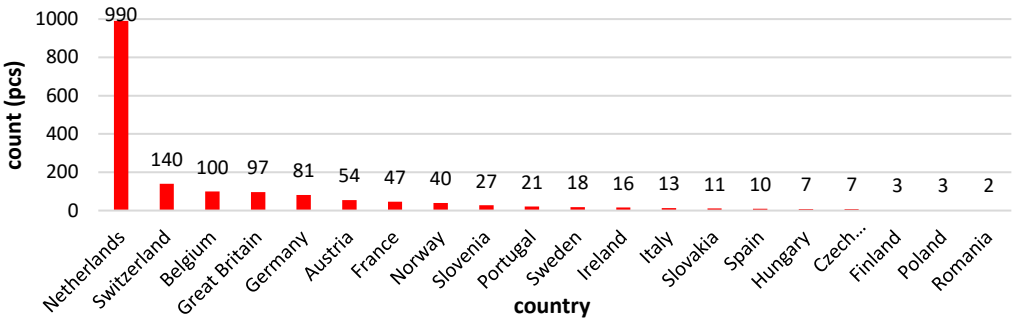

Fig. 8. Number of publicly available EV charging stations per 1000 km^2 in European countries (proprietary compilation based on (EAFO))

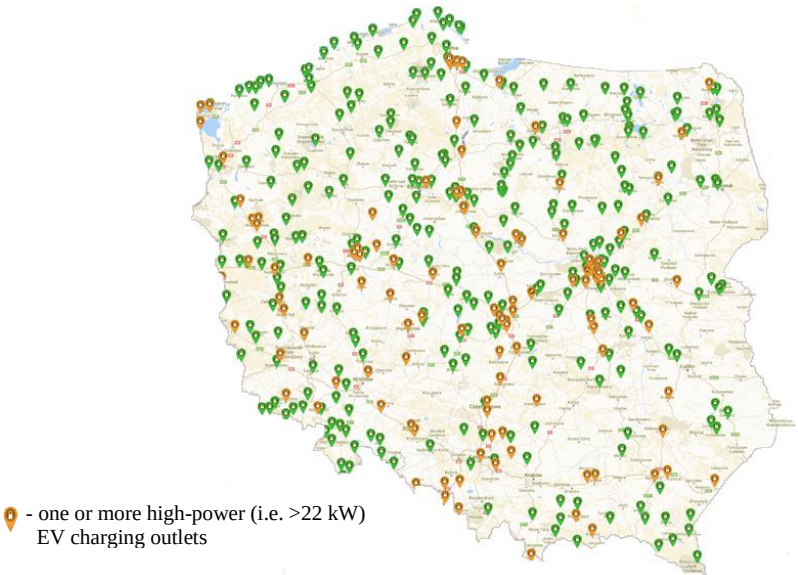

Fig. 9. Distribution of EV charging stations in Poland, in 2020 (as of March 2020) (PSEV)

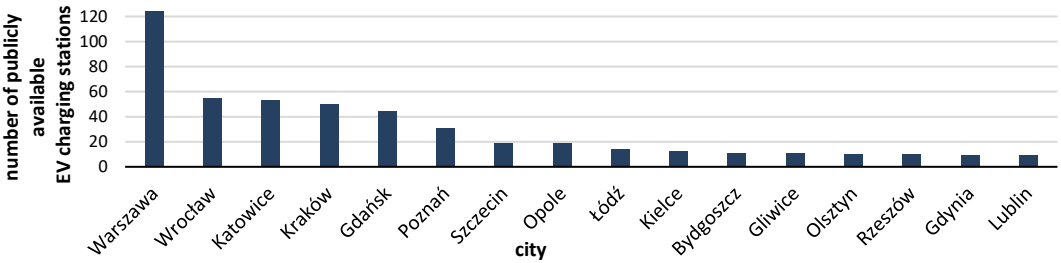

Fig. 10. Cities where most EV charging stations were located in 2019 (pieces) (own compilation based on (CROV; PAFA; PAIA))

3. EV charging infrastructure development forecasts

A correctly developed and functioning network of EV charging outlets is a factor necessary to exert impact on consumers' preferences and dispel their fears connected with driving vehicles fuelled with alternative power sources. Due to the above, in January 2018, the Polish Parliament passed the Act on electromobility and alternative fuels, in which Art. 60 obliges local governments to commission a necessary EV charging infrastructure, by 31 March 2021 (ELECTROMOBILITY, 2018). The Act defines the minimum number of EV charging outlets in publicly available charging stations, on the basis of demographic and transport characteristics of a given commune (Table 3).

While using the Central Statistical Office data for 2018 regarding the number of inhabitants and motor vehicles and referring the guidelines provided in the above-mentioned Act, it was determined that publicly available EV charging outlets must be installed only in 32 of 2477 communes in Poland. All communes where publicly available EV charging stations must be provided are urban communes (Table 4) where the number of inhabitants is at least 100,975. Taking into account the 32 communes where, according to the Act, EV chargers must be installed, there is only one commune where the minimum number of such chargers should be 1000 (as for the remaining communes - 210 chargers in 6 communes, 100 chargers in 13 communes and 60 chargers in 12 communes). According to the legislator, there must be at least 4280 new publicly available EV charging outlets provided, in total. See Table 5 for the list of communes and the minimum number of EV charging outlets to be installed.

When identifying communes in which, according to the Act, the minimum number of charging outlets is to be launched, their density in the area of a given commune was determined according to the formula (1).

$$charging\ outlets\ density = \frac{number\ of\ EV\ charging\ outlets\ (pcs)}{area\ if\ the\ communes\ (km2)} \quad (1)$$

The area of communes, the minimum number of EV charging outlets, as well as the number of EV charging outlets per 1 km^2 are presented in Table 6. Then, based on the road distance between the seats of these communes, the distances between them were determined (Fig. 12).

Figure 11 presents distances between neighbouring communes where, in line with the Act of 11 January 2018 on electromobility and alternative fuels, the minimum number of publicly available EV charging outlets is to be commissioned.

The largest distance between such communes is 359 km (Gdańsk-Szczecin), and the smallest distance is 10 km (Gliwice – Zabrze).

Table 3. Minimum number of charging outlets in publicly available charging stations in Poland (by 31 March 2021) (proprietary compilation based on (ELECTROMOBILITY, 2018))

Population	Number of mot. vehicles	Number of mot. vehicles per 1000 inhabitants	Number of charging outlets
>1,000,000	≥ 600,000	≥ 700	1000
> 300,000	≥ 200,000	≥ 500	210
> 150,000	≥ 95,000	≥ 400	100
> 100,000	≥ 60,000	≥ 400	60

Table 4. Number of communes broken down in terms of Voivodeships and number of communes where publicly available EV charging outlets must be installed, in line with the provisions of the Act of 11 January 2018 on electromobility and alternative fuels (proprietary compilation based on (ELECTROMOBILITY, 2018; CSO))

Item	Territorial division unit				Count			
	communes				communes where publicly available EV charging outlets must be installed			
	urban	rural	urban-rural	total	urban	rural	urban-rural	total
Poland	302	1533	642	2477	32	-	-	32
Lower Silesian Voivodeship	35	78	56	169	1	-	-	1
Kuyavian-Pomeranian Voivodeship	17	92	35	144	2	-	-	2
Lublin Voivodeship	20	165	28	213	1	-	-	1
LubuszVoivodeship	9	39	34	82	2	-	-	2
ŁódźVoivodeship	18	131	28	177	1	-	-	1
Lesser Poland Voivodeship	14	120	48	182	1	-	-	1
Masovian Voivodeship	35	225	54	314	3	-	-	3
Opole Voivodeship	3	35	33	71	1	-	-	1
SubcarpathianVoivodeship	16	109	35	160	1	-	-	1
PodlaskieVoivodeship	13	78	27	118	1	-	-	1
Pomeranian Voivodeship	22	81	20	123	2	-	-	2
Silesian Voivodeship	49	96	22	167	11	-	-	11
Holy Cross Voivodeship	5	58	39	102	1	-	-	1
Warmian-MasurianVoivodeship	16	66	34	116	1	-	-	1
Greater Poland Voivodeship	19	113	94	226	2	-	-	2
Western Pomeranian Voivodeshi	11	47	55	113	1	-	-	1

Table 5. Minimum number of publicly available EV charging outlets, in line with the provisions of the Act of 11 January 2018 on electromobility and alternative fuels (proprietary compilation based on (ELECTROMOBILITY, 2018; CSO))

Voivodeship	Commune	Count	Voivodeship	Commune	Count
Lower Silesian Voivodeship	Wrocław	210	Silesian Voivodeship	Bielsko-Biała	100
Kuyavian-Pomeranian Voivodeship	Bydgoszcz	100		Bytom	60
	Toruń	100		Częstochowa	100
Lublin Voivodeship	Lublin	100		DąbrowaGórnicza	60
LubuszVoivodeship	Gorzów Wielko-	60		Gliwice	100
	ZielonaGóra	60		Katowice	100
ŁódźVoivodeship	Łódź	210		RudaŚląska	60
Lesser Poland Voivodeship	Krakow	210		Rybnik	60
Masovian Voivodeship	Płock	60		Sosnowiec	100
	Radom	100		Tychy	60
	Warsaw	1000		Zabrze	60
Opole Voivodeship	Opole	60	Warmian-MasurianVoivodeship	Olsztyn	60
SubcarpathianVoivodeship	Rzeszów	100	Greater Poland Voivodeship	Kalisz	60
PodlaskieVoivodeship	Białystok	100		Poznań	210
Pomeranian Voivodeship	Gdańsk	210			
	Gdynia	100	Western Pomeranian Voivodeship	Szczecin	210
Holy Cross Voivodeship	Kielce	100			

Table 6. Minimum number of EV charging outlets in Poland per 1 km^2, in line with the provisions of the Act of 11 January 2018 on electromobility and alternative fuels (proprietary compilation based on (ELECTROMOBILITY, 2018; CSO))

Commune	Area (km^2)	Count	Number of charging outlets per 1 km^2	Commune	Area (km^2)	Count	Number of charging outlets per 1 km^2
Wrocław	292.8	210	0.72	Bielsko-Biała	124.5	100	0.80
Bydgoszcz	176	100	0.57	Bytom	69.44	60	0.86
Toruń	115.7	100	0.86	Częstochowa	160	100	0.63
Lublin	147	100	0.68	DąbrowaGórnicza	189	60	0.32
Gorzów	86	60	0.70	Gliwice	134.2	100	0.75
ZielonaGóra	278.3	60	0.22	Katowice	164.7	100	0.61
Łódź	296.2	210	0.71	RudaŚląska	77.73	60	0.77
Krakow	327	210	0.64	Rybnik	148.4	60	0.40
Płock	88.06	60	0.68	Sosnowiec	91.06	100	1.10
Radom	111.8	100	0.89	Tychy	81.81	60	0.73
Warsaw	517.2	1000	1.93	Zabrze	80.4	60	0.75
Opole	149	60	0.40	Olsztyn	88.33	60	0.68
Rzeszów	126.6	100	0.79	Kalisz	69.41	60	0.86
Białystok	102.1	100	0.98	Poznań	261.8	210	0.80
Gdańsk	262	210	0.80				
Gdynia	135.1	100	0.74	Szczecin	300.6	210	0.70
Kielce	109.4	100	0.91				

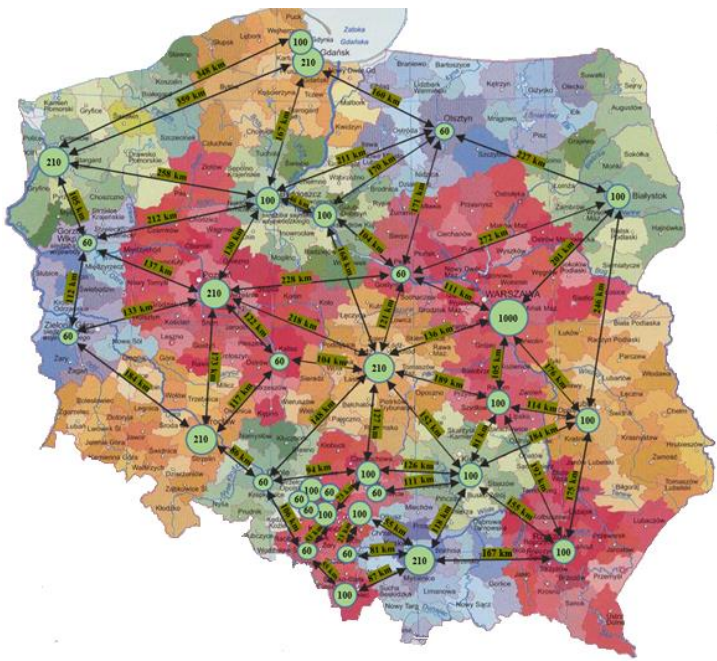

Fig. 11. Minimum number of publicly available EV charging outlets and distances between communes where the outlets should be commissioned (proprietary compilation based on (ELECTROMOBILITY, 2018; CSO)

According to the legislator, the number of charging outlets installed in publicly available EV charging stations mentioned in section 1 includes the charging outlets located along the Trans-European Transport Network (TEN-T) (ELECTROMOBILITY, 2018).
In September 2018, the General Directorate for National Roads and Motorways published the plan of publicly available EV charging station locations at Passenger Service Points within the basic TEN-T network. According to the submitted plan, from 31 March 2021, EV charging stations will be installed at 159 Passenger Service Points, along public national roads of class A and S, i.e. along motorways and expressways (Table 7).
See Figure 12 for the locations where EV charging stations should be commissioned, in line with the Act on electromobility and alternative fuels. EV charging station locations situated along the TEN-T network routes are marked green.

4. Conditions and implementation possibilities

Taking into account the existing EV charging infrastructure and provisions of the Act of 11 January 2018 on electromobility and alternative fuels, in March 2021, in Poland, there should be 4280 publicly available EV charging outlets in operation (according to (POOOIAT), in 2019, there were 7807 petrol stations in Poland), which means that their number should increase by 250% in relation to the number of outlets available in 2019.
In order to achieve the minimum number defined in the Act, in this year, the largest number of EV chargers must be commissioned in Radom. There, their number must increase by 1050%. On the other hand, the number of publicly available EV charging outlets in Katowice must increase by only 2% as compared to 2019, which is the smallest number of outlets necessary to be commissioned.

5. Conditions and implementation possibilities

Taking into account the existing EV charging infrastructure and provisions of the Act of 11 January 2018 on electromobility and alternative fuels, in March 2021, in Poland, there should be 4280 publicly available EV charging outlets in operation (according to (POOOIAT), in 2019, there were 7807 petrol stations in Poland), which means that their number should increase by 250% in relation to the number of outlets available in 2019.

Table 7. Planned number of EV charging stations located along TEN-T network routes in Poland (proprietary compilation based on (GDFNR; GM; TARGEO))

Road class	Road no.	Direction	Length of road section where an EV charging station is to be built (km)	Number of EV charging stations	Distance between consecutive EV charging outlets (km)			Direction	Length of road section where an EV charging station is to be built (km)	Number of EV charging stations	Distance between consecutive EV charging outlets (km)		
					avg.	min.	max.				avg.	min.	max.
motorway	1	Gorzyczki	555.60	19	19.59	7.95	35.70	Gdańsk	532.95	20	19.76	7.95	37.70
	2	Kukuryki	531.55	16	35.44	10.08	128.50	Świecko	532.30	16	35.49	10.08	128.30
	4	Korczowa	639.00	22	30.43	14.84	140.05	Jędrzychowice	636.15	22	30.29	14.39	140.40
	6	Szczecin	25.7	1	-	-	-	Berlin	25.70	1	-	-	-
expressway	3	Lubawka	144.10	5	36.03	16.40	46.80	Szczecin	163.70	5	40.93	19.60	52.80
	61	Ostrów Mazowiecki	39.50	-	-	-	-	Suwałki	39.50	1	-	-	-
	7	Warsaw		4	31.33	24.00	40.00	Gdańsk		7	51.47	64.17	313.58
	8	Wrocław	429.65	8	48.93	6.11	264.00	Białystok	440.40	10	61.38	11.80	267.61
	19	Rzeszów	20.76	1	-	-	-	Lublin	20.76	1	-	-	-

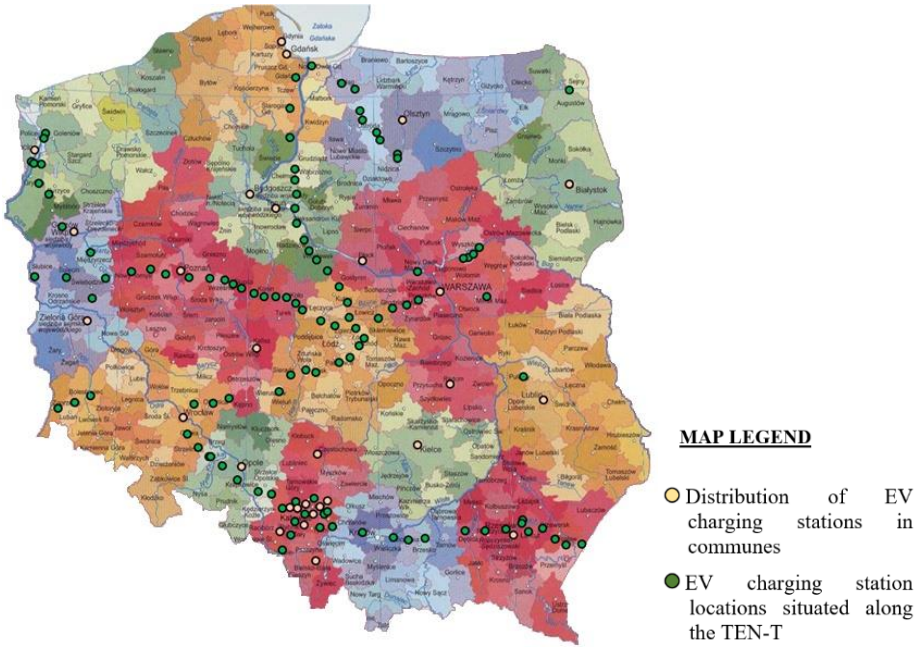

Fig. 12. Locations of EV charging outlets in Poland, in line with the provisions of the Act of 11 January 2018 on electromobility and alternative fuels (proprietary compilation based on (ELECTROMOBILITY, 2018; CSO; GDFNR))

In order to achieve the minimum number defined in the Act, in this year, the largest number of EV chargers must be commissioned in Radom. There, their number must increase by 1050%. On the other hand, the number of publicly available EV charging outlets in Katowice must increase by only 2% as compared to 2019, which is the smallest number of outlets necessary to be commissioned.

See Table 8 for the number of publicly available EV charging outlets, i.e. currently operational and recommended in the Act.

Taking into account the existing market conditions, achieving the minimum number of chargers, as assumed in the Act on electromobility and alternative fuels, in all cities is highly unlikely. The city of Katowice is an exception, as there are already 98 operational publicly available EV charging outlets and, in line with the Act, their number must be at least 100, in March 2021. It results from several premises. Presently, construction of an EV charging station is a costly, time-consuming and complex undertaking. Moreover, it requires concluding certain agreements and obtaining numerous permits. In case connection to the existing distribution network is planned, it is necessary to conclude a connection agreement, the implementation of which often involves a number of issues, i.e. lack of property owners' consent to enter the premises, process of obtaining necessary administrative permits that may last for as long as 18 months, restrictions on network expansion possibilities (e.g. within road lanes, which results from the provisions of the Act on roads) or lack of regulations facilitating acquisition of the right-of-way for new lines (no Act on transmission corridors).

Additionally, there is another formal barrier which hinders the EV charging station construction process, i.e. a problem with obtaining data concerning the power of existing connections a given station might potentially belong to. Such data is necessary to connect chargers to existing power networks. The process of obtaining necessary information regarding construction of an EV charging station is often time-consuming or even impossible to complete. Moreover, entities interested in constructing an EV charging station claim that distribution network operators

treat the connection process in a fairly "straightforward" manner, i.e. in case connection conditions are not present (e.g. due to insufficient network infrastructure in a given area), they simply refuse to connect a station, without specifying any possible alternative locations. This has particularly negative impact on car dealership networks and their service points which should be able to charge electric vehicles subject to servicing. (KPGM; PAIA; SSW, 2019).

Presently, in numerous cases, an investment project consisting in constructing an EV charging station is simply economically unjustified. The costs borne in relation to maintaining a station are disproportionate to revenues resulting from charging the still meagre numbers of electric vehicles in Poland. Agreements specifying a volume of energy that must be purchased are another issue to be faced by EV charger operators, as such energy is not always fully used by the users. Moreover, the presently applicable distribution tariffs in Poland are incompatible with market needs.

Table 8. Number of publicly available EV charging outlets in Poland (state for March 2020 and according to (ELECTROMOBILITY, 2018)

Voivodeship	Commune	Number of publicly available EV charging outlets		Increase (%)
		March 2020	ELECTROMOBILITY	
Lower Silesian Voivodeship	Wrocław	93	210	126
Kuyavian-Pomeranian Voivodeship	Bydgoszcz	29	100	245
	Toruń	22	100	355
Lublin Voivodeship	Lublin	26	100	285
LubuszVoivodeship	Gorzów Wielkopolski	13	60	362
	ZielonaGóra	13	60	362
ŁódźVoivodeship	Łódź	24	210	775
Lesser Poland Voivodeship	Krakow	168	210	25
Masovian Voivodeship	Płock	8	60	650
	Radom	8	100	1150
	Warsaw	266	1,000	276
Opole Voivodeship	Opole	32	60	88
SubcarpathianVoivodeship	Rzeszów	27	100	270
PodlaskieVoivodeship	Białystok	15	100	567
Pomeranian Voivodeship	Gdańsk	91	210	131
	Gdynia	19	100	426
Holy Cross Voivodeship	Kielce	12	100	733
Silesian Voivodeship	Bielsko-Biała	20	100	400
	Bytom	8	60	650
	Częstochowa	15	100	567
	Dąbrowa Górnicza	6	60	900
	Gliwice	28	100	257
	Katowice	98	100	2
	RudaŚląska	5	60	1100
	Rybnik	15	60	300
	Sosnowiec	8	100	1150
	Tychy	10	60	500
	Zabrze	5	60	1100
Warmian-MasurianVoivodeship	Olsztyn	11	60	445
Greater Poland Voivodeship	Kalisz	16	60	275
	Poznań	83	210	153
Western Pomeranian Voivodeship	Szczecin	28	210	650

6. Conclusions

The Act of January 2018 on electromobility and alternative fuels imposed on municipalities the obligation to launch an appropriate number of publicly accessible charging points in their area. In this study, it was determined that, according to the Act, they must be established only in 32 out of 2477 communes in Poland and they are urban communes. The identification of these communes made it possible to determine the charging station density in their area and the distance between these communes (even 359 km). Based on the analysis carried out, it should be clearly stated that the location of public charging points indicated by the legislator and their number it will not be sufficient to ensure convenient operation of electric vehicles, and the already significant disparities regarding the number of EV charging outlets between agglomerations, smaller towns and rural areas will become even greater. Although the legislator has taken into account construction of EV charging stations along public roads, the conducted analysis has shown that such stations will be installed only along 9 out of 98 existing national roads. However, there will still be areas where the number of publicly available EV chargers will be negligible or there will be no chargers at all (Fig. 13). At the same time, according to Polish drivers, a perfect electric vehicle should be manufactured in Poland, be a four-seater and have a range of 150 km, with a possibility to recharge its batteries every 50 km of the route (KTNS). However, in communes where the minimum number of charging outlets is to be commissioned, on average, 0.75 charger will be available per 1 km^2. The highest density will be in Warsaw, i.e. 1.9 charging outlets per 1 km^2, however, the smallest density will be noted in Zielona Góra, i.e. 0.22 charger per 1 km^2.

Thus it is prudent to create mechanisms supporting construction and operation of publicly available electric vehicle charging stations in Poland. Such support should differentiate between charger types to encourage investors to expand mostly the network of fastest chargers.

The process of constructing an EV charging station involves numerous entities and requires lots of formalities to be dealt with, so the objective should be to streamline procedures in order to limit their negative impact exerted on investment project implementation. An example improvement would be to limit the time required for issuing information (e.g. data regarding the power of connections in existing installations) and for obtaining permits necessary to construct a station. In order to optimise station profitability and decrease the vehicle charging costs, in particular by means of fast and ultra-fast chargers, support for EV charging station operators regarding the necessary adjustment of energy distribution tariffs must be considered. The suggested new tariff should make energy distribution fees conditional only on the energy volume, which will make it possible to adjust the distribution service payment profile to the electric vehicle market dynamics. The positive impact of proper incentives on EVC infrastructure development is illustrated by actions taken by the French government, which, in 2014, reduced tax rates for companies which would install EV charging outlets on their premises. This solution appeared effective, as, already in 2015, the number of EV chargers increased by 482% in comparison with 2014 (Sendek-Matysiak. E., 2018).

All such system solutions supporting and shortening the process of network-related investment projects should encourage EV charging station operators to construct new outlets, particularly in less attractive locations. This is of great importance as, given the locations and the minimum number of publicly available charging outlets in Poland to be established by the 31 March 2021, as indicated by the legislator (according to the Act, the distance between the communes where the minimum number of publicly available charging outlets is to operate reaches even 359 km), it will not be sufficient to ensure convenient operation of electric vehicles, and the already significant disparities regarding the number of EV charging outlets between agglomerations, smaller towns and rural areas will become even greater. Although the legislator has taken into account construction of EV charging stations along public roads, the conducted analysis has shown that such stations will be installed only along 9 out of 98 existing national roads.

However, there will still be areas where the number of publicly available EV chargers will be negligible or there will be no chargers at all (Fig. 13). At the same time, according to Polish drivers, a perfect electric vehicle should be manufactured in Poland, be a four-seater and have a range of 150 km, with a possibility to recharge its batteries every 50 km of the route (INNOGY).

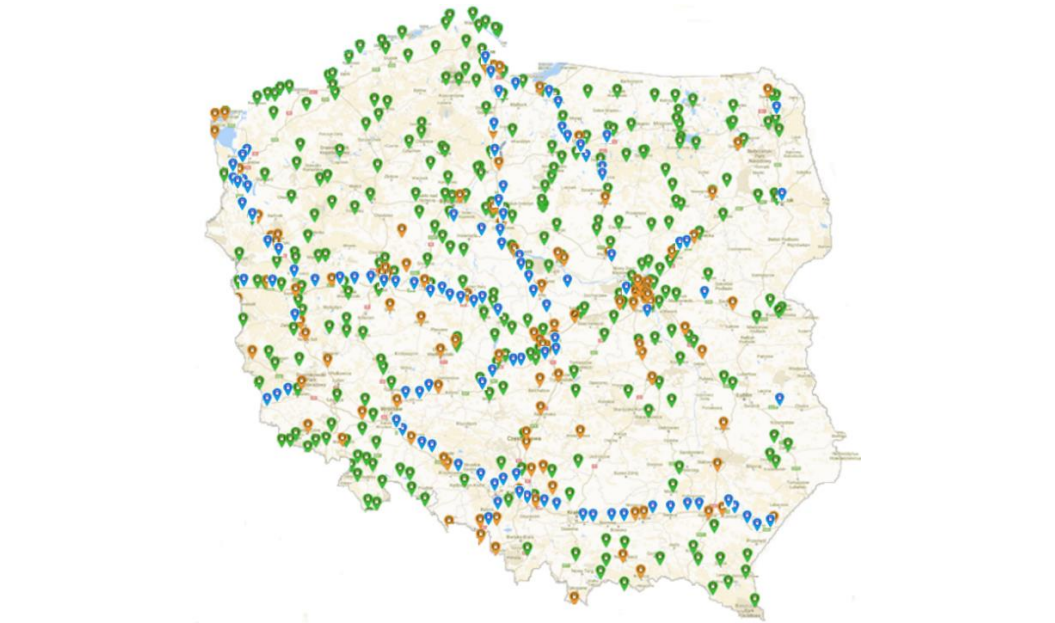

Fig. 13. Map of EV charging outlets in Poland as of 31 March 2021, in line with the provisions of the Act of 11 January 2018 on electromobility and alternative fuels (proprietary compilation based on (ELECTROMOBILITY, 2018; CSO; GDFNR, PSEV))

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