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Evaluating the Interplay of Charging Stations and Electric Vehicle Growth in Poland: Research Findings and Electromobility Outlook

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Abstract:

Purpose: *This article evaluates the interplay between the development of charging station infrastructure and the growth of electric vehicles (EVs) in Poland. It aims to identify correlations and provide insights for advancing Poland's electromobility sector through strategic development of EV infrastructure.*
Design/Methodology/Approach: *The article employs a mixed-methods approach combining statistical analysis, literature review, and case study methodology. It utilizes Pearson's correlation to quantify the relationship between the number of EVs and charging stations across Poland's regions. Additionally, the Electric Mobility Penetration Index (EMPI) is applied to evaluate the extent of electromobility integration. The study incorporates data from official reports, industry documents, and statistical sources, offering both quantitative and qualitative insights into the current state and future prospects of electromobility in Poland.*
Findings: *The study highlights a strong positive linear relationship between the number of EVs and the availability of charging stations, emphasizing that urbanized areas show higher potential for electromobility due to greater demand. It also identifies key challenges, such as insufficient infrastructure, uneven regional development, and the need for centralized policies.*
Practical Implications: *The findings provide policymakers and industry stakeholders with actionable insights into optimizing charging infrastructure and supporting electromobility growth. Strategies like integrating renewable energy sources, improving public awareness, and introducing incentives for private and public investment are proposed to overcome current barriers.*
Originality/Value: *By analyzing Poland's unique context and employing metrics like the Electric Mobility Penetration Index, the study offers a novel approach to understanding regional disparities and the dynamics of EV adoption. It provides a foundation for addressing infrastructure gaps and fostering sustainable transportation in emerging electromobility markets.*

Keywords: *Coastline tourism, tourism, destination marketing.*

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Paper Type: *Research article.*

1. Introduction

In recent years, electromobility has become one of the key trends in the global automotive market, and Poland is not lag-ging behind this trend. Transport and movement of people is an increasing problem in modern cities. These issues become a challenge for civilization solutions, because on the one hand it is about increasing the mobility of residents while limiting traffic jams, accidents and environmental pollution (Drożdż, Miśkiewicz, Pokrzywniak, and Elżanowski, 2019).

With the growing number of electric vehicles on Polish roads, the demand for the development of charging infrastructure is also grow-ing. One of the most important challenges for the Polish automotive market is to increase the number of charging stations for electric vehicles, which would increase the number of users of such vehicles and enable their free movement.

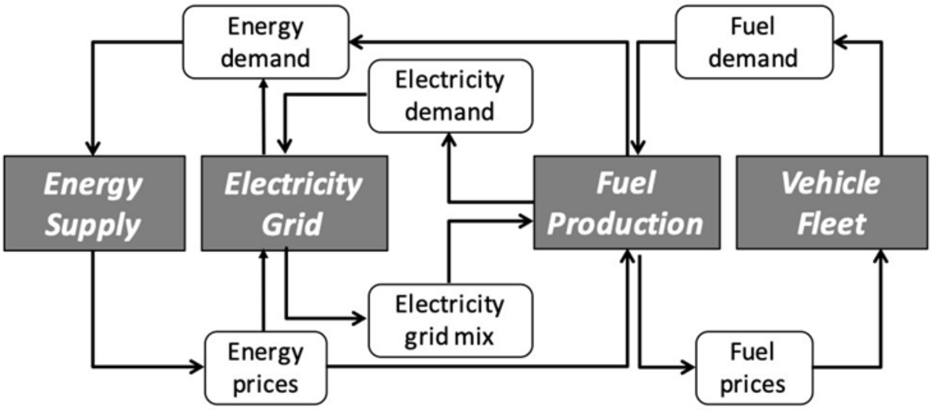
This article will analyze the current situation on the Polish electromobility market and the number of electric vehicle charging stations in Po-land in relation to the number of vehicles of this type on the roads. This is of key importance for the further development of electromobility in Poland. The article also aims to present what steps should be taken to increase the availability of electric vehicle charging stations.

The research problem is to examine the relationship between the number of electric vehicle charging stations and the number of electric vehicles in Poland. In response to the increasing challenges of environmental pollution and climate change, electric vehicles represent a promising and sustainable alternative whose popularity is constantly growing.

2. Literature Review

The last decade has seen a significant increase in interest in this sector, both from the public and private sectors. R. Levinson and T. West examined the potential impact of public charging infrastructure on electric vehicle (BEV) sales in the United States (R. Levinson, T. West, 2018). Their study showed that the wider implementation of direct current (DC) chargers translates into increased sales of BEVs. In addition, the document also analyzes regional station layout scenarios and the impact of electricity prices on consumer tolerance. The authors used the so-called the ParaChoice model, which was used to simulate the number of vehicles, their sales, fuel consumption and emissions in the years 2015-2050, taking into account various adjustable input parameters, as shown in Figure 1.

Figure 1. *An overview of the ParaChoice model and submodels.*



Source: *R. Levinson, T. West, Impact of Public Electric Charging Infrastructure*.

Singh, Kavianipour, Soltanpour, Fakhrmoosavi, Ghamami, Zockaie, and Jackson (2022), noted that current re-search and tools for planning electric vehicle charging infrastructure require detailed information, extensive resources and skills, which may pose a significant barrier for urban areas to find the required charging infrastructure to support their target EV market share. In their research, they developed Macro-scale models that can be easily implemented by policy makers and urban planners. The authors' results show that the number of charging stations decreases with the size of the battery and charging power, and in-creases with the market share of electric vehicles.

Yi, Zhang, Lin, and Liu (2020), using the example of China, point out that the rapid increase in the number of electric vehicle users has brought great demand for charging electric vehicles in recent years. However, blindly building infrastructure in cities brings problems such as wastage of land and funds, as well as irregu-lar fluctuations in power grids. The authors suggest implementing stations (slow to fast chargers) in a ratio of 50:1 in residen-tial areas, 85:1 in work areas and in commercial, entertainment and social areas at a ratio of 4:1 or 5:1.

According to reports by the European Automobile Manufacturers Association (ACEA), representing 13 leading European manufacturers of passenger cars, trucks and buses, in 2022 the automotive industry is classified as a dynamically developing sector. The report mentions many implemented innovations and investments amounting to EUR 59 billion. How-ever, the Director General of ACEA, Sigrid De Vries, refers to the urgent needs related to sector transformation. Namely, it refers to the need to urgently create new conditions that will support rapid and massive electrification of the fleet, build a network of charging infrastructure and guarantee the availability of the necessary raw materials for development.

However, a disturbing trend is the increasing average age of passenger cars (12 years), trucks (14), delivery vans (12) and buses (13) on EU roads. When putting the cleanest and safest new vehicles on the road, we need to be absolutely sure that these cars remain affordable for all European citizens. On the other hand, data on car production and sales in the EU are not optimistic. As a result of the industry's severe problems with interrupted supply chains, production levels fell once again by 8% in 2021. The decline in production translated into lower sales of new cars, because supply was much lower than demand.

In 2021, passenger car sales in the EU fell to 9.7 million units, which was 3.3 million units lower than before the pandemic. In light of the EU's declining global share in car production (15%) and in the world market (14%), urgent action is needed to consolidate its strong position on the international stage. The starting point should be decisive action that increases the resilience of European supply chains. The automotive industry is a pillar of the European economy. The sector provides employment to 12.7 million people, gener-ates an annual trade surplus of EUR 79.5 billion and generates EUR 375 billion in tax revenues for national treasuries in the main EU markets (Automotive Industry Report 2022/2023).

Electric vehicle charging stations play a key role in the development of electro-mobility. Without sufficient charging in-frastructure, the use of electric vehicles may be difficult or even impossible. Therefore, it is important to develop a network of charging stations to increase the range and convenience of using electric vehicles. The existence of a developed network of charging stations is crucial for the increase in the number of electric vehicle users. EV’s play a crucial role in promoting sustainable development across various dimensions, which in turn may contribute to reducing air pollution emissions, reducing the consumption of fossil fuels and reducing road noise.

What is more, when powered by renewable energy sources – they become an integral part of low-carbon transportation system, enhancing overall environmental sustainability. The adaptation of electric vehicles, coupled with the development of accessible charging infrastructure, promotes equitable access to sustain-able transportation, reducing disparities in mobility options. All this affects the quality of life of city residents and the protec-tion of the natural environment.

On the other hand, the lack of a sufficient number of charging stations may discourage poten-tial buyers from purchasing electric vehicles and hinder the development of electromobility. Therefore, it is crucial that the policy of the government, industry and charging station operators is focused on the development of charging infrastructure, including both the construction of new stations and the modernization of existing ones.

Therefore, with the increasing number of electric vehicles on the road, the development of charging stations is becoming an increasingly pressing problem that re-quires an immediate response. Increasing the number of charging stations is a step towards a more sustainable environment, as well as an opportunity to develop electromobility in Poland. Therefore, there is a correlation between the number of public-ly available electric vehicle charging stations in Poland and the number of vehicles on the road. What approach should Poland adopt to develop electromobility - build more vehicle charging stations or encourage the purchase of more electric vehicles?

The need for extensive charging infrastructure requires substantial investment and planning. Strategic development is essential for a seamless transition to electric mobility. EV's, when embraced within a comprehensive and sustainable framework, contribute significantly to the goals of sustainable development. Addressing challenges related to affordability, infrastructure and environmental concerns is essential to unlock the full potential of electric mobility in fostering a sustainable and equitable future.

3. Research Methods

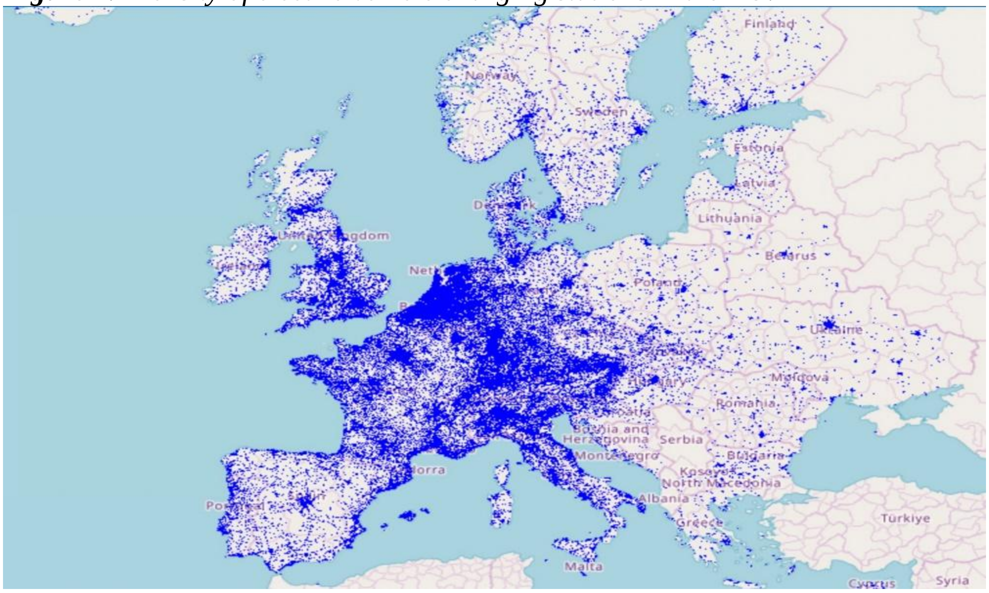
In 2021, the European Commission presented the "Fit for 55" legislative package, which aims to achieve ambitious goals related to reducing CO2 emissions and eliminating greenhouse gas emissions in the EU. According to this package, Member States will have to ensure the construction of extensive infrastructure for vehicles powered by alternative fuels, such as elec-tric cars, and limit the production of combustion vehicles (https://www.consilium.europa.eu/ 2023).

One of the main tasks of "Fit for 55" for the automotive industry will be to ensure full interoperability of infrastructure for vehicles powered by alterna-tive fuels throughout the EU. For this purpose, Member States will be obliged to build publicly available charging stations, in a number proportional to the sales of electric cars. Additionally, Member States will have to connect charging stations to the electricity grid, especially those with a power above 150 kW, every 60 km for passenger cars and with a power above 350 kW, every 100 km for heavy vehicles.

As part of "Fit for 55", the European Commission will also introduce stricter CO2 emission standards for new vehicles placed on the market. According to the plans, from 2035, cars introduced to the market by manufac-turers will have to be completely emission-free. This means that the production of new combustion cars will be limited, and the automotive industry will have to invest in technologies related to electric vehicles or other alternative drive sources.

All these steps are aimed at achieving the European Green Deal's goals of reducing greenhouse gas emissions and combating cli-mate change. "Fit for 55" aims to help with this by providing specific solutions to reduce CO2 emissions and reduce the impact of transport on the environment. The infrastructure for electric vehicles in the EU is potentially being expanded, with a total number of points across the EU of approximately 705,000. (https://alternativefuelsobservatory.ec.europa.eu/interactive-map 2023). The density of these stations is shown in Figure 2.

Figure 1. *Density of electric vehicle charging stations in the EU.*



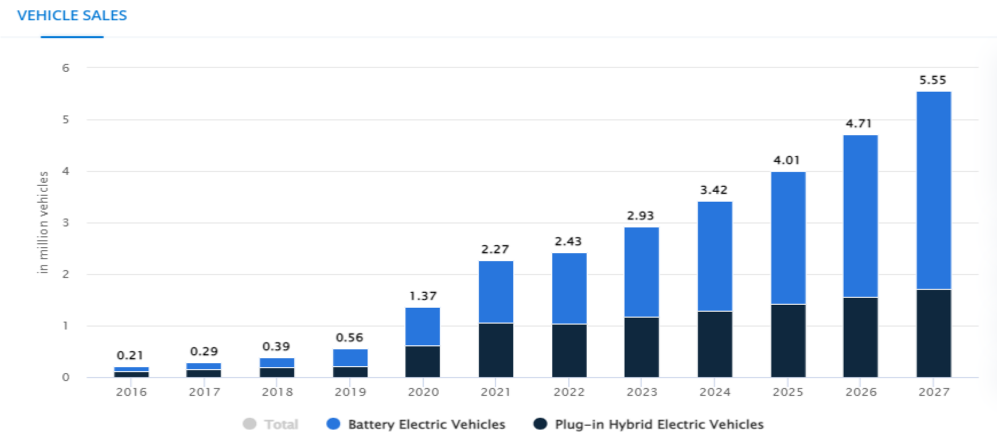
Source: *Own study.*

It is also worth paying attention to the constantly growing number of sales of electric vehicles throughout the European Union. In 2022, this value reached almost 2.5 million units sold, of which BEV vehicles - approximately 1.4 million. Therefore, a dynamically growing trend in further sales of this type of cars is forecast. By 2027, with a potential number exceeding 5.5 million electric vehicles (https://www.statista.com 2023). Figure 3 shows the relationship between electric vehicle sales and a poten-tial scenario for the further trend.

4. Research Results

In Poland, electromobility is developing at an increasingly faster pace, but it is still at a potentially initial stage of devel-opment compared to Western European countries, where it is similarly perceived as an important element of the energy trans-formation and the fight against climate change. The Polish government has introduced incentives for users and producers, including excise tax exemptions, subsidies for the purchase of vehicles, and subsidies for the construction of charging stations. However, there are still challenges in developing this sector. Too few charging stations compared to the number of vehicles, difficulties with the availability of loans and leasing for EV vehicles, as well as insufficient investments in infrastructure ham-per the development of the market.

Figure 2. *Sales trend of electric vehicles in the EU.*



Source: *Statista.com/outlook/mmo/electric-vehicles/europe#unit-sales.*

Smart cities of the future are not static, they are organic entities that constantly exchange goods, services and knowledge. As communication and transportation technologies have evolved over time, leading to over-loaded transportation infrastructure in modern cities, it has become clear that cities need to move from a static, decentralized paradigm to dynamic adaptation. The most developed national economies not only implement programs consistent with the smart city concept, but also respond to demand - products and services related to this program create technology develop-ment, thus increasing their competitive advantage on the supply side (Drożdż and Dowejko, 2021).

Electromobility is one of the main goals set out in the Polish Energy Policy until 2040 (Polish Energy Policy until 2040). The goal of PEP 2040 is pri-marily the development of infrastructure, including the expansion of charging stations. A key element in achieving this goal is the development of demand management systems, smart grids, cyber security and increasing the capacity of distribution net-works.

Currently, the most important challenge for the development of electromobility is increasing the capacity of distribu-tion networks. The implementation of intelligent charging infrastructure will improve the connection and operation of charg-ing stations, as well as increase the ability to store energy and make the entire system more flexible. A special EU agency will oversee the consistency and standardization of electrical infrastructure solutions across the EU.

According to the Polish Mobility Barometer 2019/20 report, public interest in purchasing a new electric car has been growing in recent years. In 2017, 12% of respondents considered purchasing such a vehicle, in 2018 - 17%, and in 2019 - as many as 28%. In 2019, 30% of all interested consumers declared that they would be willing to buy a car for PLN 50,000-100,000. PLN, and 31% would be willing to buy a vehicle for PLN 100-150 thousand. zloty. Unfortunately, the prices of new electric vehicles in Poland exceeded these amounts by up to 40% during this period.

In this context, subsidies would consti-tute an incentive for 76% of respondents or VAT exemptions for 72% of respondents (Miczyńska-Kowalska, 2020; Polish Mobility Barometer PSPA 2019/20). The fourth edition of this report illustrates what changes have occurred since then in Poles' preferences related to the development of this sector. In 2020, there was once again an increase in Poles' interest in purchasing an electric car. 29.4% of respondents declared that they would realistically consider purchasing a BEV (fully electric car) or PHEV (plug-in hybrid) within the next three years (https://pspa.com.pl 2023).

The latest edition of this study (2022/23) shows that over 42% of Poles are interested in purchasing an electric vehicle (https://pspa.com.pl 2023). Interest-ingly, 15% of respondents declare interest in a BEV car, which is an increase of almost 8% compared to 2020. Although public awareness of electromobility has increased in recent years, it still remains incomplete. There are still some concerns and knowledge gaps in this area.

One of the main problems is the lack of infrastructure in smaller towns. Part of the population is concerned about the vehicle's range and charging time, although with technological progress, these problems are slowly being eliminated. Some users also complain about the lack of support from the state, in the form of subsidy programs or preferential payments. It is also worth paying attention to the vehicle charging process itself, in which, under applicable regulations (in the provision of vehicle charging services), as many as four categories of entities are involved (https://isap.sejm.gov.pl 2023):

1. operator of a publicly accessible charging station - is the owner of the infrastructure responsible for the construc-tion, management, safety, operation, maintenance and renovation of a publicly available charging station. Ensures that at least one charging service provider conducts business at a publicly accessible charging station;
2. charging service provider - provides a charging service including charging and ensuring the possibility of using the charging station infrastructure, concludes an energy sales agreement with the electricity seller; settles accounts with users for the electricity consumed;
3. electricity seller - sells electricity to the charging service provider under an energy sales agreement;
4. distribution system operator (DSO) – responsible for network traffic and supplying electricity to the station under the distribution agreement. It ensures the reliability of energy supplies.

Electromobility is particularly beneficial in urban conditions. It can be assumed that there is a positive correlation between the rate of urbanization and the development of electromobility in Poland. Therefore, the greater the rate of urbanization in a given province, the more people live in cities and are likely to use cars for shorter distances.

Therefore, voivodeships with a higher rate of urbanization may have greater potential for the development of the electromobility sector. In Poland, the area with the highest level of urbanization is the Silesian Voivodeship (77.60%), while the lowest level is Subcarpatian (41.56%). The average level of urbanization in Poland is 59.66%.

According to the electromobility map in Poland prepared by PSPA in cooperation with the Alternative Fuels Infrastructure Register, the number of electric vehicles and the charging infrastructure for these vehicles were estimated. At the end of February 2023, the total number of electric vehicles was 70,574, of which the number of BEVs accounted for 52% (36,815 vehicles).

The remaining number were PHEV cars - 33,759 (https://mapaelektromobilnosci.pl/ 2023) (https://eipa.udt.gov.pl/ 2023). The detailed calculation is presented in Table 1. In the first step of the analysis, the availability rate of electric vehicle charging infrastructure should be examined. This is a measure that assesses how easily and effectively electric vehicle users can use the infrastructure in a given region. For the purposes of evaluation (Table 2 presents the results of the analysis), measures at the voivodeship level were adopted, using the formula:

$$Infrastructure\ availability\ index = \frac{Number\ of\ charging\ stations}{Number\ of\ electric\ vehicles}$$

Table 1. *Characteristics of the development of electromobility in Poland, divided into voivodeships. Own study*

	population	area [km2]	urbanization rate	number of electric vehicles (BEV+PHEV)	BEV	PHEV	number of vehicle charging stations	AC	DC	charging station density per
Dolnośląskie Region	2901225	19947	69,40%	4874	2435	2439	238	172	66	0,0119
Kujawsko-Pomorskie Region	2077775	17972	61,10%	2287	1049	1238	169	112	57	0,0094
Lubelskie Region	2117619	25122	46,50%	1940	1018	922	44	25	19	0,0018
Lubuskie Region	1014548	13988	63,50%	1091	567	524	57	28	29	0,0041
Łódzkie Region	2466322	18219	63,80%	3097	1591	1506	122	47	75	0,0067
Małopolskie Region	3400577	15183	49,40%	7087	4157	2930	220	145	75	0,0145
Mazowieckie Region	5403412	35558	64,70%	22103	11589	10514	472	362	110	0,0133
Opolskie Region	986506	9412	63,50%	1019	536	483	69	48	21	0,0073

Podkarpackie Region	2129015	17846	41,56%	1908	951	957	64	33	31	0,0036
Podlaskie Region	1181533	20187	60,32%	1455	787	668	56	34	22	0,0028
Pomorskie Region	2333523	18321	65,00%	4673	2392	2281	277	209	68	0,0151
Śląskie Region	4533565	12333	77,60%	7123	3588	3535	337	232	105	0,0273
Świętokrzystkie Region	1241546	11711	44,80%	1064	644	420	33	26	7	0,0028
Warmińsko-Mazurskie Region	1428983	24173	59,33%	1030	489	541	145	130	15	0,0060
Wielkopolskie Region	3493969	29826	55,20%	7549	4003	3546	170	95	75	0,0057
Zachodniopomorskie Region	1701030	22897	68,90%	2274	1019	1255	207	175	32	0,0090
			Total	**70574**	**36815**	**33759**	**2680**	**1873**	**807**	

Source: *Own study.*

Table 1. *Vehicle charging infrastructure availability indicator.*

	number of vehicle charging stations	AC	DC	number of electric vehicles (BEV+PHEV)	AC charging infrastructure availability indicator	DC charging infrastructure availability indicator	total charging infrastructure availability indicator
Dolnośląskie Region	238	172	66	4874	0,04	0,01	0,05
Kujawsko-Pomorskie Region	169	112	57	2287	0,05	0,02	0,07
Lubelskie Region	44	25	19	1940	0,01	0,01	0,02
Lubuskie Region	57	28	29	1091	0,03	0,03	0,05
Łódzkie Rregion	122	47	75	3097	0,02	0,02	0,04
Małopolskie Region	220	145	75	7087	0,02	0,01	0,03
Mazowieckie Region	472	362	110	22103	0,02	0,00	0,02
Opolskie Region	69	48	21	1019	0,05	0,02	0,07
Podkarpackie Region	64	33	31	1908	0,02	0,02	0,03
Podlaskie Region	56	34	22	1455	0,02	0,02	0,04
Pomorskie Region	277	209	68	4673	0,04	0,01	0,06
Śląskie Region	337	232	105	7123	0,03	0,01	0,05
Świętokrzystkie Region	33	26	7	1064	0,02	0,01	0,03

Warmińsko-Mazurskie Region	145	130	15	1030	0,13	0,01	0,14
Wielkopolskie Region	170	95	75	7549	0,01	0,01	0,02
Zachodniopomorskie Region	207	175	32	2274	0,08	0,01	0,09

Source: *Own study.*

In the case of analyzing the correlation between the number of electric vehicles (BEV + PHEV) and the number of vehicle charging stations in individual voivodeships, we are dealing with a correlation analysis. The most frequently used measure describing the relationship between two features is Pearson's linear correlation coefficient (rxy) (Czyżycki, Hundert, and Klóska, 1998). However, the use of this coefficient depends on the fulfillment of two conditions:

A. Both analyzed features are quantitative features (expressed in numbers).
B. The relationship between the studied phenomena is linear.

The rxy coefficient can be calculated for a small (correlation series) and large (correlation table) number of observations, and the shape of the relationship can be illustrated with a straight line, i.e. when the regression is linear (M. Witek, 1998). Pear-son's linear correlation coefficient (rxy) is calculated from formula (Czyżycki, Hundert, and Klóska, 1998):

$$r_{xy} = \frac{c(y,x)}{S(y) \times S(x)}$$

where:

$$c(y,x) = \overline{yx} - \bar{y} \times \bar{x}$$

$$S(y) = \sqrt{\overline{y^2} - (\bar{y})^2}$$

$$S(x) = \sqrt{\overline{x^2} - (\bar{x})^2}$$

$$\overline{y^2} = \frac{\sum_{j=1}^{n} y_j^2}{n}$$

$$\overline{x^2} = \frac{\sum_{i=1}^{n} x_i^2}{n}$$

$$\bar{y} = \frac{\sum_{j=1}^{n} y_j}{n}$$

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$$

$$\overline{xy} = \frac{\sum_{i=1}^{n} x_i y_i}{n}$$

x_i – value of feature X,
y_i – value of feature Y,
n – number of observations.
Moreover, the correlation coefficient rxy is characterized by the following properties:

A. Takes values from a closed interval <–1, 1>.
B. The larger its absolute value, the stronger the linear relationship between the variables.
C. When its value is zero, it means there is no correlation.
D. When rxy = 1, it indicates an exact positive linear relationship between the features.
E. When rxy = – 1, it means an exact negative linear relationship between the features, i.e. if the variable x increases, y decreases – and vice versa.
F. It is symmetrical rxy = ryx, i.e. it is a measure of the strength of the relationship between features x and y and features y and x.

for the analyzed data set, this value takes:

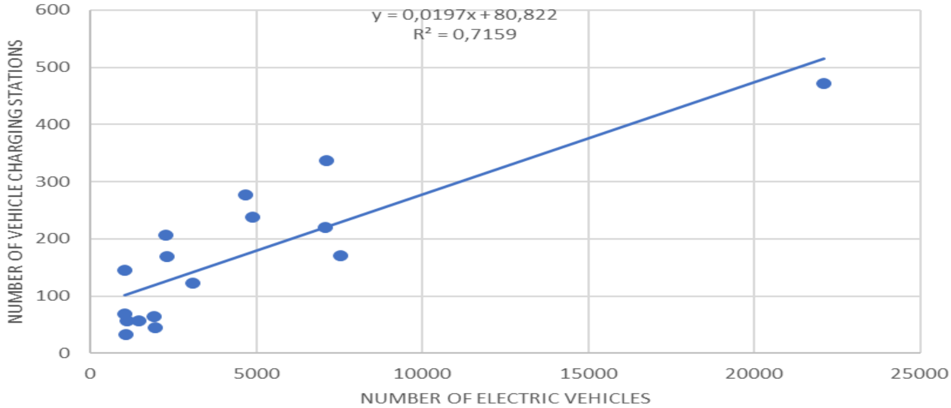
$$r_{xy} = 0{,}846$$

The correlation coefficient can be thought of as the normalized covariance. The correlation value is always in the range <–1, 1>, which allows the analysis to be independent of the domain of the studied variables. Therefore, linear regression was also used as a statistical measure of variable variance, which for the proposed range amounted to R2 = 0.7159, which proves the relatively high dependence of the data used in the model. The detailed scope is presented in Figure 4.

It is also worth considering an analysis relating to one of the electromobility indicators, i.e., Electric Mobility Penetration Index (EMPI). This indicator can help understand the degree to which electromobility is integrated in a given community or region. EMPI can be defined as the ratio of the number of electric vehicles to the total number of vehicles in a given area, expressed as a percentage.

The higher the indicator, the greater the penetration of electromobility in a given community. We refer this indicator to the voivodeship level and it is as follows:

Figure 3. *Linear regression between the number of vehicle charging stations and the number of electric vehicles.*

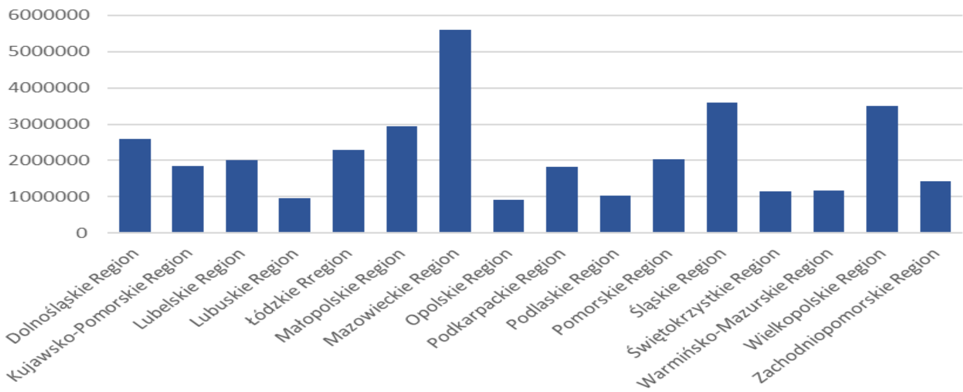


Source: *Own study.*

$$EMPI = \frac{Number\ of\ electric\ vehicles}{Total\ number\ of\ vehicles}\ x\ 100$$

For the purposes of the evaluation, data from 2023 was analyzed for the total number of passenger vehicles in Poland. Figure 7 clearly shows that the Masovian Voivodeship is the clear leader. Moreover, the Silesian, Greater Poland, Lesser Poland and Lower Silesian voivodeships have potentially similar values (as shown in Figure 5).

Figure 4. *Number of passenger cars in Poland as of October 2, 2023*



Source: *https://bdl.stat.gov.pl/bdl/dane/podgrup/wykres.*

The evaluation carried out an in-depth analysis for electric vehicles in relation to the total number of passenger vehicles. Table 3 presents the results of the EMPI evaluation.

5. Conclusions

The article pays particular attention to the relationship between the development of infrastructure for charging electric vehicles and the actual number of vehicles traveling on Polish roads. The low infrastructure availability rate may suggest that the charging infrastructure in individual voivodeships may be insufficient, e.g. in the Lubelskie, Masovian or Greater Poland voivodeships. It is worth noting that the leader in Poland is the West Pomeranian Voivodeship.

Figure 3. *The results of the EMPI evaluation.*

Region	*EMPI*
Dolnośląskie Region	0,19%
Kujawsko-Pomorskie Region	0,12%
Lubelskie Region	0,10%
Lubuskie Region	0,11%
Łódzkie Rregion	0,14%
Małopolskie Region	0,24%
Mazowieckie Region	0,39%
Opolskie Region	0,11%
Podkarpackie Region	0,11%
Podlaskie Region	0,14%
Pomorskie Region	0,23%
Śląskie Region	0,20%
Świętokrzystkie Region	0,09%
Warmińsko-Mazurskie Region	0,09%
Wielkopolskie Region	0,22%
Zachodniopomorskie Region	0,16%

Source: *Own study.*

The authors also indicated, from their perspective, key areas that constitute barriers to the development of EV infrastructure in Poland. Our study showed that urbanization also has a significant impact on the development of electromobility. In cities where it is higher, there is a greater need to develop electric vehicle infrastructure. The value of the correlation indicates a strong positive linear relationship, which means that the more electric vehicles appear on Polish roads, the more stations are installed in individual places in Poland.

High population density and the number of vehicles per unit area require more charging stations to meet the grow-ing demand for electromobility. The EMPI level of analysis means that electromobility has a relatively low share in the total number of vehicles on the roads in Poland. Low values suggest that electric vehicles today constitute only part of the total vehicle fleet moving in Poland.

However, it is worth paying attention to the relationship between the level of urbanization in this respect. In highly urbanized areas where population density is higher, electromobility may be more attractive due to shorter routes and the availability of charging stations. Conversely, in rural areas where population density is lower, electro-mobility may be less common due to longer distances to be covered and less availability of stations. It is worth adding that despite the current low level of electromobility in Poland, there is a chance for an increase in the penetration of electric vehi-cles in this area.

The availability of public transport also plays an important role, as integrating charging infrastructure with public transport can encourage residents to use electric vehicles. However, separate studies on the development of electrified public transport should be carried out to assess both the preferences of users themselves and the performance of the support-ing infrastructure.

Research also shows that public policy plays a key role in the development of electromobility, and in cities with a higher level of urbanization, there are mechanisms that allow for easier implementation of pro-ecological public poli-cies. Currently, in Poland, the development of infrastructure for charging electric vehicles is not implemented in a centrally coordinated way. There are private investors who still expect incentives from the government that will allow them to operate on a larger scale.

A compelling extension of these studies would involve conducting an analysis on the con-current reduction of tailpipe emissions with the increase in the number of electric vehicles. Understanding the synergies between the growing adoption of EV’s and the resultant decrease in traditional tailpipe emissions would provide valuable insight into the overall environmental impact of transitioning to electric mobility. Such analysis could encompass various factors, in-cluding the geographical distribution of EV’s, our evolution of infrastructure and the corresponding reduction in conventional vehicle emissions.

Such research would not only contrib-ute to understanding of the environmental benefits of EV’s but also provide practical guidance for policymakers and stakeholders seeking effective strategies to address air quality and cli-mate change concerns. Additionally, it is noteworthy to consider the integration of renewable energy sources, such as hydrogen – with electric vehicles.

The synergic between EV's and hy-drogen (particularly fuel cells) presents a holistic approach to sustainable transportation. Green hydrogen serves as a clean and versatile energy carrier. Integrating hydrogen-powered vehicles alongside BEV's contributes to a diversified and resilient electromobility ecosystem. This integration not only addresses challenges related to the intermittency of RES, but also ex-pands the scope of sustainable transportation, offering a comprehensive solution to reduce both direct and indirect emissions associated with the transport sector.

In Poland, initial endeavors have been made towards integrating RES with particular focus on the production of green hydrogen for charging EV's fleet of a major corporation in the Zachodniopomorskie Region. This serves as an inspiring example for other regions to harmo-nize renewable energy production with the electrification of transport for a greener and more sustainable future. Exploring the combined impact of electric vehicles and hydrogen-based technologies represent a forward-looking avenue for achieving a more sustainable and envi-ronmentally conscious future in the realm of transportation

6. Conflicts of Interest

Authors declares that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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