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## IS ELECTROMOBILITY IN THE SUPPLY NETWORK A GOOD WAY TO INCREASE INNOVATION?

**A b s t r a c t :** Interest in electromobility among the public has been growing in recent years. In order to determine the impact of the development of electromobility on the increase in supply network innovation, the situation of the potential use of electric vehicles in the supply network should be analysed, presenting their advantages and disadvantages. The article presents the characteristics of an innovative company operating in the supply network, referring to the electrification of transport. It then presents the electric vehicles currently available on the market for carrying loads, as well as the factors determining the level of innovation of the company in the supply network. The aim of global companies is to minimise the negative impact on the environment through the use of electromobile solutions.

**K e y w o r d s :** electromobility, innovation, logistics

**J e l C o d e :** O30, L90, N70, R40

### INTRODUCTION

The development of modern technologies has a huge impact on the functioning of enterprises, regardless of their area and scope of activity. Investments in new technologies are necessary for all organisations, as any entity wishing to optimise the processes carried out, adapt to the requirements of the market and want to gain a competitive advantage over entities operating in a given sector is obliged to develop continuously. The lack of development of a given entity could cause the competition to start to move away to a significant extent and at the same time reduce the attractiveness and competitiveness of the non-developing company. One of the many technologies determining the development

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of many economic sectors, whether national, European or global, is electromobility. Often referred to as the technology of tomorrow, it significantly contributes to an increase in innovation in many areas, such as broadly defined logistics.

## 1. THE CONCEPT OF ELECTROMOBILITY

Electromobility is sometimes referred to as e-mobility and includes all issues related to the use of electric vehicles, which include electric cars, electric bicycles, e-buses and e-vehicles. The main characteristic of these vehicles is that they are driven partly or wholly by electric propulsion, have means of storing energy on board and derive their energy mainly from the electricity grid. There are currently many categories of electric vehicles in the transport sector. These categories include [Gajewski, Paprocki, Pieriegud, 2019, p. 13–14]:

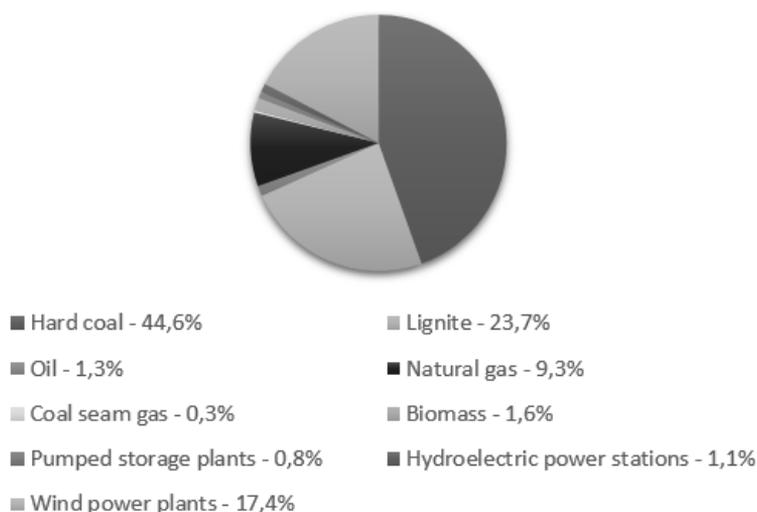
- BEV (Battery Electric Vehicle) is a category covering purely battery-powered (electric) electric cars. Cars in this category do not have an internal combustion engine and use only electricity stored in batteries (accumulators) for propulsion. Their current range is between 120 and 400 km.
- PHEVs (Plug-in Hybrid Electric Vehicle) are plug-in hybrid electric vehicles that can be recharged from the outside, from a socket (“plug-in”). Vehicles in this category have two types of propulsion: internal combustion engine and electric motor. In PHEVs, the electric motor and the internal combustion engine can run separately or in parallel, so when charged frequently enough, they can only run on electricity, as can BEVs. Batteries can be recharged from a classic socket or a special charging station for faster recharging. The range of this type of vehicle is between 500 and 1000 km [www.gov.pl, 09.04.2020];
- HEV (Hybrid Electric Vehicle) - Hybrid Electric Vehicles include vehicles equipped with both petrol and electric motors. In the HEV category, the electric motor usually only supports the internal combustion engine, while newer models of (PHEV) enable zero-emission operation and drive the vehicle exclusively with the electric motor. Batteries in classic hybrid vehicles are recharged with recuperative braking systems and engine energy;
- REEV (Range Extended Electric Vehicle) is an electric car with an extended range. In addition to the electric motor, which is the basic drive unit, they are equipped with internal combustion engines. In this type of car, the combustion engine only starts up when the energy required to recharge the battery for electric drive is needed. With this solution, the range of the vehicle can be extended to 300–500 km;
- FCEV (Fuel Cell Electric Vehicles) - This category includes electric vehicles equipped with fuel cells. The function of a battery is performed by fuel cells powered, for example, by hydrogen.

The first three types of vehicles using electric propulsion cover the majority of electric vehicles on the roads, especially in Poland.

Observed climate change, the existing scarcity of oil and the increase in air pollution are forcing international organisations to take strategic decisions aimed at transforming mobility in its broadest sense into environmentally friendly natural mobility (e-mobility) in terms of CO<sub>2</sub> emissions [www.elektromobilnosc.pl, 06.04.2020]. The emergence of increasingly restrictive exhaust emission standards and the implementation of EU directives in EU countries are forcing manufacturers to develop zero-emission vehicles, and in particular electric vehicles or vehicles using alternative fuels which do not pose a threat to the environment. Popularisation of this type of vehicle, raising public awareness and obtaining additional benefits from owning electric vehicles will drive vehicles using traditional combustion engine propulsion from one year to the next. According to the Boston Consulting Group, the share of electric vehicles in 2030 will be 50% [elektrowoz.pl, 06.04.20].

The development of electromobility is therefore an important solution for implementing the process of transforming traditional mobility into e-mobility, while taking into account one of the most important factors, namely the use of electricity from renewable energy sources only. This is an essential factor without which natural, environmentally friendly mobility would not be viable. One such example is Poland, where at present the majority of electricity is produced from non-renewable energy sources. The structure of sources of electricity production in Poland is presented in Figure 1.

Figure 1. Structure of sources of electricity production in Poland. (as of 06.04.2020).



Analysing the above data, it can be seen that it would be difficult to speak of 100% e-mobility when using electric vehicles in Poland, because the electricity used by electric vehicles is mostly obtained from coal. An additional important factor having a negative impact on the environment is the production of electric drives. The elements used to produce batteries are cobalt, lithium and manganese. During the extraction and processing of these elements, the demand for energy is enormous, resulting in increased CO<sub>2</sub> emissions into the atmosphere. According to The Brussels Times, the production of batteries for the Tesla 3 vehicle generates between 11 and 15 tonnes of CO<sub>2</sub> [www.auto-swiat.pl, 07.04.20]. If we also take into account the CO<sub>2</sub> emissions generated by the production of electricity to power a given electric vehicle, it may turn out that as a last resort electric vehicles may be less environmentally friendly than vehicles with traditional diesel engines, for example. This is one of the main reasons why individual countries are starting to invest in reducing the share of coal in the energy mix. One example is Poland where the way electricity is produced will also change. In the future, it will be based on renewable energy sources, while at the same time reducing the share of coal in the power industry from year to year, which will result in an increase in the advantage of electric vehicles [www.e.autokult.pl, 07.04.2020]. Today, electric vehicles, like all vehicles, have certain advantages and disadvantages. The most important of these are presented in Table 1.

Table 1. Advantages and disadvantages of electric vehicles.

Advantages and disadvantages of electric vehicles	
Advantages	Disadvantages
<ul style="list-style-type: none"> <li>– More environmentally friendly propulsion compared to internal combustion;</li> <li>– lower costs of using electricity obtained from alternative energy sources (e.g. solar panels);</li> <li>– electricity costs are much easier to predict than changing fuel prices;</li> <li>– simple design of electric drives in comparison with internal combustion drives;</li> <li>– subsidies for the purchase of electric vehicles;</li> <li>– quiet operation of electric drives.</li> </ul>	<ul style="list-style-type: none"> <li>– high price;</li> <li>– environmentally harmful processes for the extraction and processing of elements for battery production;</li> <li>– relatively small range on a single charge (approx. 400 km) compared to combustion vehicles;</li> <li>– insufficiently developed charging point infrastructure;</li> <li>– relatively long battery charging time in comparison with traditional petrol vehicles;</li> <li>– No or a small number of specialised services;</li> <li>– quiet operation of electric drives.</li> </ul>

Source: Own study based on: www.elektromasters.com.pl [access 09.04.2020], www.odnawialne-firmy.pl [access 09.04.2020].

Analysing Table 1 you can see that the main advantages and disadvantages include the quiet operation of electric drives. This factor is treated as an advantage because it increases the comfort of travel. However, other road users such

as pedestrians and cyclists are not used to the quiet operation of electric drives. Everyone is accustomed to the sound of the running combustion engine of an approaching vehicle and therefore emerging electric vehicles can pose a greater danger to pedestrians and cyclists.

Today, electric vehicles still have drawbacks, which definitely contribute to the fact that customers ultimately choose vehicles with a different type of drive (mainly internal combustion engines). However, the development of technology and infrastructure enabling the efficient movement and operation of electric vehicles increases their attractiveness. In addition, the restrictive emission standards imposed by the European Union on car manufacturers contribute to the increase in the price of vehicles with traditional propulsion, the limitation of the offer to several models, and contribute to the increased involvement of electric vehicles. Due to stricter emission standards in the European Union, the share of vehicles with diesel units will decrease from 48% in 2016 to 36% in 2020 and 12% in 2030 [www.orpa.pl, 06.04.2020]. The maximum level of exhaust emissions in Europe will be 95g/km in 2021 and 78g/km in 2025. This is one of the reasons why the share of electric vehicles will increase every year.

Electromobility is therefore one of the key factors shaping the modern transport system and undoubtedly influences strategic decision making by organisations operating in the broadly defined logistics sector. The development of electromobility will undoubtedly leave its mark on the sector while increasing its innovation.

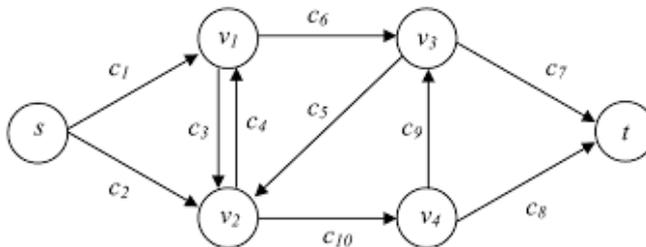
## 2. THE ESSENCE OF THE SUPPLY NETWORK

Nowadays, the constant increase in customer pressure and requirements affects all functioning organisations, forcing them to constantly search for new solutions to improve and enable efficient and effective implementation of material and information flow processes. As a result, the situation observed in the 1990s, when many companies, in order to meet the requirements set by their environment, went beyond the framework of individual organisations creating supply chains, would not be optimal today. The main reason is that individual supply chains are starting to be insufficient to provide adequate customer service. The ever-increasing demands are forcing companies to go beyond individual supply chains to create extensive supply networks [Świerczek, 2007, p. 74].

Supply networks are understood as a set of independent companies that compete and cooperate in order to make the flows of goods and related information run smoothly and efficiently according to customer expectations [Witkowski, 2003, p. 19]. The concept of a network is defined as a set of nodes linked together by specific relationships. However, despite a simple definition, the term is interpreted in many different ways, such as the railway network, the food network,

the network of commercial relations or the network of neural cells [Świerczek, 2007, p.74]. Extensive interpretations of the network appear when the concept is considered in the aspect of a specific field such as logistics, medicine, etc. When considering the concept of a network in terms of logistics, it can be seen that the main objective of companies is the continuous development of the sphere of supply, production and distribution, while increasing flexibility and taking advantage of the additional benefits resulting from cooperation with individual links of the network, the so-called synergy effects [Świerczek, 2007, p.74]. A. Spruce in the scientific article “From supply chain to supply network” explained the concept of logistics network using one of the fields of mathematics, namely graph theory. According to the aforementioned author: “A logistic network in the mathematical sense can therefore be defined as a directed graph  $G = (V, E)$  (where:  $V$  is a set of nodes and  $E$  is a set of edges), in which each edge has a non-negative capacity  $c(u, v) \geq 0$ ” [Świerczek, 2007, p.74]. According to the graph theory, the logistic network is presented in graphical form in Figure 2.

Figure 2: Example of a logistical network.



Source: A. Świerczek: *Od łańcucha dostaw do sieci dostaw*, „Logistyka” 1/2007, p. 74.

According to the theory of graphs, a logistical network is defined as a group of nodes connected to each other by lines that reflect the mutual relations of a logistical nature. Each edge is defined as a channel with a fixed capacity and through which the flow of materials and information is realized. The relations between the individual links within the network are characterised by the tension between autonomy and interdependence, loyalty and individuality to the group, competitiveness and cooperation [Świerczek, 2007, p. 74]. The flow of materials and information within a given logistic network is characterised by different size and variety due to the area of occurrence of a given flow, from the moment the raw materials are obtained to the delivery of products to the final recipient. For this reason, the logistics network is considered to be a set of direct logistical links between companies, creating interdependence and links between them, while at the same time giving the individual links specific functions. This means that an efficiently and effectively functioning supply network has greater potential than individual supply chains.

The development of the entire supply network depends on the development of all the links operating within the network. The advancement of individual entities operating within a given network results from wider cooperation between them and the implementation of modern solutions contributing to an increase in the innovation of the supply network.

### 3. ELECTROMOBILITY IN THE SUPPLY NETWORK

Nowadays, the main place where innovations are most often created is the enterprise. The innovative activity of a given entity is supposed to lead the company to the development of its innovative potential enabling the collection and implementation of the undertaken innovative processes [Urbanek, Walińska, 2016, p.172]. In highly developed countries, there is a model of system integration and network work through specialised IT programmes. System integration is also necessary for the efficient functioning of a given supply network, ultimately affecting the quality of customer service. The currently operating innovative enterprises are organisations that rely on knowledge, learn and conduct their activities with the use of innovative solutions such as modern IT systems. The characteristics of an innovative enterprise are presented in Table 2.

Table 2. Characteristics of an innovative enterprise.

Innovative enterprise	Characteristics of an innovative enterprise
carries out research and development or purchases new products, technologies	high creativity of the team and ability to create new solutions
allocates high financial resources to R&D <sup>1</sup> or the purchase of new products, technologies	ability to use the innovative potential of an enterprise to maintain or increase its competitive position on the market
gradually implement new solutions	ability to predict the future
achieves a high share of innovation in the total production of goods and services	flexibility to adapt to a dynamically changing economic environment
systematically introduces innovations to the market	constant contact with customers in order to learn about their current and future needs

Source: P. Urbanek, E. Walińska (red.): *Ekonomia i zarządzania w teorii i praktyce*, Tom 9 Część III. Wydawnictwo Uniwersytetu Łódzkiego, Łódź 2016, p. 172.

New technologies definitely contribute to the growth of innovativeness of all enterprises implementing innovative processes, which are presented in Table 2. Investments in new technologies of individual entities result in the growth of innovativeness of the entire supply network. One of the reasons for this is the closer cooperation between individual links in the network, which determines their development and use of their potential. The optimisation of processes carried out

<sup>1</sup> R&D - research and development activities.

in a given supply network is necessary for the proper functioning of the entire network and for meeting the growing expectations of customers. Examples of technologies that have contributed to the increase in the innovativeness of the supply network include modern IT systems that have optimised many processes carried out in many areas and at various levels, and as a result contribute to a more effective flow of materials and information. Called the technology of tomorrow - electromobility will also increase the innovation of supply networks, but mainly in the area of transport. The transport process plays one of the most important roles in the supply network, as it is responsible for the flow of materials within the entire network.

Currently, many companies use electric vehicles for in-house transport, and these are electric lift trucks. This is one of the first transport areas where electric vehicles are used. Electrically powered lift trucks are most often used in closed areas as they meet the highest safety standards. There are also internal combustion and gas powered lift trucks, which are mainly used in open spaces due to exhaust emissions [www.herakles.biz.pl, 09.04.2020]. However, from year to year they are systematically replaced by electric trucks [www.trans.info/pl, 14.04.2020]. Many manufacturers already have electric vans and trucks with different DMC<sup>2</sup> in their offer, the production of which began in 2018. The currently offered electric vans and trucks include among others: [www.pspa.com.pl, 14.04.2020]

1. Mercedes-Benz E-Vito:
  - Type of drive: electric (BEV);
  - Range: 150 km;
  - Maximum power: 115 hp;
  - Maximum speed: 120 km/h;
  - Price: 39 900 EUR (excluding VAT);
  - Start of production: 2018.

Figure 3: Mercedes-Benz E-Vito.



Source: www.autocentrum.pl [access: 14.04.2020].

<sup>2</sup> DMC - Permissible total weight of the vehicle or vehicle combination including the weight of the load.

2. Volkswagen E-Crafter:

- Type of drive: electric (BEV);
- Range: 160 km;
- Maximum power: 136 hp;
- Maximum speed: 90 km/h;
- Price: 275 568 PLN (excluding VAT) [[www.vwdostawcze.pl/pl/modele](http://www.vwdostawcze.pl/pl/modele), 14.04.2020];
- Start of sales: IX 2018.

Figure 4: Volkswagen E-Crafter.



Source: [www.autocentrum.pl](http://www.autocentrum.pl) [access 14.04.2020].

3. Tesla Semi:

- Type of drive: electric (BEV);
- Range: 480-800 km;
- Max. power: no data;
- Acceleration from 0 to 97 km/h in 20 seconds (at 36.2 tonnes) [[www.tesla.com](http://www.tesla.com), 14.04.2020];
- Price: 150 000 - 200 000 USD [[www.tesla.com](http://www.tesla.com), 14.04.2020];
- Start of production: 2019.

Figure 5: Tesla Semi.



Source: [www.moto.rp.pl](http://www.moto.rp.pl) [access 14.04.2020].

4. VOLVO FL Electric: [www.volvotrucks.pl, 14.04.2020]
  - Type of drive: electric (BEV);
  - Range: up to 300 km;
  - Maximum power: 225 hp;
  - Price: no data;
  - Start of production: 2019 [www.fleetowner.com, 14.04.2020].

Figure 6: Volvo FL Electric.



Source: www.40ton.net [access: 14.04.2020].

Observing the situation of the development of electromobility, the emergence of increasingly restrictive emission standards and the increase in the share of electric vehicles in the modern transport system, it can be concluded that in the coming years, the transport of both goods and passengers will be carried out using only zero-emission electric vehicles. Green transport also depends on sources of electricity production. Coal currently plays a key role in the energy sector of many countries. However, in the future, the share of coal in electricity production will decrease as individual countries increasingly invest in renewable energy sources.

However, environmentally friendly transport is not only dependent on the availability of electric vehicles or sources of electricity production, but also on the policy of logistics companies operating within certain supply networks. Global companies are planning a significant reduction in greenhouse gas emissions generated by their logistics processes using electric vehicles, among other things. An excellent example is a global courier company - UPS - in which one of the four vehicles purchased was electric or powered by alternative fuels by 2020. In 2018, UPS had 8.5 thousand vehicles of this type, i.e. fully electric, hybrid, CNG, LNG, LPG or biomethane powered, among others. In Europe, however, the German Deutsche Post intends to use only zero-emission vehicles as electric vehicles. In 2018, the company had 7,000 such vehicles. [www.pspa.com.pl, 14.04.2020].

The implementation of modern electromobility technologies by companies is a good solution, as the world's largest economies are moving towards zero-emission transport, which will ultimately contribute to reducing pollutant emissions.

The main reason for pursuing this objective is the significant increase in environmental pressure on the world which is becoming the driving force behind the development of electromobility. Despite many shortcomings and deficiencies, for example in infrastructure, electromobility is a good way to increase innovation in the supply network because in the long term, electric vehicles will be a key link in the modern transport system.

Economies in many aspects are not yet ready for the high burden of rapid electrification of transport, but with the right business models and by applying solutions that have worked well so far, it is possible to move towards a technology that works well and does not overload the network.

Technology is now moving towards cybernetics, telematics and advanced information systems. With the development of e-mobility, accompanying technologies will also develop.

On the example of Poland, electromobility is not developing at an exponential rate.

The target of one million electric cars contained in the Electromobility Development Plan seems impossible to achieve, given the state of electric cars at just over 22,000 in the first quarter of 2021 [www.pspa.com.pl, 05.05.2021], [Plan Rozwoju Elektromobilności w Polsce, Ministerstwo Energii, 2017]. However, if government institutions around the world would team up with researchers and entrepreneurs experienced in the implications of this technology and appropriate investments are made then success can be expected. Many countries have already decided to phase out traditional combustion cars. By focusing on the development of charging networks, while improving transport and technological processes, there is an opportunity to achieve tangible results in the development of electrification of transport in the supply network, thus increasing innovation.

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