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IMPORTANCE OF ELECTROMOBILITY IN THE CONTEXT OF ENVIRONMENTAL PROTECTION

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Abstract

Environmental protection is currently topic that resonates in society, and is subject of a variety of professional, scientific events, but also of interest to legislators and supervisory authorities at international, European and national level. Economic activities of population and economic sector create a wide range of externalities that has negative impact on environment. Production, manufacturing, trade and/or migration at the labor market are very closely linked to transportation sector in which the greatest effort is made to reduce its environmental burden. Our research activities are dedicated to the field of electromobility development. Electromobility is a desirable innovation that enables to eliminate the impact of transportation on environment. We conducted primary quantitative pre-research by inquiry method via standardized online questionnaire that addressed some topics: (1) consumer interest in environmental protection; (2) consumer awareness and knowledge about electromobility; and (3) consumer buying behavior in the context of electromobility development. In this paper we focus on partial pre-research result with the aim to identify consumer interest in environmental protection in order to suggest recommendations for electromobility development. The presented paper is output of the research project VEGA No. 1/0380/17 Economic efficiency of electromobility in logistics.

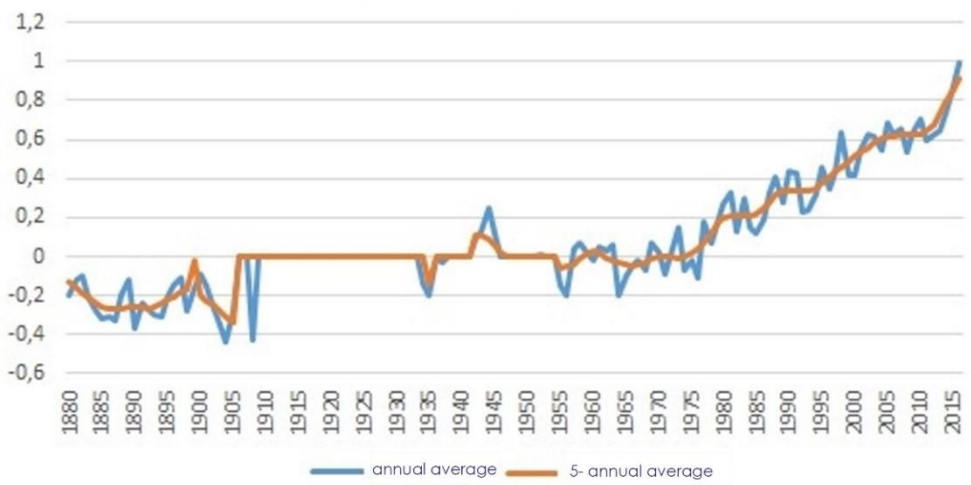
Keywords: electromobility, environmental protection, CO_2 emission, consumer behavior

Introduction

Environmentally-aware society is the basic precondition to successfully implement activities and measures dedicated to the reduction of environmental burdens. Economic activities of population and economic sector create a wide range of externalities that has negative impact on environment. Economic activity of the population is represented not

only by industry, agriculture, energy industry, business and/or transport, but also by consumer´s behavior when satisfying their needs. Negative externalities of economic activities of the population has recently caused serious global climate changes. Since the greenhouse gas emissions (especially high emissions of CO_2) has changed the global climate significantly, it requires national governmental authorities, international organizations, business sector, non-profit organizations and consumers to pay more attention to solve this serious problem. Results of CO_2 atmosphere content monitoring indicate that concentration of CO_2 in the atmosphere has been rapidly increasing since the beginning of the industrial revolution, especially due to emissions from fossil fuel combustion (coal, oil, wood, gas) and the technological emissions from industry production. Over the last 20 years almost three quarters of CO_2 emissions are represented by emissions from fossil fuel combustion and various technological processes. Every year 22 milliards tons of CO_2 and other greenhouse gases penetrate the atmosphere and almost half of the emissions remain in the atmosphere. Comparing the current concentration of CO_2 in atmosphere to the concentration before industry revolution (1750), 31% of increase has been recorded. The increase of greenhouse gases the most significantly results in the global temperature rise. There are also various secondary negative impacts on the environment and population. Data in fig. 1 show increasing global temperature index in last 130 years.

Fig. 1 The global temperature index in years 1880 – 2016



Source: NASA, 2017

Launching the conferences of the Parties (COP) under the United Nations Framework Convention on Climate Change (UNFCCC) represented the principal change in attitude to solve climate changes. Negotiations are the most important and time-consuming platforms leading to international agreements. Opinions and comments of Parties to the

Convention which are presented during negotiations often disable international agreement to be adopted. At the climate change conferences with more than 190 states regularly participated, it is almost impossible to reach consensus and easily find the mutual solution with perspective of agreement in the future. The last conference took place from 29/11/2015 to 13/12/2015 in Paris and included the 21st session of the Conference of the Parties (COP 21) to the UNFCCC and the 11th session of the Conference of the Parties serving as the Meeting of the Parties to the Kyoto Protocol (CMP 11). At that time, general secretary of the United Nations Pan Ki-mun emphasized the perspective of the document which represents new way of low carbon technology. He pointed out that national interests can be satisfied only by respecting solidarity. He appealed to make compromises when finishing the negotiation process. Later on, 175 of the 197 Parties to the Convention has ratified Paris Agreement that may significantly influence negative directions of individual countries in relation to the environment. The Paris Agreement's aim is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. Additionally, the agreement aims to strengthen the ability of countries to deal with the impacts of climate change (Allan et al., 2015).

Recently, consumer behavior related to the environment has become integral part of sustainable development. Consumer attitude to the environment is an important aspect of consumer behavior. Consumers are more sensitive to environmentally friendly products and environmental responsibility of business entities. Purchasing decision are more often influenced by products parameters and features such as energy efficiency, material, environmental aspects, toxicity, operational requirement, recycling, etc. It means that consumer is pushing on social consensus in the environmental protection and accelerates technological innovations leading to environmental burdens reduction. Consumer as a part of transport plays an important role. Using of transport in various spheres of life (personal transport, shipping, etc.) determines directions and technological innovations in transport. Business entities in the field of agriculture, industry and transport have to accept that fact.

Methods

Selection of scientific methods depends on the paper content focus and the paper aim. To elaborate theoretical knowledge, we primarily used theoretical scientific methods, including a method of analysis and synthesis, a method of induction and deduction, abstraction and concretization, but also a comparative method. As a method of collecting primary data we conducted research. We evaluated and interpreted the obtained quantitative data through statistical and graphical methods in the Statgraphics

software and MS Excel.

The basis for identification of consumer interest in environmental protection is represented by the results of primary pre-research that we conducted by the inquiry method through the standardized online questionnaire in August 2017. We focused on three topics: (1) consumer interest in environmental protection; (2) consumer awareness and knowledge about electromobility; and (3) consumer buying behavior in the context of electromobility development. However, this paper focuses on the analysis of partial results concerning the consumer interest in environmental protection. Based on the pre-research partial results, the aim of the presented paper is to identify consumers' interest in environmental protection in their consumer behavior. Attitude to electromobility and alternative propulsion.

We set the following research questions:

1 Are consumers interested in the environmental protection?
2 What do consumers think about the impact of electromobility development on reduction of environmental pollution by transport?
3 Are consumers interested in alternative energy sources?

The questionnaire consisted of 24 closed-ended and open-ended questions (including 5 classification questions). The respondent´s answers were evaluated through frequency tables and cross tabulations, in some cases relevant descriptive statistics (e.g. average, standard deviation) were calculated.

After testing for complexity, accuracy, validity, reliability and consistency, we analyzed 93 questionnaires. We can consider our results to be representative. We calculated the sample size of 71 respondents with confidence level 95%, margin of error 7% and population proportion 0.9.

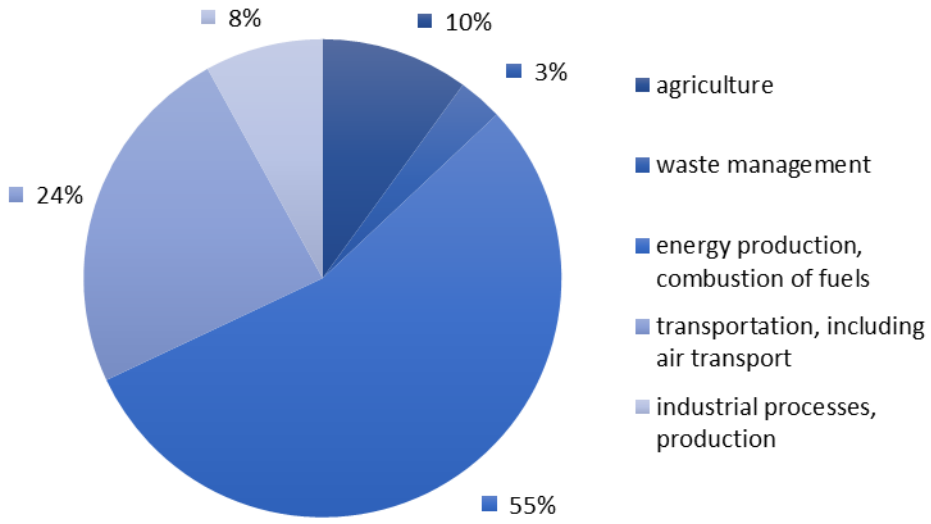
Results

Impact of transport on the environment

Transport plays an important role in economy of each country. It creates job positions for inhabitants, contributes to GDP, influences the economic growth of the country and living conditions. The number of vehicles is continuously rising worldwide, demand is high, production costs are decreasing. All these facts affect price of the vehicles (Bella, 2013). The increase of vehicles in personal, public and freight transport is one of the main reasons why greenhouse gas production increases. Road transport is an economic sector that is globally growing in most indicators (fuel consumption, energy, number of cars and transport performance) significantly faster than GDP growth. At the same time, it results in negative impact on the environment and human health. The data in fig. 2 show the share of transport on emissions compared to other sectors of global economy. In 1990 the share of transport on greenhouse gas emissions was 15 % which is

by 9 percentage points less than in 2015 (Eurostat, 2017).

Fig. 2 Greenhouse gas emissions by sector, EU-28, 2015



Source: EUROSTAT, 2017

To minimize negative impact of emissions from transport on environment, EU legislation set the goals in the area of climate and energy industry which should be met by the year 2020. EU has adopted integrated and ambitious system of policies and measures focused on climate changes that represent one of the five main goals within strategy Europa 2020 for employment and economic growth. In the area of climate and energy the main goal is to decrease greenhouse gas emissions by 20 % compared to 1990. Based on transport emissions analyses, the most significant source of emissions is represented by personal transport, especially cars which account for two-thirds of share on road traffic emissions. While personal vehicle emissions are decreasing, emissions of freight transport are continuously increasing. Transport emissions depend on three elements: transport activity level, energy intensity of transport and types of energy sources used in transport. As it is unlikely that technological development itself enables to reduce emissions, activities and measures of all three elements will be required to decrease emissions significantly (Gerceľová et al., 2012).

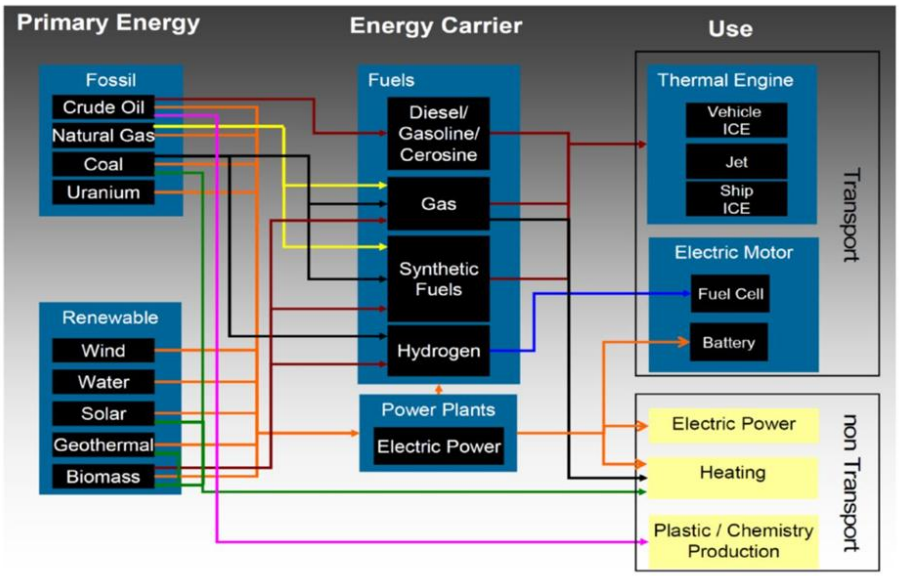
Alternative propulsion systems for transportation

In general, diesel and combustion engines are not going to “save the day” in the near future of up to 2050. In term of technology, we can identify the alternative transport technologies relating to the potential energy and emission reduction.

The viable segmentation of three important areas regarding energy use in transport has to be recognized (see fig. 3). First, for all means of energy pathways into transport the selection of a primary energy source is necessary, be it fossil or renewable. Second,

an energy carrier has to be selected from a variety of options, i.e. diesel, gas, synthetic fuel, hydrogen or electricity. Third, the use section distinguishes different engine options that can be applied (combustion, electric motor with fuel cell or battery) in addition to the unlisted electricity line networks used for railway transportation (electric motor with network supply of electricity). Fig. 3 indicate very high number of combinations resulted from this distinction. There will likely be no single solution for all transport modes and applications.

Fig. 3 Energy pathways in transport and other sectors



Source: European Expert Group on Future Transport Fuels, 2011

Based on previous studies (Mwangi et al., 2015; Van Keulen et al., 2012), shorter transport range simplify replacement of combustion engines with electric drives. In any case, overall energy consumption and greenhouse gas emissions do not depend so significantly on the second and third stage of the concept as on the used primary energy. Therefore, a truck system using a combustion engine with synthetic fuel from renewable biomass production may be more sustainable than an electric truck powered by electricity that is produced from fossil coal energy (Klumpp, 2016).

Electromobility in transport

The history of electromobility, also referred to e-mobility, is interesting because it was preceded by conventional combustion engines commonly used at present. The first mention of an electric motor as a concept of propulsion is recorded in 1829 and is associated with the name of the Hungarian inventor Ányos Jedlik, born in the village Zemné (Nové Zámky district, Slovakia). The first concepts for propulsion based on the

combustion of hydrocarbons appeared some years later. They were associated with the name Gottlieb Daimler who built the first four-stroke high-rev spark ignition engine in 1884 or Rudolf Diesel that began to deal with the use of fuel such as coal or other heavy fuels for the necessary circulation process in 1893. When looking for reasons why e-mobility failed at its beginnings, we can find a certain links to reasons of the slow start-up of e-mobility at present. Current and previous barriers of electromobility include the high initial costs of producing electric cars, vehicle´s driving range per one charging cycle and insufficient network of charging stations. At present technology of battery driving range is continuously developing and the quality of road infrastructure is improved. Probably the most significant impulse for the revival of electromobility in the world has become an ecological aspect. In general, combustion engines emit to the atmosphere greenhouse gases and other pollutants which threaten the human health and contribute significantly to global warming. For these reasons, governments in all developed countries around the world set limits for greenhouse gas emissions. Some EU countries (e.g. France, Germany, the Netherlands, the United Kingdom) and even non-EU countries such as Norway, consider banning the use of combustion engines in passenger transport from 2025 (Daňo & Drábik, 2017).

In recent years technological innovations in electromobility have been very dynamic. Market pressure (consumer preferences and attitudes) and environmental aspects drive dynamics of the development of electric motors, batteries, but also the charging network infrastructure. Current technologies enable to launch several types of electric vehicles and hybrid technologies at the market that can be described as follow (Rezvani et al., 2015):

- *Battery electric vehicles (BEVs)* are powered solely by electrical energy from a battery and have a fully electric drivetrain. Battery can be charged in many different ways, usually by plugging in to a charging point connected to the local electricity grid. BEVs have the highest energy efficiency among all vehicle propulsion systems. They can convert approximately 80% or more of the electric energy stored in the battery into motion (i.e. kinetic energy) (Grauers et al., 2013). The other advantage is the significantly higher energy efficiency, since most of the energy actually gets to the drive train, unlike with an internal combustion engine, in which a large part of the energy is converted into heat loss (Markus, 2016). The electric motor is extremely efficient and regenerative braking system helps to recharge the battery in the vehicle by converting unused energy. There are no exhaust emissions when driving BEV thus it helps to improve local air quality. The strongest argument is the ability to power electric vehicles with green electricity, i.e. to charge with CO_2-free generated electricity, and therefore enable sustainable road transport with virtually no CO_2 emissions. With the current European average power mix and its emissions of 275.9g

CO_2/ KWh, electric vehicles emit less than 50% of what an average internal combustion engine car emits today. The share of electricity generated from renewable sources is growing rapidly and reached more than one quarter of all gross electricity generation in the EU-28 (29 % in 2014). Eurelectric predicts that 80% of European electricity will be carbon free (half from renewable and half from nuclear electricity generation) in 2030 (European Commission, 2015). At present disadvantage of BEVs is shorter driving range compared to conventional vehicles and battery charging time.

- *Hybrid electric vehicles* (HEVs) have been commercialized for more than 15 years. The hybrid technology combines internal combustion engine and electric motor driven by battery. The battery in HEV cannot be charged from the grid, but it is charged by regenerative braking or while driving. Since HEV is primarily powered by its conventional engine, hybrid technology is added to conventional vehicles to increase fuel efficiency, reduce pollutants and CO_2 emissions. HEVs usually have lower fuel consumption and exhaust emissions than conventional technologies. The more sophisticated hybrid technology indicates greater potential to reduce emissions. There are many different HEV types and models, for example 'micro-HEVs', 'full HEVs'. Batteries for hybrid vehicles tend to be more expensive than electric vehicle batteries in terms of price per kWh. Higher price is mainly caused by greater power-to-energy performance of hybrid vehicles
- *Plug-in hybrid electric vehicles* (PHEVs) are development of the HEVs with improved battery capacity and plug-in charger, which makes it possible to recharge the battery from the electricity grid. PHEV are powered by an electric motor and an internal combustion engine which are designed to work simultaneously or separately. The built-in battery can be charged from the grid, and the combustion engine supports the electric motor when higher operating power is required or when the battery is low. The electric driving range is shorter compared to BEVs due to battery capacity that is primarily designed for short trips in the city. However, the combustion engine allows a much longer overall driving range compared to REEV (range-extended electric vehicle). PHEV batteries tend to be more expensive than BEV in terms of price per kWh. Higher price is mainly caused by higher energy efficiency of PHEV. The impact of PHEV on the environment depends on their mode of operation. Running in full-electric mode results in zero exhaust emissions, but reliance on a conventional engine can lead to fuel consumption and undesired emissions that are the same or higher than conventional vehicles of similar size because additional batteries increase vehicle weight.
- *Extended-range electric vehicles* (E-REVs) run on a battery that can be charged from an electric outlet and has a fuel tank which allows the driver to extend the range of

driving. A battery electric vehicle (BEV) has an all-electric drivetrain powered from a large capacity battery (compared to PHEV and E-REV), which is recharged from the electricity grid. E-REVs have a serial hybrid configuration in which their combustion engine has no direct link to the wheels. The combustion engine of E-REV serves as an electric power generator and is used to power an electric motor or charge the battery when charging level is low. One of the advantages of E-REV is that the conventional engine may be small, because it is needed only when the vehicle exceeds its electric driving range. That helps to reduce the vehicle's weight.

- *Fuel cell electric vehicles* (FCEVs) are also entirely powered by electricity that is not stored in an extensive battery system, but it is supplied by a fuel cell "reservoir" which uses hydrogen from a tank combined with oxygen from the air. Comparing to BEV, the main advantages of FCEV are its longer driving range and faster refueling, similar to conventional vehicles. Due to the current size and weight of fuel cell storage technology which is in first stage of development, FCEVs are more suitable for medium and large vehicles and for longer distances. Only some FCEV models are currently launched at the market. Further technological development is needed to prolong the life of FCEV vehicles, cost reduction will be based on the construction of a hydrogen supply infrastructure, including stand-alone stations or hydrogen pumps.

Global obstacles and barriers of the electromobility development

We point out selected obstacles and barriers in the development of e-mobility globally. Regarding the importance of lithium mining, lithium is the most important part of battery production. As lithium is a relatively available raw material, it can be mined in several places around the world. The problem relates to the component of lithium-ion batteries that is cobalt. Two-thirds of world cobalt production are mined in the politically unstable Democratic Republic of the Congo representing strong element of instability in the term of price and logistics processes. Currently, research and development of suitable alternatives of this battery component is carried out.

Another barrier of e-mobility development can represent the production of electricity. If the electricity is produced in a conventional way (from conventional sources), it results in significant carbon footprint. Will be CO_2 emissions really reduced by the e-mobility development? The wide-spread use of electric vehicles powered by electricity from renewable sources promises a substantial reduction of local emissions in urban area as well as greenhouse gas emissions. The most important players in the field of electricity production (including the European Union) are aiming at greenhouse gases reduction of 20% by 2030 compared to 2008. In order to achieve this aim, the European Commission proclaimed to halve the use of "conventionally-fuelled" cars in urban transport and to replace production of electricity from fossil fuels by renewable energy

sources up to 2030 (Bühne et al., 2015).

The low-intensity of charging infrastructure deployment can be considered as the obstacle of e-mobility development. The European Commission proposed to invest €2.7 billion in 152 key transport projects that support competitive, clean and connected mobility in Europe. Out of the total €2.7 billion, the Commission decided to allocate €1.8 billion for the 15 Member States eligible for support from the Cohesion Fund (For the 2014-2020 period, Cohesion Fund support concerns Bulgaria, Croatia, Cyprus, the Czech Republic, Estonia, Greece, Hungary, Latvia, Lithuania, Malta, Poland, Portugal, Romania, Slovakia and Slovenia) in order to further bridge infrastructure disparities. Selected actions include development of a high-speed electric vehicle charging network across Sweden, Denmark, Germany, France, the United Kingdom and Italy (European Commission, 2017).

Electromobility and consumer

Technological development often depends on motivation of business entities to gain competitive advantage and/or on consumer preferences. Electromobility is perceived as the most dynamically developing technological innovation of the present. Globally, the current development of electromobility can be partially explained by the efforts of business sector, countries to gain a competitive advantage. Vast majority of conventional car manufacturers proactively respond to trends in the electric car market and plans to expand their portfolio and invest in the electric car sector despite a lack of customer demand at present.

A lack of consumer interest poses a significant obstacle for electromobility. Previous studies show that consumers are satisfied to use conventional vehicles. Vast majority of consumers does not consider buying an electric car. The most important barriers include the high price of electric cars, the short driving range per one battery charging cycle, the lack of charging stations, lifetime and price of the batteries. On the other hand, fossil fuels are not expensive enough to motivate consumers to think about buying an electric car to reduce operating costs.

It is unlikely that the development of electromobility will be driven only by market forces which means that policies at national and regional level will play, precisely already play a key role (Grauers et al., 2013). Various trends can be observed at both public and private sector. Many cities, regions and countries are developing plans to enhance the development of the electromobility eco-system through incentives, infrastructure and fleet change. Besides tramways and metro systems, electric buses are now being introduced on the market to provide zero-emission public transport. (Platform for Electromobility, n.d). These steps in different parts of the world can also be a response to the adopted legislative requirements to reduce CO_2 and noise emissions and to

improve the quality of life. Electromobility is a means for car manufacturers to comply with legislation that sets performance standards for new vehicles.

In other words, there is currently insufficient market power on the part of the consumer to promote electromobility in the absence of significant policies and measures to promote electromobility at national, regional or international level, although significant developments in electro mobility are expected on a global scale. In Slovakia, electromobility is only at the beginning, but its development depends directly on the design and implementation of effective state support measures. These initiatives concern the regulatory framework for electromobility, vehicle financing, charging infrastructure deployment and design of the electricity market. We distinguish some interested parties that play a key role in the development of electromobility:

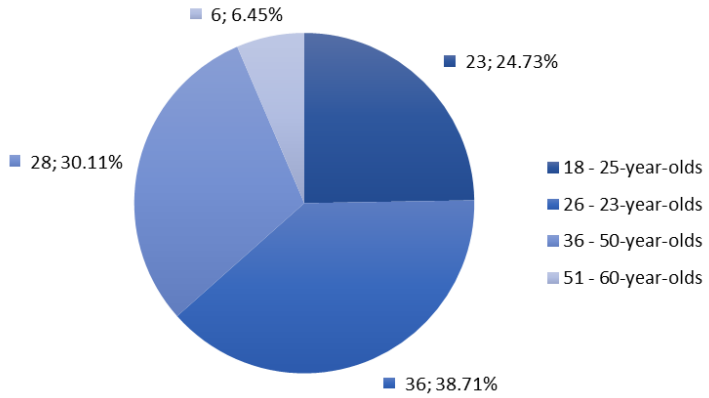
1 automotive industry - manufacturers of electric vehicles and their suppliers, dealers,
2 energy industry as suppliers of electricity,
3 providers of charging infrastructure for electric vehicles,
4 consumers who create demand for electric cars,
5 public and state sector, governments of individual countries
6 non-governmental organizations, universities, research centers, etc.

Consumer interest in environmental protection and electromobility

In this part of the paper, we present partial results of the pre-research which provide us with answers to the research questions and also testify to consumer interest in environmental protection.

A total of 93 consumers participated in the pre-research, of which 48 (51.61%) were men and 45 (48.39%) women. In terms of age structure (see fig. 5), there was the largest representation of consumers aged 26 –35 (36, i.e. 38.71%) and 36 –50-year-olds (28, i.e. 30.11%). 18 –25-year-olds were represented by 23 consumers (i.e. 24.73%), and more than 51-year-olds by 6 consumers (i.e. 6.45%). In terms of net monthly household income, there were three levels of income with similar representation of consumers: 22 consumers (i.e. 23.66%) declared €1,501 – 2,000; 21 (22.58%) consumers declared €1,001 – 1,500 and the same number of consumers (21, i.e. 22.58%) more than €2,500.

Fig. 5 Age structure of respondents

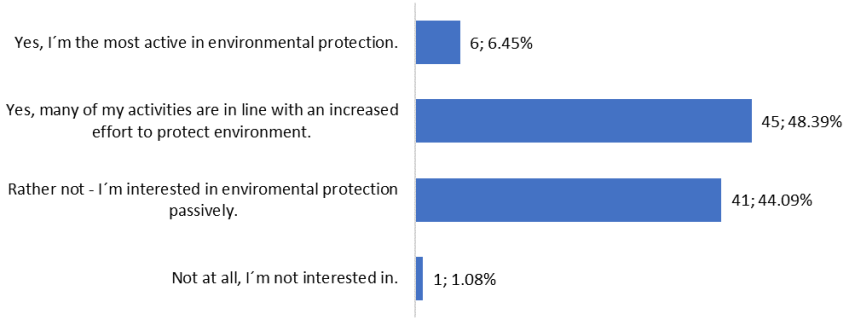


Source: own results

Are consumers interested in environmental protection?

Pre-research results in fig. show that 44.09% of consumers play passive role in environmental protection. We evaluate result of 1.08% consumers not at all interested in environmental protection to be positive. On the other hand, only 6.45% of consumers claim that they do their best to protect environment. Since 48.39% of consumers express their increased effort to protect environment, there is possibility to improve their awareness and interest. Environmental protection policies should be aimed to improve consumer awareness and knowledge about possibilities how to protect environment more intensively.

Fig. 6 Consumer interest in environmental protection

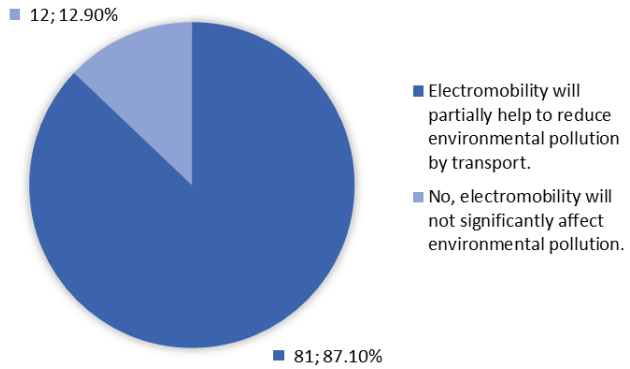


Source: own results

What do consumers think about the impact of electromobility development on reduction of environmental pollution by transport?

Vast majority of consumers (87.10%) is aware of the positive impact of electromobility development on the environment and reduction of pollution. It is questionable, what criteria consumers had when evaluating the reasons why electromobility is a way to reduce environmental pollution by transport. This issue will be part of further research.

Fig. 7 Impact of electromobility development on environmental pollution

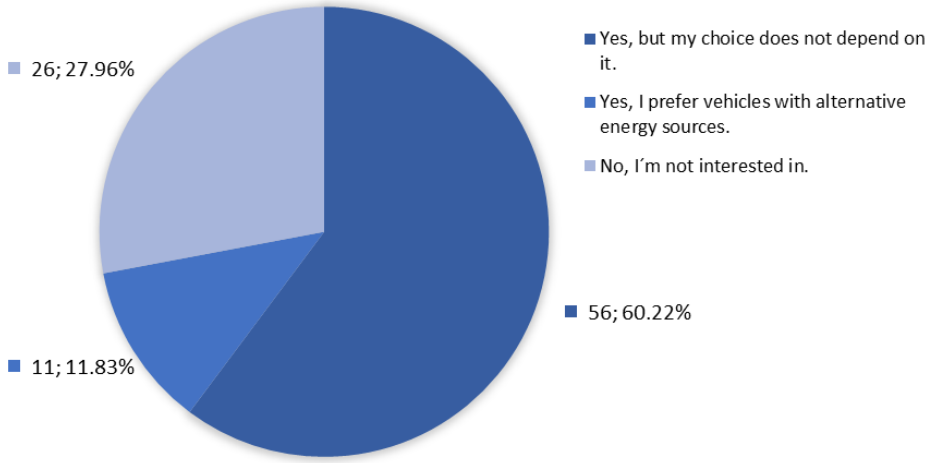


Source: own results

Are consumers interested in if the vehicles use alternative energy sources?

The electromobility development and its impact on reducing the environmental burdens is closely linked to use of alternative energy sources when producing electricity and batteries. Since 60.22% of consumers are interested in energy sources that are used for vehicles drive we evaluate these results positively (see fig. 8). The fact that their choice of vehicle does not depend on it relates to current trends and possibilities at the car market and/or public transportation. However, we think it is positive signal for electromobility development. The total of 27.96% consumers that do not pay attention to the alternative fuel vehicles correspond to the number of consumers that are not interested in electromobility.

Fig. 8 Consumer interest in alternative energy sources



Source: own results

Conclusion

Electromobility covers a wide range of issues related to the environmental protection.

We focused on selected aspects of electromobility in the context of environmental protection. Electromobility is a multidisciplinary topic and seems to be complicated. We can conclude that electromobility represents the only one technologically developed and market accepted alternative drive used in the transport. Alternative energy sources, precisely electricity production from renewable energy sources are appropriate way to reduce environmental pollution.

According to paper aim and research question we can conclude, that consumers in Slovakia are environmentally-aware. Almost half of the consumers (48.39%) expressed their increased effort to protect environment and other 44.09% of consumer are passively interested in environmental protection. We think there is possibility to improve their awareness and interest. Since 60.22% of consumers are interested in energy sources that are used for vehicles drive we evaluate these results positively. It is not surprising that vast majority of consumers think that electromobility development will partially help to reduce environmental burdens of transport.

We point out that electromobility development depends on many factors that have to be researched. There are several limitations of this paper. First, we conducted pre-research of limited sample size of the respondents. At the same time, the pre-research sample size of 93 respondents can be considered to be representative. Since we focused on selected aspects of electromobility, further research is recommended.

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