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Electromobility and its Development Prospects in the Context of Industry 4.0: A Comparative Study of Poland and the European Union

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Abstract:

Purpose: *The purpose of the article is to present selected results of a survey on the prospects for the development of electromobility in the context of Industry 4.0. A particular emphasis has been put on a precise analysis of consumer demand and social trends influenced by the IT and technological advancement.*
Approach/Methodology/Design: *The survey used CAWI techniques and was implemented in a period of June-December 2020. The sample included 500 respondents from selected EU member states, including Poland, and the survey concentrated on the demand side.*
Findings: *The importance of modern forms of mobility is expected to grow in the future. However, further promotion and development of electromobility in the context of Industry 4.0 remains an open issue. In the article, the authors point to the power generation technology which should prevail according to opinions expressed by representatives of the demand side and support the development of electromobility that will revolutionize individual transport.*
Practical implications: *According to the survey, apart from the growing number of electric vehicles on the market, equally important is the development of charging infrastructure, since it is an indispensable component of electromobility. This is particularly important in the light of EU plans to develop electromobility based on Industry 4.0.*
Originality/Value: *The study attempts to fill the gap in the literature. The experimental research approach can help to understand links between electromobility and its development prospects in the context of Industry 4.0. At the same time, it is the first attempt to indicate the energy technology which should be used in electric vehicles as a basis for the future mobility in the European Union.*

Keywords: *Industry 4.0, electromobility, development plan, market research*.

JEL Classification: *L62, N74, O24, P42, R40*.

Paper Type: *Research article.*

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1. Introduction

Researchers agree that the contemporary European economy has faced new challenges due to the rapid technological advancement coupled with growing customer expectations (Biloslavo *et al.*, 2020; Centobelli *et al.*, 2020; Arnold *et al.*, 2016). In the literature, the idea of Industry 4.0 is described as the fourth industrial revolution aimed at the production of technologically advanced products that meet customer expectations in terms of techniques, information technology and economy (Dos Santos *et al*., 2020; Xu *et al.*, 2018; Piccarozzi *et al.*, 2018).

Moreover, environmental regulations have become more stringent for the EU member states as regards the conservation of the natural environment (Cucchiella *et al.*, 2015). One of key objectives is to improve the quality of air, which can be achieved by reducing emission from the automotive industry. A number of researchers claim that the development of electromobility may contribute to the improvement of air quality by reducing CO_2 and NO_X emissions (Skrucany *et al*., 2019; Tucki *et al.*, 2019). Therefore, today, the implementation of transport solutions based on the use of electricity has become an important part of the development strategy in every EU member state (Christidis and Focas, 2019). In the era of coopetition, automotive corporations increasingly often offer electric vehicles next to conventional or hybrid cars. In the opinion of many researchers (Cansino *et al.*, 2018; Mahwish *et al.*, 2020), the trend is global and applicable to almost every market segment.

Although an opinion prevailing in the literature is that the TCO of electric vehicles might be higher than combustion engine vehicles (Fridstrøm, and Østli, 2021), some researchers highlight the increased energy efficiency of electric engines due to the implementation of Industry 4.0, which should also translate into a lower maintenance cost (Johansen, 2020). This effect can be reached by improvements in energy generation and storage, as well as the development of charging infrastructure. All these objectives fit into the contemporary idea of electromobility. As researchers (Pietrzak and Pietrzak, 2020) claim, Industry 4.0 will deliver products of the top notch quality combined with their eco-friendly design.

Therefore, considering the current market reality, knowledge about consumer demands and social trends in combination with the IT sector and technological advancement, i.e. Industry 4.0, the electrification of the automotive industry in Europe is imminent (Sendek-Matysiak and Łosiewicz, 2021). The research question discussed in the article refers to prospects for the development of electromobility in the context of Industry 4.0 with particular emphasis on the energy parity. In the literature, the examined development of electromobility still remains a controversial and disputable topic, since it necessitates to examine choices determined by the supply and demand sides.

For this reason, the article contains a number of important practical implications, both political and economic. The article has the following structure. Chapter 2 contains a detailed description of the research method, as well as research questions and research tool. Chapter 3 describes results of experimental studies and their interpretation. Chapter 4 discusses results achieved by the authors and presents conclusions while pointing to their limitations in the context of previous research. It also outlines directions for future research into the development of electromobility in the context of Industry 4.0 in Poland and the European Union.

2. Research Approach

2.1 Conceptual Assumption

The objective of the research has been to present selected results of studies on the prospects for the development of electromobility in the context of Industry 4.0. The description concentrates on the analysis of customer demand and social trends in combination with the development of IT and advancement of technology. The research has focused on identifying mutual relations between the development of electromobility and Industry 4.0. An attempt has been made to find answers to the following research questions:

- In the opinion of the demand side, does the development of electromobility converge with Industry 4.0?
- Do representatives of the demand side plan to purchase electric vehicles in the nearest future?
- According to the demand side, which IT solutions and technological advances typical for Industry 4.0 may contribute to the development of electromobility?
- In the opinion of the demand side, how does the energy source used in electric vehicles converge with the idea of Industry 4.0?

2.2 Sampling Method

Considering that electromobility is evolving and specific features of Industry 4.0 still need to be defined, the choice based on objective criteria has been limited, since it is not possible to select a representative sample for the demand side, a sample which meets requirements of the probabilistic method. It is neither possible to secure a sample that guarantees probability of respondent participation above zero, nor the same probability for all observed entities (elements of population). For this reason, the selection of respondents did not follow a representative scheme. Methodological arguments supporting the decision are based on the following premises: descriptive character of research, in particular the implementation of the research goal which refers to a comparative study that includes a survey of Polish and foreign respondents, non-homogenous demand side, inability to standardize the access to respondents, and consequently create and plan homogenous and efficient examination of the sample.

People have been carefully selected to the sample group by contacting communities and individuals who are aware of changes related to electromobility and Industry 4.0. The awareness was the main criterion determining the selection of individuals. During the survey, all respondents agreed and gave positive answer to the first question. Respondents were selected from among Poles and EU citizens (from such countries as Germany, Czechia, and Slovakia). Since the group of respondents was very diverse in terms of their knowledge about electromobility and Industry 4.0, two independent research courses have been implemented using the communication channel both in the case of Poles and other EU nationals. The study covered 500 respondents. Since the non-probabilistic scheme did not define the number of people in the sample as a required minimum, the sample was considered sufficient for the purpose of analysis and supported the comparison between respondents from Poland and other EU countries.

2.3 Description of the Tool

The survey consisted of 10 merit-based questions (answers to 4 of them are discussed in the article). Considering the concept of targeted research, the study involved both Polish and EU respondents with the use of the same tool and questions. The questionnaire was emailed to respondents who expressed their intention to participate in the survey. Findings correspond to answers given questionnaires returned. The survey was conducted in January-December 2020.

2.4 Analysis Scheme

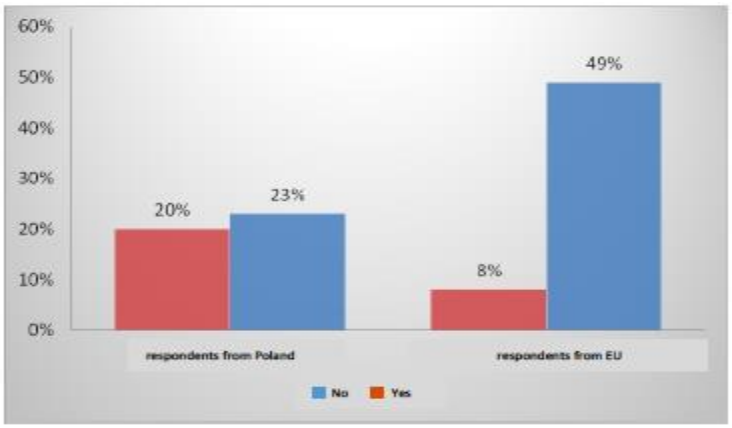
As mentioned in the introduction, the survey included 500 interviews. The empirical analysis method was based on quantitative and qualitative techniques that comprise generic analyses. The quantitative analysis determined and described the distribution of answers to survey questions, whereas the typological analysis (qualitative) accompanied the quantitative analysis of closed-type questions and enriched it with information about qualitative features. The comparative analysis (comparison between categories) was crucial from the point of view of research goals and it was based on the analysis of differences in distribution and values of variables in compared groups.

The respondents were divided into categories (observation sub-sets) distinguished by the distribution of features (variables). The main difference was the status of respondents defined by their nationality. Two basic comparative groups were distinguished: Polish respondents) and other EU nationals (250 observations). No division and analyses were performed regarding several variables, such as respondent age, sex, employment, professional status, financial situation, etc. Unless specified otherwise, percentage values sum up to 100 percent in independent groups of Poles and other EU nationals (distinguished by variables).

3. Results

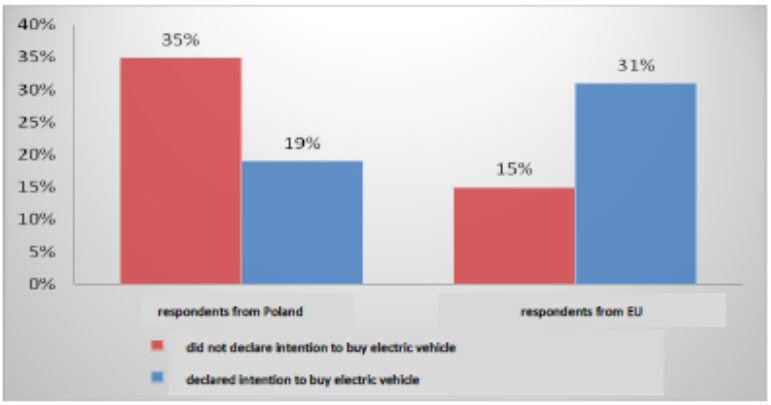
Stage one of the survey in included a question about the development of electromobility and its relationship with the idea of Industry 4.0 (Figure 1).

Figure 1. *Does the development of electromobility fit into the idea of Industry 4.0?*



According to the survey, more than 72% of respondents confirmed that the development of electromobility fitted into the idea of Industry 4.0. It is worth noting that more negative answers were given by respondents from other EU countries than from Poland, respectively 49% and 23%. Interestingly, 28% of respondents believe that electromobility fits into the idea of Industry 4.0. Another stage of the survey included a question about respondents' intention to buy an electric vehicle in the nearest future (Figure 2).

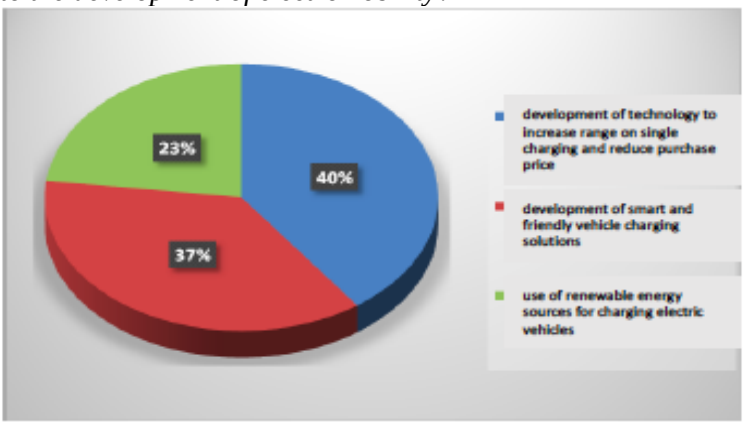
Figure 2*. Do you intend to buy an electric vehicle in the nearest future*



Answers show that 50% of respondent declared their intention to by an electric car. It is worth noting that EU respondents accounted for 39% of the total, which means

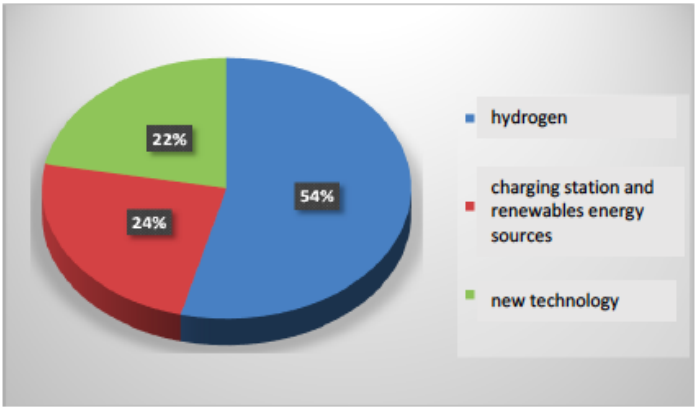
that more than 3 times from other EU nationals intend to buy an electric vehicle than Poles (11%). It should be emphasized that 50% of respondents did not declare their intention to buy an electric vehicle in the nearest future. In this group, Poles account for much larger part of the total (29%). Then, respondents were asked which IT and technological solutions may contribute to the development of electromobility (Figure 3).

Figure 3. *Which IT and technological solutions attributable to Industry 4.0 may contribute to the development of electromobility?*



Results show that 40% of respondents pointed to the development of solutions that increase the range of electric vehicles per single charging and reduction of the purchase price. Moreover, 37% of respondents mentioned the development of smart and user-friendly charging solutions. These are followed by the opinion of 23% respondents that there is a need to use renewable energy sources. Finally, respondents were asked which source of energy for electric vehicles is in line with the idea of Industry 4.0 (Figure 4).

Figure 4. *What energy source for electric vehicles is in line with the idea of Industry 4.0*



The analysis of responses shows that 54% of respondents mentioned the energy parity from hydrogen, 24% of them pointed to energy from batteries and the grid and, at the same time, emphasized that the renewable energy sources should be used. 22% of the surveyed indicated the need to develop a new technology. In this particular case again more other EU nationals than Poles supported such solutions.

4. Discussion and Conclusions

The literature emphasizes that Industry 4.0 is a collective term embracing innovative technologies integrated with a value chain (Massaro *et.al.*,2021). The use of cyber-physical systems in smart manufacturing plants is designed to monitor physical processes and implementation of decisions in a decentralized environment (Hoffmann and Rüsch, 2017). According to the authors, the concept applies not only to individual organizations but entire value chains. The aim is to create global networks integrating machines and production lines, as well as storage systems and plants based on cyber-physical systems. The authors agree with the thesis promoted by other researchers (Silva *et al*., 2018; Andreli, 2014) that in such an environment Industry 4.0 will play a major role in development of electromobility. Although the literature attempts to define technical, economic, legal and organizational barriers that have a direct impact on the development of electromobility, the observation of the market shows that such barriers still have not been eliminated. The authors agree with a number of other researchers that Industry 4.0 is the answer to the problem.

The survey of the demand side examines whether electromobility fits into the idea of Industry 4.0. Although according to 75% of respondents electromobility and Industry 4.0 are interrelated, which has been confirmed by other studies (Curiel-Ramirez *et al.,* 2020; Brach, 2017), there is a major disproportion between opinions of Poles and other EU nationals. The authors concluded that action focusing on Polish citizens must focus on changing the awareness of the demand side by broadening their knowledge about possible advantages of Industry 4.0 and its direct impact on the development of electromobility. According to the authors, only a comprehensive change of the awareness may produce the desired effect. Such attempts are made in other countries where governments have been promoting low-emission solutions in transport for a long time (Cansino, *et al*., 2018).

About 50% of respondents declared their intention to buy an electric vehicle in the nearest future, despite the COVID-19 pandemic. This may indicate an increase in the demand for electric vehicles. A detailed analysis of data shows disproportions between opinions of other EU nationals and Poles. Their consumer attitude has been reflected in other research (Szumska, *et al.,* 2019). According to the authors, this attitude may result from a justified conviction that electric vehicles are more expensive to buy and maintain than conventional combustion engine cars (Johansen, 2020).

In the context of IT solutions and technological advancement attributable to Industry 4.0 and their influence on the development of electromobility, results of the survey highlight three basic postulates, namely the development of technology should lead to the increase of the range of electric vehicles (40%), production cost should be reduced and so the price of electric vehicles (37%), and smart and user-friendly charging solutions should be developed and renewable energy sources used (23%). The postulates have been confirmed by other authors (Rezvani *et al.,* 2015). Moreover, the survey showed that the awareness on the demand side in Poland and other EU member states is similar, except for the use of renewable energy sources (Malek *et al.,* 2020). However, the authors expect that with the transition of the Polish economy toward low-emission solutions, the awareness of the demand side with this respect will reach a level similar to other countries covered by the survey.

Finally, according to the demand side, the energy source considered for electric vehicles is in line with the idea of Industry 4.0. Results of the survey definitely point to the use of hydrogen. This has been confirmed by other researchers (Diaz, 2020) who consider this source of energy to be the future for the development of electromobility. It should be emphasized that more than 22% of respondents highlighted the need to develop a new technology. In the opinion of the authors, it fits directly into the idea of Industry 4.0.

Summarizing, the increase in the significance of modern forms of mobility seems to be unavoidable in the context of Industry 4.0. According to the literature and observations, the choice of a prevailing technology for electric vehicles is still an open issue. In the opinion of respondents, hydrogen can be a solution. The authors claim that once the price is reduced and technology developed for the use of hydrogen, it can be a convenient and accessible solution (Sing *et al.,* 2020). Thus, Industry 4.0 may contribute to the development of electromobility in the nearest future. Yet another very important aspect highlighted by the survey is the need to develop energy storage technology and charging infrastructure supporting electric vehicles (Abu-Rayash and Dincler, 2019). These are indispensable elements of the electromobility system. According to the authors, only a comprehensive development of all electromobility components (technology, reduced cost and smart IT solutions) will enable to reach the goal and revolutionize mobility in the EU.

The article uses data collected through a survey involving 500 respondents. For certain, there is a need for interdisciplinary analyses in the future. Such analyses should examine changes due to technological advances related to Industry 4.0. Moreover, one of priorities should include pilot studies regarding the development of electromobility in particular EU member states, with the focus on the demand side and identification, promotion and development of a dominating energy source to support electromobility.

Summarizing the survey and prospects for the development of electromobility in the context of Industry 4.0, the study comparing Poland and the European Union is by no means exhaustive. It reflects the original approach to the research problem. For certain further analyses and studies are needed. For this reason, such analyses should be included in future studies regarding the impact of Industry 4.0 on the development of electromobility in the European Union.

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