The directions of development and potential of Lower Silesia in the area of electromobility

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1. Introduction

The growing risks associated with climate changes and increased environmental awareness of communities contribute to the intensification of actions of the European administration designed to stop these processes. The European Union (EU) creates different policies aimed at reducing CO₂ emissions. The EU Parliament formulated the “3x20” plan which provides for a reduction in CO₂ emissions by 20% until 2020, relative to the baseline year. The European Commission has recently expressed its apprehension that only half of this objective can be achieved and therefore it will undertake new initiatives. The European Council and Parliament suggest that a new ambitious strategy in the area of energy efficiency should be pursued in order to utilise the existing potential in this respect. On 8 March 2011, the European Commission announced the new “Energy Efficiency Plan” (EEP). Its proposals go beyond the current target of 20%. The strategic goal is now to achieve a 30% reduction in CO₂ emissions by 2020 and to move to a low-carbon economy in 2050. One of the most important areas of action designed to reduce CO2 emissions is transport within the EU. The document “White Book – Transport”, also published on 8 March 2011¹, is an expression of these plans. This document states as follows: “The future prosperity of our continent will depend on the ability of all of its regions to remain fully and competitively integrated in the world economy. Efficient transport is vital in making this happen.” The analysis of the European Commission also shows that that while deeper cuts can be achieved in other sectors of the economy, a reduction of at least 60% of greenhouse gases (GHGs) by 2050 with respect to 1990 is required from the transport sector, which is a significant and still growing source of GHGs. By 2030, the goal for transport will be to reduce GHG emissions to around 20% below their 2008 level. These ambitious goals are planned to be achieved through many concurrent innovative measures both in the area of transport organisation and the development of appropriate infrastructure and technologies. The above-mentioned document also states the following: “Technological innovation can achieve a faster and cheaper transition to a more efficient and sustainable European transport system by acting on three main factors: vehicles’ efficiency through new engines, materials and design; cleaner energy use through new fuels

and propulsion systems; better use of network and safer and more secure operations through information and communication systems. The synergies with other sustainability objectives such as the reduction of oil dependence, the competitiveness of Europe’s automotive industry as well as health benefits, especially improved air quality in cities, make a compelling case for the EU to step up its efforts to accelerate the development and early deployment of clean vehicles.” An essential element of these efforts is the development and wide use of electric powered vehicles.

![Green eMotion](https://www.greenemotion-project.eu/about-us/index.php)

The EU and its individual member states are already introducing new measures to develop and use various types of electric vehicles. An example can be the Green eMotion project\(^2\). This project is a part of a larger initiative aimed at developing electromobility which is called the European Green Cars Initiative (EGCI). Its aim is to develop pan-European interoperability of infrastructure for the development of electric vehicle applications, together with the development of an adequate network of services. The main objectives of this project include the following:

- To recommend selected standards for electromobility systems (in fact, standards for the whole of Europe);
- To define the IT architecture for a European marketplace;
- To recommend approaches to an optimised grid and charging infrastructure;
- To test and demonstrate the interoperability of an electromobility system in selected demo regions;
- To fine-tune/adapt the standard solutions to existing conditions;
- To make technical analysis, to evaluate the operation of equipment, to prepare recommendations for applications.

As regards the standardisation of electric vehicle power systems and EV charging systems, such standardisation efforts are undertaken by the CENELEC\(^3\). The establishment of different associations and the construction of various types of pilot installations in numerous European cities are a good example of the activities aimed at developing electric vehicles.

An example of such an association can be the Light Electric Vehicle Association (LEVA)\(^4\). This association represents the strategic interests of light electric vehicle makers, manufacturers, distributors, retailers, and users. Members of this association receive support for their businesses, taking into account legislation, regulation, promotion, or best practices.

Many European cities develop different electromobility projects. Berlin is an example of a large city that creates its own development plans in the area under discussion.\(^5\) The Berlin Agency for Electromobility (eMO) is a platform that links the activities and projects not only at the regional level. eMO works out strategies used and developed in Berlin which can be further promoted in other metropolitan cities. One of the activities of eMO is to develop an action plan until 2020\(^6\). The main aim is to create highly visible, integrated projects under real-world conditions and to support the development of a market for electromobility. Berlin already now has significant advantages – an intelligent energy system that relies on renewable resources and a variety of electric vehicles, including electric trucks, cars, scooters, and bicycles. When considering the prospect of electromobility in Lower Silesia, one can draw from this experience.

The electric vehicles market shows high increasing trends. According to American sources, the share of such vehicles in the American market can reach 35% in 2025, including 25% of hybrid vehicles and 10% of all-electric vehicles. This is attributable, among others, to an increase in driving range up to about 400 km per charging cycle. This applies both to all-electric vehicles and hybrid vehicles. It is also estimated that lithium batteries, e.g. such as those manufactured by LGChem, will last even up to 10 years, and not for 3 years as it is now

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\(^4\) http://www.levassociation.com/

\(^5\) www.emo-berlin.de

\(^6\) The Action Plan: Joining forces for a successful transition to the electrically mobile future. www.emo-berlin.de.
on average. This will definitely improve the economy of use of such vehicles. It is estimated that within 10 years the prices of hybrid cars can be at the price level of vehicles with a conventional drive system.

2. The development of electromobility technology

The key for the development of electromobility is to develop infrastructure, mainly for battery charging, and to fit it into the existing system of services. The main areas of research and development include the following:

- batteries;
- propulsion technologies;
- vehicle integration;
- development of designs, primarily for light vehicles and cars;
- recycling.

According to a report of the German National Platform for Electric Mobility (NPE)\(^7\), Germany has more than 2,200 (2012) publicly available charging points for over 4,500 electric vehicles on the roads. The continued development of this infrastructure, with the participation of many industries, will give the leadership position to this country.

The strategy for promoting electric powered vehicles is based on a market-based approach and the readiness to use the widest possible range of technologies. The following vehicle propulsion technologies are taken into consideration as reference technologies: BEV (Battery Electric Vehicle), REEV (Range Extended Electric Vehicle), PHEV (Plug-in Hybrid Vehicle), and light commercial vehicles for urban use.

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Review of electric vehicle technologies.

<table>
<thead>
<tr>
<th>Electric vehicles in general</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reference categories of the NPE</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel and petrol engines will be further developed and optimised. They have not yet reached the limit of their potential efficiency.</td>
<td>Hybrid vehicles are equipped with both an electric motor and internal combustion engine. The engine charges a battery while the vehicle is in motion. The battery is also recharged during braking.</td>
<td>The battery can be charged from the mains. It is also recharged during braking.</td>
<td>When required, power is produced by an internal combustion engine via a generator. This significantly extends the range of the vehicle.</td>
<td>Drive power is provided exclusively from the battery which is recharged from the mains.</td>
<td>Energy is supplied by the fuel cell installed in the vehicle. Chemical energy from hydrogen is converted into electrical energy in the fuel cell.</td>
</tr>
</tbody>
</table>

The market analysis shows that the potential user will only purchase a fully functional product – with the overall service, a capability of charging energy from, preferably, renewable sources, an integrated transport system, and a variety of vehicles to choose from. In the perspective of applications under consideration, the electric vehicle/system is integrated with the transport system through information and communication technologies – the vision of the smartgrid.

For the application of electromobility technologies, one of the key issues is the quality of batteries that can be used. Research in this area is focused on lithium-ion (Li-Ion) battery...

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technologies in the time horizon until 2025 and is designed to increase the driving range of BEV, REEV, and PHEV vehicles. In the post-2025 period, new generations of lithium-sulphur, zinc-air and lithium-air batteries are to be introduced. A measure of activity in this research area is the creation of more than 21 different consortia in Germany which link the activities of various institutions, primarily involved in research as well as in research and development.

The roadmap for the expected development of electromobility technologies.

<table>
<thead>
<tr>
<th>2010</th>
<th>2012</th>
<th>2017/18</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electric Motors</strong></td>
<td>Permanent Fe-based magnets and Cu/Al. coils</td>
<td>Electric motor designs optimised for electromobile applications</td>
<td>Alternative designs and materials</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alternative magnet materials and recycling</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alternative electric drives</td>
<td></td>
</tr>
<tr>
<td><strong>Power Electronics</strong></td>
<td>Parts and components from non-automotive applications</td>
<td>Integrated circuit packaging (IPC) modules and components</td>
<td>Automotive standards achieved, standardised solutions available</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Research into modality and scalability</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Increased integration (electronics, mechatronics)</td>
<td></td>
</tr>
<tr>
<td><strong>Drive Systems</strong></td>
<td>Low level of integration</td>
<td>New topologies and highly-integrated approaches</td>
<td>New system designs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Energy and thermal management</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Charging technologies and power grid integration</td>
<td></td>
</tr>
<tr>
<td><strong>Production Technology</strong></td>
<td>Low production volumes</td>
<td>Automated production facilities for inverters and electric motors</td>
<td>Automated manufacturing solutions capable of flexible output levels</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Concepts for moving from small to large-scale production</td>
<td></td>
</tr>
</tbody>
</table>


In the whole development of the electromobility industry, it is very important to develop new material and component technologies. Such materials will be used in automated manufacturing processes associated with multi-material designs.

The use of lightweight components in a vehicle\textsuperscript{11}.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{car_d-mat.png}
\caption{Car body material distribution.}
\end{figure}

\textsuperscript{11} Progress Report of the German National Platform for Electric Mobility, http://www.elektromobilitaet.din.de

3. Transport conditions in Lower Silesia

Lower Silesia has a dense network of municipal infrastructure and many very good advantages from the point of view of potential development. This is a result of different determinants, e.g. historical determinants, economic conditions, and the region’s strategic location. From the perspective of electromobility development, its high urbanisation rate (71%), as compared with Poland’s average rate (60%), is very important. A relatively dense network of cities with interesting historical buildings can also be considered to be an asset.

Lower Silesia has a well-developed road network with the road density index above the national average. It is likewise with the railway network – its density index is also above the national average.

Lower Silesia’s strengths in the area of transport, tourism and other sectors that create the potential for the development of electromobility also include the following:
• The Wroclaw airport, air ambulance airports, agricultural airstrips, and sports airfields.

• The Odra River transportation axis for cargo and passenger water transport.

• Cultural values of European importance (historical sites, palace and monastery complexes).

• Three centres of subregional impact in the area of administration, judiciary, culture, and higher education, etc.

• Good natural conditions for winter tourism with numerous winter sports centres and well-developed skiing facilities.

• Interesting nature and landscape values, including large protected areas – national and landscape parks as well as nature reserves and places of natural beauty.

• Numerous historical sites and places of historical interest, such as: monuments of architecture and historical buildings, museums and open-air ethnographic museums, places of pilgrimage, places of martyrdom, cultural and tourist events.

• The highest class urban historical sites and Cistercian monuments of international importance, attractive to foreign tourists.

• Extensive spa and leisure facilities of different standard, well equipped to handle tourists all year round.

The chances of electromobility development are enhanced by the efforts to improve the existing road infrastructure, and also energy infrastructure. These efforts can be considered to be the strengths in the region’s conditions, since they confirm the importance of these problems to the community and authorities of the region as well as they document the activity of the local administration. The above-mentioned activities include the following:

• Improvement of cross-border telecommunications links.

• Increase in the number of border crossings.

• Expansion of cross-border connections as elements of the European transport network.
• Construction of a full expressway and motorway system, including a ring road of Wroclaw.
• Modernization of the national railway system, infrastructure, and rolling stock.
• Generation of renewable energy (hydroelectric power plants, windmills, biogas power plants).
• Creation of joint cross-border tourist complexes (e.g. for winter sports with the Czech Republic, half-timbered architecture with Germany and the Czech Republic) and cross-border tourist railway lines (Ring).
• Inclusion of the region in the trans-European transport and telecommunications systems that are being built.
• Intensification of cooperation of the R&D sector with industry in the area of environmental protection as well as effective commercialisation of environmental technologies.

4. Light electric vehicles

Two-wheeled light electric vehicles, i.e. bicycles and scooters, are a very important element in the development of the electromobility sector. This is associated with the fact that the buyer generally does not assume that he will use some external highly developed structure of a charging station to charge the bike batteries. Due to the low requirements in this respect, the charging process can take place in any place where there is access to any 230V socket, for example at home. The buyer of such a vehicle is therefore independent in his decisions and can do without the above-mentioned infrastructure. Such vehicles are targeted at the mass, not very affluent consumer living both in city and in rural areas. In the situation where fuel prices are rising, road infrastructure is plagued by traffic jams, and there are widespread traffic restrictions on other types of vehicles, light electric vehicles (LEVs) can be a good solution.
4.1. Electric power assisted bicycles

Every ordinary bicycle can become an electric bike. In making a choice, you should be guided by the same principles as when you are buying an ordinary bike. It must suit the buyer in terms of the type of construction (road, mountain, city, touring bike, etc), frame size, and all other anthropometric requirements. The bike must be comfortable and fitted to the rider. Such an approach guarantees the pleasure and safety of its use. In general terms, an electric bicycle is a bike plus a motor, electronics, controls, a controller driving the motor, and a battery pack with a charger. In accordance with the applicable Act of 20 June 1997 - Road Traffic Law [Dz. U. (Journal of Laws) of 2005 No. 108, item 908, as amended]: “bicycle – a vehicle with a width of not more than 0.9 m powered by muscle power of the person riding it; a bicycle can be equipped with an auxiliary electric drive system, activated by pedalling and supplied with current with a voltage of not more than 48 V, with a continuous power rating of not more than 250W, whose power output gradually decreases and drops to zero after a speed of 25 km/h is exceeded.” This means that electric bikes that meet the following four requirements will also be considered to be the bicycle:

- The auxiliary electric drive must be activated by pedalling;
- Power supply voltage may not be higher than 48 V;
- The continuous power rating of the motor may not be higher than 250 W;
- The power output must gradually decrease and drop to zero at a speed of 25 km/h.

The failure to meet these requirements (e.g. by installing a stronger motor), when riding on public roads, will result in treating such a vehicle as a moped – with all consequences of this.

The basic components of the electric drive are as follows:

- Battery: It is a source of power supply. In most cases, new generation lithium-ion batteries are now used, which guarantees their very long life (more than 500 full charging cycles, that is, on average about 20,000 kilometres). An important parameter
of batteries is their capacity expressed in Ah (as a standard, these values are in a range of 8-12 Ah), since it depends on the battery what distance we can cover without the need to recharge the battery.

- Electric motor: The main component of the electric drive. Modern, reliable brushless motors are now installed in all e-bikes. Their construction provides a high power of 250 watts (the upper limit allowed by the EU), with very silent operation of the motor. Motors are mounted in the (front or rear) hub of the bike. The electric motor assists the rider up to a speed of 25 km/h (EU regulation).

- Intelligent controller: This is the brain of the whole system. The controller consists of an electronic circuit to which all electric wires are connected and it controls the operation of the bike’s motor. Using a sensor recording pedal revolutions, it checks how much power we need (faster pedalling – more power, slower pedalling – less power). We ride the bike in the same way using the speed throttle. When we want the motor to stop operating, it is sufficient to stop pedalling or to turn the speed throttle. At this moment, the controller cuts off power supply.

Electric bicycles should be one of the alternatives not only to conventional bikes, but also to mopeds, scooters, motorcycles, and even cars – e.g. in summer months to travel to work or school without excessive effort. The most important advantages of e-bikes, which affect the development of this market in spite of the above-mentioned regulatory requirements, include the following:

1. **Electric bicycles, designed using modern technologies and produced on a mass scale**, have been known in the world only for several years and recently they have also appeared in Poland.

2. **In accordance with our traffic regulations, an electric bike user has the same rights as a classic bicycle rider, provided that the power of the motor does not exceed 250 W and the electric powered vehicle can reach a speed of up to 25 km/h** (if you ride quicker, the motor will be automatically cut off and you will have to pedal on your own!).

3. **The cost of full battery recharge is from about 30 groszys up to PLN 1 and it is enough to cover 30-140 km, depending on the model.**
4. The electric drive is rain resistant!

<table>
<thead>
<tr>
<th>Eco Bike Ecotrump 2010, PLN 3699 [30]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suspension - front – suspension fork</td>
</tr>
<tr>
<td>Gear system - 7-speed Shimano Acera. Wheel - 20</td>
</tr>
<tr>
<td>inches. Brakes - double V-brake PROMAX. Weight -</td>
</tr>
<tr>
<td>21.5 kg (aluminium design). Brushless motor, 250W,</td>
</tr>
<tr>
<td>frictionless.</td>
</tr>
<tr>
<td>Voltage 24V. Range 40-50 km. Max. speed up to 25</td>
</tr>
<tr>
<td>km/h. Lithium-ion battery 9 Ah. Battery life &gt; 7000</td>
</tr>
<tr>
<td>recharges. Charging time 5-8 hours.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Code E-Bike 1000, PLN 1139 [30]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery: acid-lead. Power supply: battery 36V 10 AH 3x battery</td>
</tr>
<tr>
<td>12V 10AH. Charger type [V]: AC 230 (110). Charging time [h]:</td>
</tr>
<tr>
<td>brake. Weight [kg]: 39</td>
</tr>
</tbody>
</table>

The basic drawbacks of electric bicycles include the following:

1. Still relatively high prices;

2. **Weight**, up to 38 kg. This is due to a massive battery and a motor mounted in the rear or front wheel.

Prices of electric bicycles are higher by at least 30 - 40% compared to conventional bikes. As of today (October 2012), the cheapest\(^{12}\) e-bike in our market costs PLN 1139 – Fig. 2. The average prices range PLN 2,000 – 4,000. The price of good brand bicycles is in the range of PLN 8,000 – 13,000.

\(^{12}\) www.ceneo.pl
The weight of an electric bike is in the range of 25-40 kg. It is not easy to carry a heavy machine up the stairs and a woman will not carry such a vehicle even for a small distance. This weight causes yet another problem, in particular in our country where roads are full of potholes and high kerbs, while road construction companies obstinately use granite setts to build cycle lanes (in most countries, cycle lanes have an asphalt surface). The heavy and massive electric bike is subjected to greater shocks on each bump, which causes all tightened components, e.g. fenders, to loosen.

The modernisation of Lower Silesia’s road infrastructure is ongoing all the time. This primarily involves the construction of segregated cycle lanes. Such lanes or pavements are being constructed in many rural municipalities/villages. Likewise in other cities, such lanes are also being built in Wroclaw. A dense network of safe bike lanes is one of the essential factors of the potential development of this market. Local initiatives to undertake promotion and marketing activities, both by the local administration and different types of associations or societies, can also be important. The strengths of Lower Silesia which can contribute to an increase in the number of e-bike users are as follows:

- Location of large cities with high tourism values in Lower Silesia;
- Location of tourism and spa areas with traffic restrictions for internal-combustion engine vehicles in Lower Silesia;
- Development of cycle lanes. In The Regional Environmental Protection Programme for Lower Silesian Voivodeship for 2008-2011, taking into account the period 2012-2015, there is the following provision: “To reduce technical constraints in the development of bicycle transport by constructing or designating cycle lanes and properly equipped bicycle parking spaces in all built-up areas” included in the measures designed to improve transportation conditions;
- Development of Wroclaw’s Bicycle Policy\(^\text{13}\), 2010;
- Installation of dropped kerbs;

\(^{13}\) http://rowerowy.wroclaw.pl/imgturysta/file/Polityka_Rowerowa_wersja%20ostateczna.pdf
• Active involvement of many associations and societies promoting the development of bicycle transport, e.g. The Lower Silesian Association Cyclists’ Society – Wrocław Bicycle Centre;

• Active promotion of bicycle tourism on the Internet.\(^{14}\)

In the document *Wrocław’s Bicycle Policy*, there are many comprehensive provisions, e.g.: "*Wrocław’s Bicycle Policy is an element of the City’s development strategy aimed to ensure a high quality of living in the City*." Another paragraph of this document describes expectations from this policy: “*Wrocław’s Bicycle Policy implemented for this purpose is based on the principle of supporting this effective and non-conflict-generating form of transport, notably the bicycle, which should become an alternative means of transport in the city*." It is recognised that the spread of bicycle transportation is associated with many environmental, economic and social benefits, among which the following should be included:

• Destinations are reached in short time in 100%, in particular in the centre of the City;

• Reduced parking problems;

• Increased traffic capacity of the streets congested with car traffic;

• Improvement in the quality of living space in the City – minimised noise and pollution levels, reduced risks associated with road traffic, reduced demand for transportation space;

• Improved health of bicycle users;

• Possibility of combining the bicycle with other means of public transport.

The main strategic goal of Wrocław’s Bicycle Policy in the long term is to achieve at least a 15% share of bicycle traffic in the total number of trips in the City in 2020.

The above-mentioned Bicycle Policy creates good conditions for the development of different types of businesses and service providers related to the sector in question. Firms involved in electric bikes are being set up.

Taking into account its strategic location, transportation and tourism conditions, the activity of its local administration and other groups as well as the preparation of Bicycle Policy, Lower Silesia has very good prospects for the development of bicycle transportation, including electric powered bicycles.

The company Eco Bike can serve as an example. Eco Bike is a branch of the Wrocław-based company Motorbiker which owes its established position to its 25-year tradition and experience. Eco Bike is involved in retail and wholesale sale of electric power assisted bicycles using traditional sales channels and via the Internet.
4.2. Electric mopeds and scooters

A moped does not have to be combustion-powered, it can be electric!

Electric mopeds and scooters can be a good proposal for travelling to school or work, especially for young people – secondary school or university students. A good example is a moped manufactured by the company Solex. This motorized bike is equipped with front and rear disc brakes which provide greater safety. The battery recharge time is from 3 to 6 hours and the batteries can be removed from the moped. The maximum speed of the vehicle is 35 km/h and we can travel about 45 km. With economical riding, that is, with an average speed of 22 km/h, we will cover even 60 km. The price is about PLN 4,000 and the cost of a spare battery is about PLN 1,500.

The market strength of such light vehicles lies in the synergy of low operating costs and ecology – no noise and exhaust gas emissions. These latter advantages create the possibility of travelling in zones with traffic restrictions for internal-combustion engine vehicles. It seems that an urban agglomeration such as Wroclaw, with a larger number of secondary school and university students and, at the same time, with serious parking problems, can be an excellent platform for a model project for the development of this method of transportation. The chains of Lower Silesian hotels could be a partner/beneficiary in such a project. The availability of such vehicles in the hotels’...
offers would be an excellent way of promoting the city and its environs as well as a good proposal for tourists. Under such a project, the first charging stations and related services could be located in the hotel car parks. Electric scooters are also a very good solution for the police, the Post Office, or a number of other different businesses, e.g. pizza restaurants.

An electric scooter can be an optimal choice when:

- we travel the same number of kilometres every day to get to work or school, etc.;
- we want to be sure that our child will not ride faster than 40km/h;
- we use our scooter to travel distances up to 5 km (with such a distance, using a car is uneconomical); with one recharge, the scooter will go for over 50km, so we can travel to school/work and back home for five days;
- we live near a city, in its suburbs;
- it is too far to walk to the nearest shop;
- we plan trips to a park or forest;
- we want to travel 100 kilometres for a mere penny.

Very many models of electric scooters are now marketed, from cheap ones, with the cost in the order of PLN 4,000, to luxurious ones, tailored to satisfy different tastes and needs of customers. An advantage in the development of electric scooters in Lower Silesia is the appearance of a renowned manufacturer of such vehicles.

In 2009 the Munich-based company Govecs GmbH opened in Wroclaw a plant manufacturing electric scooters - Govecs Poland Sp. z o.o\textsuperscript{16}. It is worth noting that, in addition\footnote{http://www.ekoskuter.pl/skutery/govecs}
to manufacturing operations, a **research and development team (about 40 persons)** is also based in Wrocław.

Four models of electric scooters are now offered by this manufacturer. All Govecs two wheelers are equipped with a brushless motor driving the rear wheel through a belt transmission. One model has a gel battery pack, while the other scooters are equipped with a lithium-ion battery pack. The prices of these scooters start from PLN 13,000.

<table>
<thead>
<tr>
<th>Characteristics of Govecs scooters:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Motor power from 3 to 7 kW.</td>
</tr>
<tr>
<td>- Range – depending on the model – from 40 to 100 km.</td>
</tr>
<tr>
<td>- The maximum speed is about 45 km/h, and in the case of the model with a 7 kW engine – 80-85 km/h.</td>
</tr>
<tr>
<td>- The battery charging time is about 4-5 hours, but after 2 hours the battery is charged in 85 percent.</td>
</tr>
<tr>
<td>- Price: it ranges from PLN 8,000 to 12,000; compared to internal combustion scooters, the price tag is even twice higher.</td>
</tr>
<tr>
<td>- However, Govecs scooters are <strong>much cheaper</strong> in operation. It costs only PLN <strong>1.2</strong> to travel a distance of 100 km on a Govecs scooter.</td>
</tr>
</tbody>
</table>

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17 http://www.wroclaw.pl/bez_rury_wydechowej.dhtml
The American company VECTRIX, one of the leaders in the manufacture of environmentally friendly electric scooters, has also based its operations in Wrocław. The first units of this exceptionally innovative vehicle designed by VECTRIX rolled off the assembly lines already at the end of 2006. Even up to 35,000 scooters are planned to roll off the assembly line in Wrocław every year. Italy, France, Spain, England, and the USA will be the first countries to receive these vehicles.

During this year’s gala event in Brussels, the American Vectrix, as one of the leading companies manufacturing electric scooters, won the “European e-Scooter of the Year” award for its models VX-1 Li/Li+ and VX-2. This award was awarded in the categories of e-Scooters (under 25 km/h, under 45 km/h, and over 45km/h), e-Bicycles, e-Quadricycles, and e-Bikes. The selection criteria included, among others, energy consumption, exhaust gas emission, noise emission, recycling, price, aesthetic design, market availability, quality, charging method, and riding easiness. The scooter Vectrix VX-1 Li/Li+ won in the category "over 45 km/h", while Vectrix VX-2 won in the category "under 25km/h". Unfortunately, the price of these scooters is not affordable to the mass consumer.

19 http://www.motogen.pl
4.3. Electric wheelchairs and pallet trucks

In Lower Silesia, including Wrocław, there are many companies that are involved in the distribution and servicing of different types of wheelchairs and trucks intended for different uses, e.g. pallet trucks to transport goods. These companies fit well into the Lower Silesian economy and the development of the electric vehicle sector.

4.4. Segway

A company providing rental of Segway vehicles to tourists was set up in Wałbrzych. Segway PTs are vehicles “(...) which you can use to travel and, at the same time, to enjoy the area you are travelling through. It allows you to be closer to nature, to get to know new places, to do sightseeing. And you can do all this in the company of your closest friends or family (...)”. The Segway company based in Lower Silesia offers rental of Segway PTs to individual people and small groups, sale of vehicles as well as services related to Segway PTs, e.g. attractions during events (team building, picnics, festivities, company events), mobile advertising, leaflet distribution, promotion, sampling
campaigns (at fairs, in hypermarkets, in streets, etc. - Segway tours (organised city tours or off-road trips))\textsuperscript{20}. The idea – the convenient location of a city, the presence of historical sites, and the vicinity of spa resorts can be a good tourist attraction. The company plans to open a Segway PT showroom and rental facility in the capital of Lower Silesia - Wrocław. This type of vehicles is not targeted at the mass consumer, but can prove to be a success as a proposal to expand the offer of tourist services. The purchase price of such a vehicle is about $7,000 – 10,000.

4.5. Electric forklift trucks

In Lower Silesia, including Wrocław, there are many companies engaged in the distribution, sale, and servicing of different types of electric powered forklift trucks. This is illustrated in the below map from a directory of companies.

\textsuperscript{20} \url{http://www.pkt.pl/s/walbrzych/100739605/segway_dolny_slask.html#ixzz2CKPnfl1dT}
The location of companies engaged in the distribution and servicing of electric powered forklift trucks in Wrocław.

Panorama Firm (yellow pages) [32]

An important element in the picture of transportation by electric powered vehicles is the operation of several companies involved in tourist trips using Melex electric vehicles in Wrocław – the project “WrocławTrip”\(^\text{21}\).

An example of the offer of the company EKO-TUR: “(...) EKO-TUR invites you to an unforgettable tour of Wrocław in a comfortable electric powered vehicle – a quiet and environmentally friendly Melex provides a comfortable ride and sightseeing. Thanks to on-board audio equipment, you can listen to interesting facts, in a chosen

\(^{21}\) http://www.wroclaw.pl/przejazdzki.dhtml
language, about the sites you are passing by. The vehicle is furnished with a plastic sheet that effectively protects against rain and wind. By prior arrangement, it is possible to organise special events (e.g. transportation of wedding or First Communion guests) or tours on request (e.g. Wrocław by night or a guided tour of selected places)

Conclusion: Such services should be proposed to be expanded to other cities of Lower Silesia, in particular cities such as Jelenia Góra, Wałbrzych, Świdnica, and especially in many spa resorts.

5. Electric passenger cars

Many different electric car models appear on the market. Most of these cars are prototype concept vehicles. Models available on the market are manufactured, among others, by Honda, Citroen, and Mercedes. A list of various car models can be found on many websites[22]. Technical barriers to this class of models are successively eliminated or will be solved within a reasonable timeframe, e.g. by 2025. A weak element of the existing solutions is the battery and therefore a low driving range on one charge. As mentioned in Chapter 2, the following vehicle technologies are taken into consideration as reference concepts: BEV (Battery Electric Vehicle), REEV (Range Extended Electric Vehicle), PHEV (Plug-in Hybrid Vehicle), and light commercial vehicles for urban use.

The development of the electric vehicles market seems to be not only an economic problem, due to high prices, but also a political and organisational problem. It involves building a

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[22] np.: http://www.samochodyelektryczne.org/kategorie/display_left_samochody.htm
whole chain of services associated primarily with ensuring efficient battery charging or replacement.

In spite of the growing interest in the subject of electric cars and the introduction of the first EV models into the Polish market, their sales in our country are not the best. According to the Samar Institute, in the first half of 2012 barely 17 electric cars were registered in Poland - 37% less than in the first half of 2011 when 27 electric cars were registered. In the opinion of this Institute, the electric cars market in Poland will long remain a niche market and this type of vehicles must become more functional and cheaper. In the opinion of the Institute’s experts, in Poland electric cars have been purchased so far only for image purpose. The Samar Institute informs that in Poland the highest sales of EVs have been recorded by Renault which has sold 12 electric Kangos this year. Peugeot has sold 5 vehicles, 5 - Ford, 2 - Citroen, and the manufacturer of the iMiEV, Mitsubishi, has sold only one electric vehicle.

The first Electric Vehicle Charging Stations have been installed in Wrocław. There are 9 such stations in the city:

1. Scandic Hotel, 49 Piłsudskiego St.;
2. Astra Shopping Centre, 4-6 Horbaczewskiego St.;
3. Borek Shopping Centre, 52 Hallera St.;
4. Tęcza Shopping Centre, 1 Bajana St.;
5. Ford dealership (Germaz Sp. z o.o.), ul. Strzegomska 139 St.;
6. Marino Shopping Centre, 7 Paprotna St.;
7. Hornet dealership (Hornet Sp. z o.o.), 250a Krzywoustego St.;
8. Subaru dealership (Subaru JM Auta Sp. z o.o.), 1 Krakowska St.;
9. Peugeot dealership (KIM sp. z o.o.), 13 Łagiewnicka St..

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The Wrocław Electric Vehicle Charging Station System (WEVCSS) operates within the structure of a nationwide operator of vehicle charging stations - Galactico.pl. This means that together with the development of Galactico.pl charging stations, users of the WEVCSS will be able to recharge their vehicles also outside the boundaries of Wrocław, which will allow them to drive their electric vehicles more easily and more freely across the country. Each charging station of the WEVCSS supports various charging standards (socket-outlets) which meet the standards of all electric and hybrid vehicles available on the market. When a new standard for sockets appears, the charging stations will be modified accordingly and adapted to such new standards.

As regards the prospects for building such systems and the development of the electric vehicles market, it can be expected that there will be a strong alliance of the vehicle manufacturers, consumers, and the local administration. Oil companies and exporters can lose on that. The introduction of charges for using traditional cars in big cities, e.g. in Warsaw or Wrocław, in the future can be a development factor. Such charges are already being introduced in Germany for entry into city centres by cars that do not meet high ecological standards – the so-called Environmental Badge\(^{25}\). As an effect of that, the popularity of electric cars, exempt from

such charges, will increase and battery replacement stations will also be set up.

Information about the construction of a hybrid car at the Opole University of Technology is important information from the point of view of the development of local electromobility transport\textsuperscript{26}. This is evidence of the involvement of the local academic communities. It would be extremely desirable if the Wrocław University of Technology additionally joined such undertakings.

\textit{``The University of Technology is building a hybrid Fiat Panda. Two electric motors located by the two rear wheels, a system of special controllers, a battery pack in the boot, and all this together environmentally friendly and reliable – a hybrid car is being designed at the Opole University of Technology. This car will be electric powered and when the electric power runs out it can switch back to the traditional drive.''}

\section*{6. Electric delivery vehicles}

Many models of delivery vehicles appear on the market. An example can be the MINICAB-MiEV manufactured by the Mitsubishi Motors Corporation (MMC) – an electric minicar-class commercial vehicle. It was presented on 8 December 2011. The MINICAB-MiEV is derived from the utility vehicle MINICAB Van. The designers have managed to deliver very good environmental performance inherent to an EV, together with the high levels of operating economy, payload capacity, drivability and reliability demanded of a commercial vehicle. The vehicle is equipped with the CD 10.5 kWh battery version that provides a cruising range of 100 km (at JC08 mode), while the CD 16.0 kWh version takes this up to 150 km. The final price for the CD 10.6 kWh and CD 16.0 kWh versions will be about PLN 75,000 – 85,000.

\textsuperscript{26} Politechnika buduje hybrydowego fiata pandę (Gazeta Opole, 13.04.2012)
Another example of this type of vehicles is the British MegaVan\(^{27}\). They are presented as cheap electric vehicles for business.

These vehicles are environment-friendly, cheap, and economical. They perform very well in the city jungle. Besides, they are completely noiseless. The whole chassis is made of aluminium. The vehicle batteries are charged in 5 to 8 h and they are sufficient for 100 – 150 km. It is an ideal solution for the city. Its operating costs are not higher than the cost of electric power consumed. The maximum speed of these vehicles is \textbf{50-60 km/h}.

Such vehicles can be used for transport of goods in special protection zones, e.g. in city centres or spas. The author is not aware of the existence of this type of vehicles in Lower Silesia.

### 7. Minibuses

Electric minibuses are an excellent solution for tours in protected areas, for example, to visit historical sights located in urban zones closed to other types of vehicles. An example of such use is the Minibus running in the Vatican Gardens\(^{28}\). Two such vehicles operate in the Gardens.

\(^{27}\) [http://www.megavan.org/mega-van.htm](http://www.megavan.org/mega-van.htm)

Each minibus can seat 14 passengers. They will serve the Vatican Museums which organise visits in this “oasis of nature in the heart of Rome” – as the Gardens were described by Cardinal Giuseppe Bertello, President of the Governorate of Vatican City State. He stressed that “in choosing electric vehicles, Vatican supports sustainable development through zero exhaust gas emissions, which will ensure respect for this place, its flora and fauna. In summer, the minibuses carry tourists along the alleys of the Gardens. From autumn, they will also bring them to the archaeological excavations in the Vatican Necropolis. These vehicles are equipped with audio guides in different languages. They are also adapted to carry disabled people, who will be thus able to visit the Gardens for the first time. Both minibuses were donated to Vatican by an Italian company specialised in car rental.”

As of today, it is difficult to assess if and when such minibuses can appear in Wroclaw. But it seems possible since it can be an excellent business and tourist proposal, especially for the hotel chains that want to enrich their offer.

[Image: An electric minibus of the Vatican City [23]]
8. Electric buses

The first electric powered bus in Poland was designed and built based on the low entry Solaris Alpino with a length of 8.9 m. A 120 kW four-pole asynchronous traction motor was supplied by the company Vossloh Kiepe. Energy for the traction motor is stored in two batteries weighing 700 kg each. The Warsaw-based Polish company Wamtechnik is the supplier of the batteries. These lithium batteries have a rated voltage of 600 V and the capacity to store 120 kWh. The energy stores are liquid cooled. Recharge of the batteries from the 3*400 V 63 A terminal takes up to 4 hours when the batteries are completely drained. Warsaw and Poznań already have such buses. Hence, the proposal that Wrocław should buy them seems to be entirely natural.

The Solaris Urbino 12 electric received a medal at the 10th International Fair of Public Transport Transexpo in Kielce as the best product in the category of buses. This entirely low-floor vehicle, 12 m long and equipped with lithium-ion batteries, can travel as far as 150 km on one charge with passengers on board and air-conditioning on. The total charging time is only 1 hour. The battery can be charged in several ways: using a plug-in connector and an external charging station, through induction loops, a pantograph or overhead traction lines, or by quick replacement of empty batteries with fully recharged ones, which takes only 10 minutes. The company Solaris presented its first electric bus in 2011. Since then, this vehicle has undergone a number of tests in city traffic. Among others, during the European Football Championship in June 2012 an electric Solaris Urbino carried football fans between the Ławica airport and the centre of Poznań. Solaris sold the first vehicle of this type

29 http://www.solarisbus.pl/busmania,aktualnosci,news_list,780,0.html
in September this year. Its purchaser was a bus operator from the city of Braunschweig in Germany. The bus, which will be charged by induction, will be delivered to the customer in 2013.

9. Tram transportation

Wroclaw is strongly developing its tram transportation. The tram rolling stock is being upgraded, but perhaps the introduction of the Integrated Rail Transport System is even more important\(^3^{0}\). This is evidence of a comprehensive approach that also improves the functionality of the whole urban transport system. This system can be an example of modern traffic organisation and tram transportation management in a large urban agglomeration. “The Integrated Rail Transport System in Wroclaw and its agglomeration”\(^3^{1}\) is the city’s development project designed to increase the role of public transport and to integrate the city with the region (agglomeration). The aim of this project is to improve transportation within the city. The essential concept provides that the attractiveness of higher standard tram connections would be increased. The concept envisages that new lines of the “Tram Plus” and „Cross-City Routes” subsystems will be launched, at the same time using these subsystems to carry passengers on the most congested transportation lines.

In effect, this means that these subsystems will also provide tram connections, with as high frequency as possible, to the city centre areas, leaving it to traditional trams to provide links to the peripheral housing estates, whereas in the areas where there are no tram lines – leaving it to city buses.

\(^{30}\)http://edroga.pl/inzynieria-ruchu/komunikacja-publiczna/5167-wroclaw-zintegrowany-system-transportu-szynowego,

\(^{31}\)Ibid.
Wrocław’s “Tram Plus” project is related to this system. Its main objectives are as follows:

- To construct new connections, e.g. the tram crossing in the streets Legnicka – Na Ostatnim Groszu with the EURO 2012 Stadium through the Kozanów district, and to modernise other tram lines.
- To supply tram rolling stock that will operate on the lines of the Tram Plus and Cross-City Routes systems.
- To expand the interchange nodes and other elements that serve to integrate the rail system with other transport systems.

10. Rail links – electric multiple units

The company Koleje Dolnośląskie S.A. (Lower Silesian Railways) is undertaking new initiatives associated with the modernisation and new functionalities of local rail links. This company has quite a dense network of local rail links that have started to lose their functionality. This situation is to improve radically by “bringing” the larger Lower Silesian cities closer to the region’s capital. Wrocław is interested in a radical improvement in the quality of transportation links of the municipalities and districts comprising the Wrocław Metropolitan Area with its main centre, i.e. Wrocław. A preferred form of connections should be a modern public transport system consisting of the Wrocław Agglomeration Railway, a system of local bus links used to carry residents of the agglomeration to the Wrocław Agglomeration Railway stations and, as a supplementary
solution, bus connections of the municipalities and districts with Wrocław in the areas where it is impossible to provide public transport services using the Wrocław Agglomeration Railway system.\textsuperscript{32}

The Wrocław Agglomeration Railway is a joint undertaking of the local governments of the Wrocław City and Lower Silesian Voivodeship. Its aim is to launch passenger rail transportation services on selected agglomeration-wide lines. The transportation system of the Wrocław Agglomeration Railway will also be a means of urban transport for the residents of Wrocław.

From the point of view of development of regional transportation, two advantages can be noticed in these projects:

- a local rail operator;
- modernisation and integration of the regional infrastructure.

New electric multiple units will run from Wrocław to Oleśnica, Żmigród, and Legnica. They will be equipped with air-conditioning, monitoring, bike racks, and Internet access.

In 2010 an agreement was signed between Koleje Dolnośląskie S. A. and the Lower Silesian Voivodeship to provide co-financing for the project entitled “Purchase of five new Electric Multiple Units for the needs of passenger transportation services provided by the Company Koleje Dolnośląskie S.A. under the suburban transportation system” under Priority No. 3 - Transport, Measure No. 3.3. – Urban and suburban transport, of the Regional Operational Programme for Lower Silesian Voivodeship 2007-2013\textsuperscript{33}.

The total value of this project is PLN 103.8 million. The value of co-financing from the Regional Operational Programme is about PLN 70.7 million. EMUs will be able to travel at a maximum speed of 160 km/h. The project’s overall objective is to contribute to an improvement in the quality and efficiency of regional transport infrastructure. The specific

\textsuperscript{32} http://rpo.dolnyslask.pl/index.php?id=774

\textsuperscript{33} http://rpo.dolnyslask.pl/index.php?id=774
objective is to provide appropriate means of public transport, with respect to railway rolling stock used for passenger transport purposes in urban and suburban transportation, which would be characterised by:

- low burden on the natural environment; and
- adaptations for disabled people and adequate travel comfort.

It seems that the concept of a cheap intercity rail system that uses short compact multiple units is a developmental solution. In the future, such a rail system may connect many Lower Silesian cities, not only with Wroclaw. Ideas of this kind are already being implemented and in the future they can be further developed. The existence of cheap rail links can contribute to the development of Lower Silesian tourism and, as a result of that, bring benefits for the whole region.

11. Strategy, activities of the administration

One of the essential elements of a region’s economic development is well-developed transportation infrastructure, i.e. a diverse and dense network of road and rail links as well as bicycle trails, together an appropriate system of services. As a rule, such a network is built over a longer period of time.

The Lower Silesian Voivodeship has its own development strategy and an update of this strategy has recently appeared.34 In this strategy, transportation problems are also noticed and priority measures are formulated. The strategy states as follows, among others: “Transportation constraints affect the mobility of residents inside the region and cause negative consequences in the area of employment and education. The collapse of public transport also influences the situation of transportation, which primarily results from the preference of individual means of transport; therefore, the strategy supports measures aimed at restoring the popularity of using public transport.”

The proposed priorities are as follows:

34 http://www.umwd.dolnyslask.pl/rozwoj/aktualizacja-strategii-rozwoju-wojewodztwa-dolnoslaskiego
TRANSPORT INFRASTRUCTURE

- To improve transport availability in the region (internal and external connections);
- To improve the quality and standards of transport (road, rail and air transport as well as inland water navigation);
- To increase the share of air transport;
- To increase the competitiveness of inland water navigation.

These measures are intended to produce the following benefits:

- Increased investment attractiveness of the region due to improved transport availability;
- Increased tourism attractiveness of the region;
- Connecting the region’s peripheral areas with the growth centres as well as improved access to tourist attractions of Lower Silesia;
- Streamlining of the home – work – home traffic (easier access to places of work);
- Improved accessibility of health, education and cultural services.

The below projects can be examples of specific measures that may serve to develop electromobility:

- Construction of integrated public transport systems within the city agglomerations, including the development of the Wrocław Railway Junction in order to transform it into an agglomeration railway system, modernisation of railway lines in the Legnica-Głogów Copper District, the implementation of the projects associated with Wałbrzych Agglomeration Railway and the Jelenia Góra City Railway;
- Maintenance, modernisation, and construction of roads and rail links that provide access from small peripherally located towns and villages to the main cities of the region (e.g. from the localities in the Kłodzko Valley, Turoszów Basin, and Barycz River Valley).

Transportation problems are also indicated in the Regional Operational programme for 2007 – 2013. Interregional initiatives may also affect the development of modern transportation.
Among others, the participation in the Smart Specialisation Platform, designed to support the regions, can be included in such initiatives:

“As the first region in Poland and thirty fourth in Europe, Lower Silesia intends to join the Smart Specialisation Platform35. This event is important in the context of its efforts to secure the next EU funds after 2013, since: - Only the regions that will be able to show their strengths and to specialise in specific areas have a chance to obtain EU funds - the guests from Brussels and representative of the regional authorities jointly stressed.

Smart Specialization – means emphasizing your assets in order to be able to continue their intensive development through financial support for investment projects and any possible assistance to entrepreneurs, since they create jobs and pay taxes. Smart Specialization involves cooperation of businesses, research centres, and higher education institutions”.

It seems that the problems of electromobility development can be formulated explicitly in the specific measures of the above-mentioned strategy.

12. Participation of scientific communities

In Lower Silesia there are strong academic and research and development centres. From the point of view of electromobility development, the Wrocław University of Technology, with its Faculty of Electrical Engineering, Faculty of Mechanical and Power Engineering as well as Faculty of Mechanical Engineering, and the Wrocław University of Economics can play a significant role. At the Wrocław University of Technology, the problems of electric vehicles are strongly stressed particularly at the Institute of Electrical Machines, Drives and Measurements. To implement larger research projects, the universities can collaborate with other European academic centres, e.g. German ones. There are strong links, among others, with the Otto van Guericke University of Magdeburg. The Opole University of Technology can play a major role in the activities supporting the development of electromobility.

35 http://rpo.dolnyslask.pl
13. Conclusions

Lower Silesia has many favourable conditions for dynamic development of electromobility. The most important of them are as follows:

- Its favourable geographic location – at the border with the Czech Republic and Germany;
- Richness of tourist attractions – sites attractive to tourists, including places with restricted traffic zones for internal-combustion powered vehicles;
- Lower Silesia’s large potential, in particular in the automotive and electric industries;
- Development of transport infrastructure;
- Active modernisation efforts and environment-oriented measures of the local authorities;
- Regional policy that takes into account the development of the local power industry (a regional energy strategy) and environmental protection problems as well as the Bicycle Strategy;
- In Lower Silesia, there are already many businesses that provide their services using electric powered vehicles;
- Strong scientific and research centres are located in Lower Silesia which provide a large potential for the development of electromobility in the region.

Taking into consideration these conditions, the following conclusion can be formulated:

*Lower Silesia may have a significant contribution to the development of electromobility in Poland. It can be one of important pillars of regional development.*
14. REFERENCES


The University of Technology is building a hybrid Fiat Panda (Gazeta Opole, 13 April 2012)

The University of Technology is building a hybrid Fiat Panda (Gazeta Opole, 13 April 2012)


