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Electromobility in public transport – good practices and experiences of cities in Poland

Elektromobilność w publicznym transporcie zbiorowym – dobre praktyki i doświadczenia miast w Polsce

Abstract. Social and economic transformations in the 21st century brought many new changes in the lifestyle of the inhabitants, in the system of social values and urban mobility. In recent years, the desire to improve the quality of life of the inhabitants of urban areas was recognised by an increasing emphasis on environmental issues. For this reason, both national and European strategic documents indicating the direction of the development of public transport impose a number of restrictions on the negative impact of transport on the environment. One way of achieving ambitious targets in this area is to develop and popularize electromobility in cities. The article presents technical, economic, social and legal conditions of electromobility in Poland. Moreover, a review of good electromobility practices in public public transport was made and perspectives of further development of Polish cities in the aspect of electromobility were described and a SWOT analysis was made. The aim of the article is to identify factors, potential and limitations resulting from the implementation of electromobility in public public transport in Poland.

Key words: electromobility, electric buses, collective public transport

Synopsis. Przemiany społeczno-gospodarcze w XXI wieku przyniosły ze sobą wiele nowych zmian w stylu życia mieszkańców, systemie wartości społecznych i mobilności miejskiej. W związku z chęcią poprawy jakości życia mieszkańców aglomeracji miejskich, w ciągu ostatnich lat coraz większy nacisk kładziony jest na zagadnienia związane z ekologią. Z tego względu zarówno krajowe, jak i europejskie dokumenty strategiczne wskazujące kierunek rozwoju publicznego transportu zbiorowego narzucają wiele ograniczeń dotyczących negatywnego oddziaływania transportu na środowisko naturalne. Jednym ze sposobów osiągnięcia ambitnych celów w tym zakresie jest rozwój oraz rozpowszechnienie elektromobilności w miastach. W artykule przedstawiono techniczne, ekonomiczno-społeczne i prawne uwarunkowania elektromobilności w Polsce. Ponadto dokonano przeglądu dobrych praktyk elektromobilności w publicznym transporcie zbiorowym oraz opisano perspektywy dalszego rozwoju polskich miast w aspekcie elektromobilności, oraz dokonano analizy SWOT. Celem artykułu jest identyfikacja czynników, potencjału

i ograniczeń wynikających ze wdrożenia elektromobilności w publicznym transporcie zbiorowym w Polsce.

Słowa kluczowe: elektromobilność, autobusy elektryczne, publiczny transport zbiorowy

Introduction

The electrification of road vehicles in collective public transport has now become a global megatrend. The key to understanding it lies in urban mobility. In European capitals, the share of public collective transport is often above 30%. In Helsinki and Lisbon, the share of collective public transport in the city is 34%, in London and Paris 36% and in Vienna, which is known for its high quality of these services, as much as 39%. In Madrid this percentage is 42%, in Prague 43%. Warsaw is even higher in this ranking. In the Polish capital as much as 47% of all urban traffic is served by subway and buses [Czernicki et al. 2019].

Public transport is the core of electromobility in Poland. Investing in new electric buses is a global trend. The main stimulus for its development is the desire to become independent of oil-derivative fuels and to reduce direct emissions from vehicles, which may contribute to the improvement of air quality in a given area. One of the pillars of the European Union's socio-economic policy is sustainable development aimed at a low-carbon economy, and electromobility is a part of this approach. For Poland, this is important for both environmental and energy security reasons. Poland belongs to the countries at the forefront of collective electro-mobility. Electrification of road vehicles in public collective transport provides certain environmental and operational benefits, improving the quality of life in cities. These include, among others, the lack of pollutant emissions at the place where electric buses are used, and the possibility of creating Clean Transport Zones, improving travel comfort and reducing noise emissions. This means that electric buses are becoming more and more popular and their supply is steadily growing.

Legal aspects of electromobility in Poland

In Poland, electromobility began in 2017, when the government adopted the Electromobility Development Plan on 17 March [Olkuski and Grudziński 2019]. The Electromobility Development Plan is one of the flagship projects of the Strategy for Sustainable Development (in Polish: SOR). This strategy assumes the production of electric vehicles and the construction of the necessary infrastructure, which will allow, among other things, for the creation of ecological public transport in Polish cities. The multidimensional objectives and activities to be brought about by the development of electromobility in Poland are based on a number of strategic documents, which form the formal basis for any actions to be taken by private bodies or entities. The implementation of the SOR objectives and the Electromobility Development Plan became the basis for the creation of a regulatory package consisting of the following strategic documents:

- the Electromobility Development Plan "Energy to the Future", adopted by the Council of Ministers on 16 March 2017,
- National Policy Framework for Development of Alternative Fuels Infrastructure, adopted by the Council of Ministers on 29 March 2017,
- Electromobility and Alternative Fuels Act of 11 January 2018,
- the Act establishing the Low-Emission Transport Fund, i.e. the Act of 6 June 2018 amending the Act on Biocomponents and Liquid Biofuels and other acts, signed on 10 July 2018.

The first package of regulations is the Electromobility Development Plan in Poland, which defines the benefits associated with the popularization of electric vehicles in our country and identifies the economic and industrial potential of this area. It includes detailed objectives of the electromobility plan, e.g.:

- to create conditions for the development of electromobility in Poland through the popularization of charging infrastructure and incentives to purchase electric vehicles,
- industrial development in the field of electromobility,
- the stabilization of the electricity grid through the integration of vehicles into the grid.

The foundations of the electromobility ecosystem along with the coordination of the development of the electromobility industry and the stimulation of the demand for electric vehicles will be provided for the successful development of electromobility [Ministerstwo Energii 2017]. In addition, the role of the administration plays a key role in the implementation of this process. In order to implement the assumptions of the Electromobility Development Plan in Poland, actions should be taken in the area of social, technological and legal conditions, as shown in Figure 1.

The Electromobility Development Plan in Poland provides for the use of appropriate tools that will create an algorithm optimizing and limiting the deployment of infrastructure to the so-called critical locations, i.e. where the lack of charging points will reduce the functionality of an electric vehicle. It is important that the algorithm should seek synergy between the development of passenger car charging infrastructure and the development of public transport infrastructure. At the same time, the Plan proposes tools for the development of the electric vehicle market, which will lead to an increase in the number of electric vehicles when a significant part of the infrastructure is ready. An additional factor that has been taken into account when proposing a sequence of actions consists in the need to link the development of the electromobility industry and the vehicle market with the development of the electricity grid. Incentives to purchase vehicles will be stepped up as soon as the industry is able to respond to the demand generated by the support instruments and the network is able to meet the growing demand for vehicle charging capacity and energy. The social aspect is also a tool for the development of electromobility in Poland. Increased awareness of city dwellers and the resulting change in the choice of means of transport from individual to public transport will positively affect the state of the natural environment and reduce the chronic phenomenon of congestion.

The second package of legal regulations is contained in the National Policy Framework for the Development of Alternative Fuels Infrastructure, adopted by the Council of Ministers on 29 March 2017. Alternative fuels within the meaning of the Directive are fuels or energy sources which serve, at least partially, as a substitute for crude oil

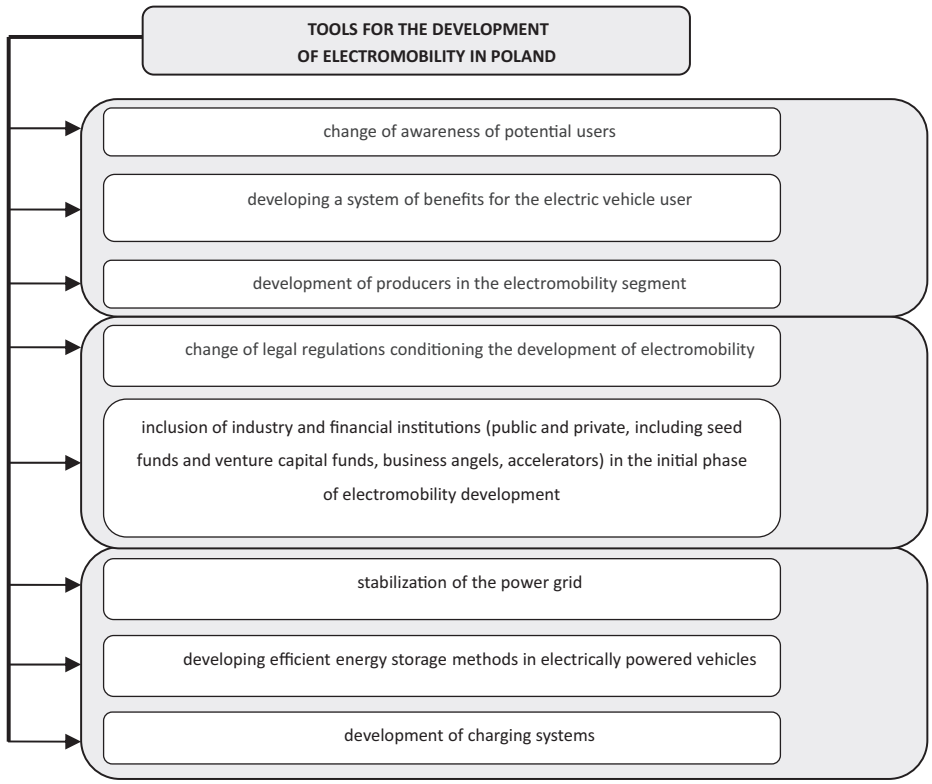

Figure 1. Tools for the development of electromobility in Poland
Rysunek 1. Narzędzia rozwoju elektromobilności w Polsce
Source: own elaboration based on [Ministerstwo Aktywów Państwowych 2019].

sources of energy in transport and which may potentially contribute to reducing the dependence of EU Member States on oil imports and to increasing the climate neutrality of transport and improving the environmental performance of this sector. These include, inter alia, electricity, hydrogen, biofuels, synthetic and paraffin fuels, natural gas (including biomethane) in the form of compressed natural gas (CNG) and liquefied natural gas (LNG) and LPG.

According to the report presented by the Ministry of Energy at the end of July 2019, 971 normal capacity charging points, 486 high capacity charging points and 28 CNG filling stations were available in Poland [Centrum Informacji o rynku Energii]. The national policy framework for the development of alternative fuel infrastructure sets out objectives, according to which, by the end of 2020, 32 selected agglomerations in Poland should offer six thousand charging points of normal power, 400 charging points of high power and 70 refueling points of compressed natural gas (CNG) [Ministerstwo Energii 2017]. At the same time, the report shows that 4,009 electric vehicles, 2,321 plug-in hybrid vehicles and 4,900 CNG vehicles were in use in Poland at the end of July [Ministerstwo Energii 2017].

The National Policy Framework for the Development of Alternative Fuel Infrastructure predicted that in 2020 and 2025, approximately 70,000 and 1 million electric cars would be registered in Poland, respectively. The draft of National Energy and Climate Plan assumes that there will be 50,000 electric cars in 2020 and about one million electric cars in 2025. Similar values are also provided for in the draft of Energy Policy of Poland until 2040. According to the data presented in the National Policy Framework, in the years 2020 and 2025, in Poland, almost 9.6 thousand and 54.2 thousand vehicles powered by natural gas CNG and about 0.5 thousand and over 2.7 thousand vehicles powered by natural gas LNG are to be registered respectively.

The monitoring of the level of achievement of the objectives set out in the National Policy Framework for the Development of Alternative Fuels, as well as the assessment of the level of achievement of these objectives by the Minister of Energy results from the provisions of the Directive of the European Parliament and of the Council on the development of alternative fuel infrastructure and the Act of 11 January 2018 on Electromobility and Alternative Fuels, which is the third package of electromobility regulation in Poland.

The Act on Electromobility and Alternative Fuels sets out the conditions for the development of and rules on the deployment of alternative fuel infrastructure for transport, on the provision of charging services for electric vehicles and on the refueling of natural gas vehicles. It also sets out information obligations on alternative fuels and the establishment of clean transport zones. The infrastructure for alternative fuels is to be developed in urban agglomerations, in densely populated areas and along major roads at an early stage. In this context, the Act focuses on charging stations for electric vehicles and natural gas stations. It defines the rules concerning the way of informing consumers about alternative fuels, the way of marking distributors and vehicles and the rules of creating and functioning of the Alternative Fuel Infrastructure Register. The Act provides a number of benefits for electric vehicle drivers, including an exemption from excise duty on the purchase of electric vehicles and hydrogen-powered vehicles, the possibility to drive electric vehicles on bus lanes, additional parking spaces and exemption from certain fees. The Act provides a legal framework for testing autonomous vehicles on public roads. In addition, it provides a legal basis for municipalities to introduce clean transport zones for environmentally friendly vehicles. The first clean transport zone in Poland was established in Kraków. It limits the movement of cars with combustion engines, thus promoting the so-called ecological transport, i.e. electric cars. The Act on Electromobility and Alternative Fuels is to stimulate the development of electromobility and promote the use of other alternative fuels in the transport sector in Poland.

The fourth package of electromobility regulation in Poland takes the form of the Low-Emission Transport Fund, which is administered by the Minister of Energy. The task of the Fund is to finance projects related to the development of electromobility and transport based on alternative fuels. Thanks to the funds from the Fund, the activities listed, among others, in the National Policy Framework for Alternative Fuel Infrastructure Development, the Electromobility Development Plan in Poland and the act of 11 January 2018 on electromobility and alternative fuels, i.e. documents implementing into Polish law the assumptions of EU regulations on the development of alternative fuel infrastructure will be carried out. The Low Emissions Transport Fund supports the development of alternative fuel infrastructure and the creation of a market for vehicles using these fuels.

The main benefits of launching financing from the Low Emissions Transport Fund include:
- the development of infrastructure for refueling natural gas, liquid biofuels and other alternative fuels and for charging electric vehicles,
- the possibility of introducing new business models based on alternative fuels and their infrastructure,
- the development of low-carbon vehicle fleets and low-carbon public transport,
- possible reduction in the costs of using alternative fuel vehicles for citizens,
- improvement of air quality resulting from the reduction of harmful emissions from road vehicles, particularly in large agglomerations.

According to the forecasts of the Ministry of Energy, the implementation of four regulatory packages dedicated to the development of electromobility in Poland is expected to result in the achievement of the following objectives for 2020 and 2025 [Ministerstwo Aktywów Państwowych 2019].

In 2020, in 32 selected agglomerations:
- in the electric vehicle segment: 50,000 vehicles will be moving on the roads, 6,000 points of normal charging power (the so-called slow charging points with a power not exceeding 3.68 kW) and 400 points of high charging power will be constructed,
- in the segment of cars powered by natural gas in the form of CNG (compressed natural gas), 3,000 vehicles will be moving on the roads and 70 refueling points will be constructed.

On the national level, the following indicators concerning electromobility are forecast for 2025:
- 1 million electric vehicles on the road,
- in the CNG segment of natural gas vehicles: 54,000 vehicles will be on the roads and 32 charging points will be available along the TEN-T core network.

Apart from the indicated documents, the political and legal grounds for the development of electromobility in Poland are based on the resolutions of the municipal councils in the form of Sustainable Development Plans for Public Transport and Sustainable Urban Mobility Plans.

Electromobility and sustainable development of public transport in the cities

At present, there is no turning back from urban transport development based on low-emission vehicles. Implementation of innovative solutions in the aspect of urban rolling stock electrification is aimed at improving the quality of life of the inhabitants by reducing the external costs of transport, i.e. noise or environmental pollution. Pro-ecological actions taken by city authorities are based on the principles of sustainable development. Before presenting the concept of sustainable development, one should look at the definitions of sustainability and development itself. The fundamental human desire to protect and improve the quality of life can be called sustainability. The concept of sustainability includes integrated human activities (the need for coordinated decisions between different interest groups, sectors and legislative systems) [Fajczak-Kowalska and Kowalska 2017]. On the other hand, development is inseparably connected with the continuity of

the process of transformation (constant movement and related mutual influence of phenomena taking place in the surrounding reality). This process cannot exist without stable institutional, ethical, social, legal, technological and organisational foundations, which set directions and shape the behaviour of development entities.

Sustainable development of transport is a concept based to a large extent on creating an opportunity to seek a compromise between three components: economic, social and ecological reasons [Rokicka and Woźniak 2016]. A sustainable urban public transport system is a transport system that meets the communication needs of city dwellers [Chamier-Gliszczyński 2011]:

- in a safe manner that does not endanger human health or the environment,
- using renewable energy sources,
- economically accessible for the city residents,
- aiming at reducing harmful gas emissions,
- capable of functioning effectively, sustaining the economy and regional development,
- not causing congestion.

Public transport has important social, economic, spatial and environmental impacts and therefore it is an essential factor in relation to the sustainability of society and the economy. This is due not only to the implementation of legislation, both at European and national level, but also to the increasingly widespread greening of urban agglomerations and city authorities encouraging the use of electrified forms of transport.

From the passenger's point of view, the fact that an electric or diesel bus will drive to a bus stop does not determine the passenger's transport decisions. Only a holistic approach to urban transport services can determine its choices. Skillful application of road traffic incentives and privileges for public transport is currently a priority action, carried out within the framework of the implementation of sustainable mobility and development policies in order to increase the use of environmentally friendly forms of urban transport over individual transport.

Regardless of the rolling stock used, privileged treatment makes it possible to improve travel conditions for public transport passengers and improves the modal split between individual and public transport towards greater use of public transport [Motowidlak et al. 2019]. This in turn translates into a reduction in the number of individual means of transport in daily urban traffic, which is reflected, inter alia, in a lower need for space for car infrastructure (roads, parking lots) and a reduction in the chronic phenomenon of congestion on city roads.

Traffic is one of the factors that influences the poor air quality in cities. Although it is not the main cause of smog, but it significantly raises its level. It is also a substantial source of other pollutants. Road transport vehicles are also the main cause of noise in the vicinity of roads. The use of traffic priorities for public transport is an adequate means of action in the framework of urban transport policies. The most common solutions encouraging residents of urbanized areas to use low-emission public transport implemented in cities include the bus lanes. These are dedicated lanes where only bus traffic (or of other selected vehicles, e.g. taxis or special vehicles) is allowed. They are particularly effective on road sections with traffic jams [Szada-Borzyszkowski and Szada-Borzyszkowska 2017]. It is also possible to separate a part of the roadway for buses within the tram track. A special case of priority for bus transport is the bus lock, which consists in giving a sig-

nal to the bus allowing it to occupy any lane at the entry to the crossing before it is filled up with other vehicles.

Each of these measures is designed to reduce public transport travel times, which is an incentive for city dwellers. Thanks to the independence of bus transport from road traffic, the reliability of this means of transport is also increased and the randomness of its travel times is reduced.

City dwellers expect a high quality of life, which is considered to be the most important factor influencing the development of electromobility. Striving to improve the quality of life should be considered the overriding premise for the development of electromobility in urban public transport. It has mainly a social dimension.

Additional important drivers for the development of electrification of public transport in cities include the following aspects [Szumska and Witkowski 2018]:

- business – related to supporting the national capacity to build strong operators at all stages of the electromobility value chain,
- economic – resulting from the pursuit of rationalization of urban transport costs,
- transport – subordinated to the need to improve road traffic conditions,
- technical-technological – resulting from the possibility of powering vehicles with electric energy,
- operational – related to the susceptibility of public transport to implementation of electromobility,
- ecological – the expression of the aspiration to protect the natural environment.

Public collective transport is more susceptible to electrification than individual transport. This is due in particular to the fact that public transport has a regular character and is based on a timetable which determines the route, stops and departure times. Therefore, this specificity makes it easier to adapt the location of charging points due to the limited range of electric buses. In the case of a bus, there is no urgent need for a change of route or additional transport, which is acceptable in the case of cars used by private individuals or companies in the TSL sector.

This is why city buses have the greatest chance to become the first fully electrified group of means of transport in Poland.

Good practices of electromobility in public transport on the example of Polish cities

Solaris Urbino 12 electric is the most popular example of electric bus in Poland. It is a low-floor bus designed for passenger transport in cities. The energy of the vehicle is stored in two lithium-ion batteries with a capacity of 240 kW, which are located in the roof superstructure of the bus. The vehicle can be loaded in two ways. Either by means of a pantograph (Figure 2), which enables charging at bus stops or a plug-in connector (Figure 3), enabling charging by means of a charger located in the bus depot.

The bus is 12 meters long and has 30 seats. Buses of this brand have been manufactured in electric version by the manufacturer Solaris since 2011. In September 2017 Solaris Urbino 12 electric (new generation) was awarded at the prestigious fair in Hannover with the statuette "Bus of the Year", winning in its category city buses with manufacturers such as: Irizar, Mercedes, Ebusco, Van Hool [Wierzbowski 2019]. Until 2015, these

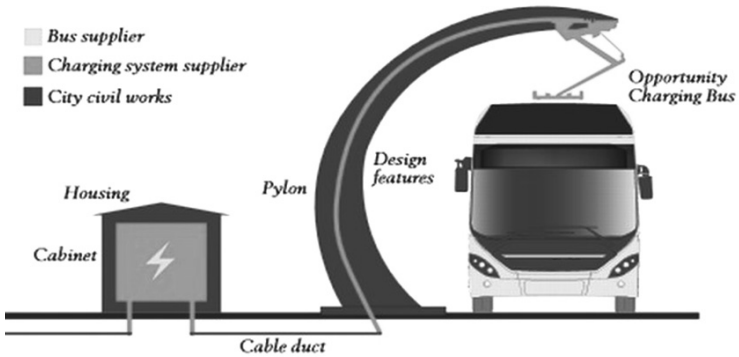

Figure 2. Electric bus charging scheme based on pantographs
Rysunek 2. Schemat ładowania autobusów elektrycznych oparty na pantografach
Source: [MM Magazyn Przemysłowy 2015].

Figure 3. Electric bus charging scheme based on the plug-in connector
Rysunek 3. Schemat ładowania szyny elektrycznej oparty na złączu wtykowym
Source: [TrackFocus 2011].

buses were mainly delivered to foreign customers, among which we can mention: Czech Republic, Spain or Germany.

The buses of this brand were also delivered to cities in Poland, serving urban passenger transport in cities such as Warsaw, Cracow, Jaworzno and Inowrocław.

Warsaw (Warszawa)

In June 2019, the fleet of electric buses operated by Miejskie Zakłady Autobusowe Sp. z o.o. in Warsaw (MZA Warszawa) consisted of 31 vehicles, which constituted 2% of the city bus fleet [Dybalski 2019]. 20 Solaris Urbino 12 electric buses and 10 Ursus City Smile 12 LFE buses operated in the city. When operating low-emission buses, Warsaw is

guided primarily by social expectations regarding the quality of life in the city and the need to meet the requirements of the Act on Electromobility and Alternative Fuels. These expectations can be met by through total elimination of conventional fuels from city bus supply systems in the perspective of several dozen years to come [Urbanowicz 2018].

Warsaw MZA is one of the largest communication companies in Europe [Motowidlak et al. 2019]. Every day, it sends over 1.2 thousand buses to the streets of Warsaw. MZA Warsaw is also one of the European pioneers in the introduction of electricity and a low-carbon fleet to operate public transport. The development of electromobility is financed by MZA Warsaw with own funds, EU funds and loans. The limited availability of financial resources and the lack of bus charging points in the city are perceived by MZA Warsaw as the main barriers to the development.

Cracow (Kraków)

Cracow was the first of the big Polish cities to start testing electric buses. It is the first city in Poland to have a regular line operated by electric buses and a station for charging buses by a pantograph [Dybalski 2018]. It was also the residents of the capital of Małopolska Region who, as the first in Poland, had the opportunity to travel by the articulated electric bus. Deciding to operate electric buses, the city of Cracow is looking for solutions that will allow on the one hand to develop public transport, and on the other hand, to meet increasingly stringent environmental standards.

The use of electric buses to provide urban transport services is part of Cracow's strategic, low-carbon policy and reducing air pollution from urban transport [Motowidlak et al. 2019]. As early as in 2014, Miejskie Przedsiębiorstwo Komunikacyjne Sp. z o.o. in Cracow (MPK Kraków) tested electric buses in urban traffic.

Many months of testing confirmed, among other things, large savings for the carrier. It turned out that electricity costs for electric buses account for about a quarter of diesel costs. On average, MPK Kraków spent PLN 1327.21 thousand on driving a diesel bus for a million kilometers, while PLN 335.2 thousand for electricity is needed to cover this distance by the electric bus [Motowidlak et al. 2019].

With the objective of meeting the requirements of the Act on Electromobility and Alternative Fuels, the Cracow authorities have adopted general assumptions regarding the increase in the number of city bus fleets. These assumptions imply that at least 153 such buses must be purchased in the coming years, with the purchase to be carried out in the following manner: 3 electric buses until 2021.

The Cracow authorities plan that in 2025 one third of the city buses will be electrically powered and the others will meet the combustion standard of at least Euro 6 or use hybrid drive. The implementation of this plan may ensure the position of the city as one of the leaders in the development of electromobility in Poland.

Jaworzno

Jaworzno was the first city in Poland which in 2015 introduced an electric bus to permanent operation. In 2019, as of July 31, from about 60 buses used in the city, 23 were the electric vehicles [pap/mg 2019]. All electric buses have been equipped

with a pantograph charging system, thanks to which the batteries can be recharged both on the route and in the depot. As a standard, the vehicles have a Plug-In connector for night topping up the battery from a stationary charger located in the depot. Thanks to the use of both depot chargers and pantograph chargers installed in the city, the operation of electric buses in Jaworzno is practically unlimited. Buses, thanks to wheelchair ramps and special bays, are adapted for the transport of disabled people. In addition to the extensive passenger information system, the manufacturer has installed an intelligent fleet management system in vehicles consisting of a location device and a GPS antenna, enabling real-time display of arrival and departure times from individual stops.

By 2020, the city intends to buy another 20 electric buses, and will also participate in the tests of prototypes of autonomous public transport vehicles. Thanks to the purchase of 20 new electric buses, as much as 80% of the PKM Jaworzno fleet will be electric vehicles, which will mean that in 2020 Jaworzno may become the first Polish city with completely zero-emission public transport.

Inowrocław

Inowrocław in 2020 enrolled on the map of Poland as the leader of electromobility. This is the first city in Poland with completely ecological rolling stock. Inowrocław is a spa town. 85 hectares of brine park are areas under special supervision. Therefore, the idea of introducing zero-emission vehicles was a priority for the city's authorities. It was one way to improve air quality in the city. The first activities towards the implementation of electromobility were carried out in 2015, when classic hybrids (eight buses) were purchased. The effects were visible after a year from the implementation of the newly purchased rolling stock. In 2015, according to the World Health Organization, Inowrocław was the only Polish city that met stringent requirements for air purity [Motowidlak et al. 2019]. WHO examined around 150 cities in Poland in terms of air quality. Inowrocław took first place in 2016. All types of buses for Inowrocław were entirely manufactured in Poland, at the Volvo factory in Wroclaw. The city successively implements its activities in modern transport trends and already today meets the legal requirements for zero-emission public transport, which will be in force in Poland only from 2025. However, the city does not stop there and strives for further development. To this end, it is necessary, however, to plan and set directions for action, what the current Strategy for the development of electromobility for the City of Inowrocław is to help. A modern charging infrastructure has also been created – four pantographs are used for quick charging of electric buses during the implementation of courses in various parts of Inowrocław. Volvo 7,900 electric hybrid buses differ from classic hybrids in that they are mostly powered by electricity on most routes. The small internal combustion engine has only an auxiliary function. They can travel in electric mode about 70% of the route (depending on the conditions in which it moves), and the battery is topped up at the end stops and lasts only three to six minutes [Motowidlak et al. 2019]. Electric hybrids can also be charged in the depot using a plug-in connector, with a full charge of their battery requiring about two hours. Both charging methods are used in Inowrocław.

Prospects for further development of electromobility in Poland – SWOT analysis

The process of transformation in public transport from a fleet of conventional buses to a fleet of 100% electric buses requires a scientific approach, but and rational planning of all processes. This requires an analysis of the political, economic and business environment in Poland. Such an analysis must include planning future activities in order to create conditions for the realization of these intentions, depending on the importance (attractiveness). For this purpose, a SWOT analysis was carried out to determine the current state of electromobility in Poland and the prospects for its further development. The results of the analysis are presented in Figure 4.

STRENGTHS	WEAKNESSES
– energy efficiency – environmental benefits – promoting modal shift – enrichment of opportunities for travel for sers	– cost of living – limited travel range – demand for dedicated spaces – initial investment in rolling stock and charging stations – long charging time for buses using low-budget chargers – local shortages of power reserves and capacity of the power grid
OPPORTUNITIES	THREATS
– possible synergies in combination with low emission zones and parking activities – possible renewal of the public transport fleet – possibility to optimise electricity consumption by adjusting the charging time to the minimum load of the energy systems or building an infrastructure for replacing vehicle batteries	– underdeveloped network of voltage lines, necessary for power output in case of building significant electricity sources – uncertainty in the market (such as plugs and charging standards) – difficulties in obtaining land for network investment

Figure 4. SWOT analysis of electromobility in Poland
Rysunek 4. Analiza SWOT elektromobilności w Polsce
Source: own elaboration.

The basic problems in the implementation of the plan for the development of electromobility in Poland are the functionality of low-emission rolling stock in public transport. There is no doubt that low fuel and operating costs (e.g. no need to change oil or some filters) are a very attractive asset for the electric rolling stock, and financial incentives can offset the high acquisition cost, which is a significant barrier to access.

Batteries are a key element of electric rolling stock in public transport, but for the whole electromobility ecosystem, charging stations are also important. Lack or inadequacy of these stations is currently the main barrier to be overcome on the road to the spread of electromobility in Polish cities.

The issue of ensuring sustainable urban mobility will be one with the most important tasks that will be faced by metropolitan self-governments in the future. Already today, many of them are facing increasing vehicle traffic, an overloaded and inefficient public

transport system and at the same time want to combat air pollution. Settlement factors In the city, access to work, infrastructure, including low-carbon public transport, is now a major challenge in terms of planning and urban transport efficiency.

Conclusions

Transport is currently responsible for a significant proportion of CO_2 emissions. Forecasts assume that by 2050 carbon dioxide emissions from this sector will increase from 6–7 gigatons to 16–18 gigatons [Leonardo ENERGY.pl 2018].

In addition, around 30% of Europeans live in cities where air pollution levels exceed EU air quality standards. Conventional fuels consumed by buses are one of the largest sources of emissions of: CO_2, nitrogen oxides and particulates. In order to improve the quality of life and protect the natural environment, a law on electromobility and alternative fuels has been adopted in Poland, and the Electromobility Development Plan and the National Policy Framework for the Development of Alternative Fuel Infrastructure have been introduced. Electrification of transport has become a common trend leading to the achievement of sustainable development. Electric buses in Polish cities improve the quality of life of city dwellers by reducing air pollution and noise. Environmental protection and constant technological progress make electric buses the future of public transport, along with trams, subways, fast urban railways and other electric vehicles.

The number of electric buses in Polish cities is growing at a record pace, bringing benefits to residents, transport operators and vehicle manufacturers. Electromobility is able to significantly reduce air pollution and noise in cities, and electrification of public transport can be the first important step in the transition to "clean" individual transport for citizens.

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