POVILAS MAČIULIS

ASSESSMENT OF THE MEASURES PROMOTING THE USE OF RENEWABLE ENERGY SOURCES IN THE TRANSPORT SECTOR

SUMMARY OF DOCTORAL DISSERTATION

SOCIAL SCIENCES, ECONOMICS (S 004)

Kaunas
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KAUNAS UNIVERSITY OF TECHNOLOGY
KLAIPEDA UNIVERSITY
LITHUANIAN ENERGY INSTITUTE

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This doctoral dissertation was prepared at Lithuanian Energy Institute, Laboratory of Energy Systems Research during the period of 2015–2020

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INTRODUCTION

Relevance of the topic

Globally recorded steady growth in energy demand, as well as forecasting of its long-term scenarios, do not show any signs of decline. On the contrary, global energy demand is projected to increase by 35 per cent in 2030 compared to 2010 (Simionescu et al., 2017). Medium and long-term drivers of global energy demand include economic and population growth in developing countries (Miškinis et al., 2014). The main cause of carbon dioxide emissions into the atmosphere is fossil fuels which have a direct impact on the greenhouse effect and climatic changes. In the last century, the use of fossil fuels has generated their highest carbon footprint that has reached unprecedented levels (Pacesila et al., 2016). Due to the changing climate, air and ocean temperatures are warming, mountain snow and glaciers on both poles of the Earth are melting. Melting glaciers along with the thermal expansion of water are rising global water levels, thus increasing the risk of floods, full submersion and the number of extreme meteorological events.

In terms of greenhouse gas emissions, the transport sector is second only to the energy sector. The transport sector, therefore, has a particularly strong impact on governmental efforts to meet carbon emission reduction targets. In the transport sector as a whole, it is worth highlighting the road passenger car segment, where the main challenge is to switch to clean vehicles driven on renewable energy sources (RES). In Europe, for example, road transport alone emits almost one-fifth of the total greenhouse gas (GHG) emissions. Thus, clean vehicles can increase energy efficiency, help diminish the dependence on oil imports and reduce carbon emissions.

The Lithuanian context is also important for the implementation of the research of this dissertation. Fuel and energy consumption in the Lithuanian transport sector increased by 42.4 per cent from 2010 to 2018, while diesel consumption increased by 11 per cent from 2010, and in 2018 accounted for 74 per cent of the total fuel consumption in the transport sector. 90 per cent of all fuels used in the transport sector are consumed by road transport. The passenger car market, public transport fleets and freight transport are dominated by petrol- and diesel-driven vehicles. The issue of promoting the use of RES is one of the main objectives of the energy policy of the Republic of Lithuania set out in the National Energy Independence Strategy of Lithuania and in the Law on Energy from Renewable Sources. At the end of 2019, the National Energy and Climate Action Plan for 2021–2030 was approved. This plan envisages that after the implementation of all the measures by 2030, GHG emissions in the Lithuanian transport sector will decrease by 8.1 per cent. This is a major challenge as the share of RES in the transport sector decreased from 4.6 to 3.7 per cent in 2015–2017 due to the growth of energy consumption in the above-mentioned sector. The main part of RES consists of biofuels, and only a small part – of electricity consumption in railways and trolleybuses.

Despite the environmental benefits of clean cars, a number of technical and economic barriers prevent the mass development of these cars in the overall vehicle market (Quak et al., 2016, Sierzchula et al., 2014, Kley et al., 2010). One of the reasons why the natural entry of clean cars into the market is comparatively slow is their price which is higher than that of conventional cars with internal combustion engines using fossil fuels. Another relevant reason is the lack of filling/loading infrastructure for RES using cars, which prevents consumers from feeling comfortable and safe when driving a non-fossil fuel vehicle (Wang et. al, 2017, Stevens and Schieb, 2013). Governments are therefore implementing particular promotion policy to increase the competitiveness and popularity of the above-mentioned products among consumers (Yang et al., 2016). There are mechanisms to promote clean cars that are implemented at the municipal level. In many cases, the measures implemented by national and local authorities vary due to the different promotion policies which are determined by the scale of a promotion system. What is more, promotion measures vary widely in their scope, type, administrative level of implementation, etc. The result is also different: some states (or cities) have already achieved a major breakthrough in the development of the RES-powered car market, while others are moving very slowly. A considerable body of scientific literature and studies can be found to analyse clean car markets and thus assess the relevance of financial and non-financial promotion measures. This research addresses the links between car sales dynamics and the data indicating the scale, value and impact of purchasing incentives.

Scientific problem and its investigation level

Rising world population, soaring consumption, economic growth in developing countries and the development of urbanisation lead to a steady increase in energy demand (Ghenai et al., 2020, Simionescu et al., 2017, Miškinis et al., 2014). Growth in energy production and use has an impact on GHG emissions which directly contribute to global warming and climate change. The prevailing view among scientists is that the dangerous scale of climate change can only be prevented by reducing GHG emissions (Gielen et al., 2019, Pacesila et al., 2016, etc). There is also a general consensus that these global challenges can be addressed through implementing the objectives of sustainable development, while the latter requires an efficient, secure and clean energy supply system. Due to the above-mentioned reasons, RES have become the focus of research. The relationship between energy consumption and economic growth has been analysed by many researchers, including Bhattacharya et al. (2016), Rezitis and Ahammad (2015), Blazejczak et al. (2014), Sebri and Ben-Salha (2014), Böhringer et al. (2013), Lehr et al. (2012), etc. RES are mainly analysed by researchers who focus on energy and sustainable development issues (Mckenzie et al., 2012, Shamsuzzoha et al., 2012, etc.). However, Klevas et al. (2018) note that there is still a lack of research that would provide answers to the questions about the economic background, would link energy policy to economic performance and would justify the benefits of using RES at the national level. RES are analysed in the context of employment and economic growth (Bilan et al. 2019, Pacesila et al., 2016, Bhattacharya et al. 2016, etc.). Despite the fact that most scientific studies substantiated the positive relationship between the use of RES and economic growth, there are studies that provide the opposite results (Bhattacharya et al., 2016, Bobinaitė et al., 2011, etc.). As a separate group of existing studies, those focusing on direct or indirect barriers to the development of the use of RES and RES promoting factors can be distinguished (Proença and Fortes, 2019, Wang et al., 2017, Quak et al., 2016, etc.). The transport sector uses relatively large amounts of fossil fuels compared to other sectors. Due to the negative environmental impact of the transport sector at micro and macro levels, the use of RES in this sector often becomes an object of scientific research. Despite the diversity of alternative fuels in the area of transport, scientists tend to focus on the following ones: biofuels (Navas-Anguita et al., 2019, Simionescu et al., 2017, etc.), electric energy (Navas-Anguita et al., 2019, Dominković et al., 2018, etc.) and hydrogen (Nocera and Cavallaro, 2016, Sorensen, 2012, etc.). It should be noted that, compared to other alternatives, the use of electricity in the area of transport has been researched in great detail.

The studies that focus on the measures promoting the use of electric vehicles can be categorised as a separate group of existing research. Due to the growing popularity of electric vehicle technologies in society and the issues of their environmental impact, financial mechanisms and promotion schemes have become a common object of research addressed by Hall et al. (2017), Hall and Lutsey (2017), Jin and Slowik (2017) and other authors. By the research method, the studies assessing electric vehicle promotion measures can be divided into three groups. The first group comprises the studies based on statistical analysis conducted by Javid and Nejat (2017), Sierzchula et al. (2014), etc. The second group comprises survey-based studies conducted by Krupa et al. (2014), Wang et al, (2017b), etc. The last group comprises the studies based on other methods employed for assessing electric vehicle promotion measures; the methods include an agent-based model, dynamic modelling and literature review. The research of this type was conducted by Sun et al. (2019), Adepetu et al. (2016), etc.

To reduce emissions in the transport sector, individual countries and cities are seeking to replace conventional vehicles with internal combustion engines with alternative technologies using RES. When developing policies to promote this transformation, it is necessary to research the impact of different promotive measures on the relevance of the entire promotion system. Naturally, all countries face the challenge of limited resources, which necessitates the need to determine how particular results can be achieved with the lowest possible material and time costs. In all countries, the majority of the road vehicle fleet consists of privately owned cars. Therefore, to assess the relevance of particular measures, it is necessary to take into account not only expert opinions and financial gains but also consumer preferences that can become a major barrier to the development of the use of new technologies. Summarising, it can be stated that despite the growing interest in the problems related to RES-driven vehicle promotion systems, scientific literature still lacks an empirically grounded assessment methodology that would allow to comprehensively evaluate promotive measures with consideration of consumer preferences as well as feasibility and efficiency aspects. Thus, the analysis of the scientific problem investigation level leads to the formulation of the following **scientific problem:** how to assess and compare the particular financial and non-financial promotive measures?

It should be noted that in Lithuania, at both national and municipal levels, the beginnings of electric vehicle promotion systems can be discerned, and the efforts to implement individual promotive measures can be observed. However, since neither individual measures nor their entirety has thus far been empirically researched, it can be stated that the fragment implementation of an electric vehicle promotion system lacks scientific substantiation.

Scientific research object – the measures promoting the use of RES-driven vehicles.

The purpose of the scientific research – to develop the model and methodology for the assessment of the measures promoting the use of RES consuming vehicles that would allow identifying the most relevant measures in terms of consumer preferences, implementation costs, efficiency, and feasibility.

Objectives:

1. To analyse the concept of RES in the context of sustainable economic development and to determine the possibilities of using renewable energy (RE) technologies in the field of transport.
2. To identify the determinants that promote the use of the RES consuming vehicles and analyse the prevailing market barriers.
3. To systematise the promotion measures and their assessment indicators.
4. To develop the model for assessment of the promotion measures and introduce the methodology of its implementation.
5. To evaluate electric vehicles promoting measures in the Lithuanian context.

6. With reference to the research results, to carry out a comparative assessment of electric vehicle promotion measures and present the conclusions and recommendations.

Research methods

To accomplish the research purpose and objectives, various research methods were employed. In the first and second sections, when analysing the concept and preconditions of the use of RES in the transport sector as well as the theoretical aspects of electric vehicle promotion measures and developing the theoretical substantiation of the evaluation model, comparative and systematic scientific literature analysis was conducted. To estimate the values and sizes of promotive measures, a preliminary consumer survey was conducted and the method of expert evaluation was employed. The method of expert evaluation was also employed for estimating the weights of the promotive measure feasibility, efficiency and evaluation criteria. Consumer preferences were identified by employing discrete choice models, Probit and Logit regressions. Simple Additive Weighting (SAW) method was employed for multi-criteria assessment of the indicators and the conduct of the comparative analysis.

Scientific novelty of the research

- the measures promoting the use of RES-driven vehicles have been systematised by administrative levels, and the main criteria and indicators for assessing these measures have been identified.
- the practice of assessing electric vehicle promotion measures has been summarised; based on the methodology selected and on how the data analysed in the research was obtained, different methods for evaluating electric vehicle promotion measures have been systematised.
- After summarising the results of the analysed theoretical and empirical research, a new original model for assessing the measures that promote the use of RES consuming vehicles has been developed; the model illustrates a systematic approach to evaluating RES consuming vehicle promotion measures. The assessment model comprises four parts that are combined to provide a comprehensive assessment of the promotion measures: consumer preference identification, aggregation of the promotion measure implementation costs, estimation of the promotion measure feasibility and efficiency indicators. This model can be applied for assessing state or municipality issued promotion measures; the research can also incorporate hypothetical promotion measures.
- When applying the model, electric vehicle promotion measures were for the first time assessed in the context of Lithuania.

Research limitations

Even in countries where the penetration of electric cars in the passenger car market is relatively low, consumers have a basic understanding of electric cars. This is confirmed by the results of the preliminary consumer survey conducted in the empirical part of this dissertation. Since hydrogen and biofuel technologies are not so popular (and known) among consumers, the development of the model for assessing the measures that promote the use of RES-driven vehicles in the context of hydrogen and biofuel driven cars can be hampered by a high probability of error when conducting a consumer preference survey.

The model developed for assessing RES-driven vehicle promotion measures is best suited to the countries that have relatively little experience in the area of electric vehicle promotion policies and have not achieved any significant results in this area. Based on the model developed, the efficiency and feasibility of particular financial and non-financial promotive measures, consumer choice and implementation costs can be assessed. The assessment is performed by applying expert evaluation, conducting a consumer preference survey and estimating measure implementation costs, however, neither the changes in the car market have been assessed nor market dynamics has been analysed. The countries (or cities) with a breakthrough in the area of the use of RES-driven vehicles could have the model proposed for assessing the promotive measures supplemented with another component, i.e. assessment of the dynamics of the clean car market. The application of this model, however, requires statistical data for at least several years that would suit this type of assessment.

Preparation of the dissertation was started in 2015, the empirical research (preliminary consumer survey, expert evaluation, consumer preference survey, electric vehicle development scenario forecasting) was conducted in 2018, the results of the research were summarised at the beginning of 2019. A part of the empirical research (electric vehicle development scenario forecasting) is related to the forecast for 2020, i.e. the year when this dissertation is defended. The forecast of the size of the electric car market and the sales in this market was completed in order to be able to estimate the costs of implementing a particular promotive measure. It should be noted that at the time when the dissertation was completed, no generalised statistical data on either the electric car market development or the costs of implementing particular promotive measures in 2020 was available. Therefore, the empirical research employed forecast-based data.

Possible practical application of the results

The barriers to the development of the use of RES in the transport sector along with RES-driven vehicle market development determinants were systematised, including the analysis of the impact of governmental promotion policies. The researched examples of the implementation of particular electric vehicle promotion measures and systems reveal how national governmental schemes supplemented with local municipal measures can contribute to creating a favourable environment for the use of electric cars and reduce the barriers to development.

The systematisation of electric vehicle promotion measures and their classification by administrative levels summarises the most common roles and activity areas of different governance levels (national and municipal). Such a summary can help authorised decision-making institutions to understand the electric vehicle promotion directions and implementation alternatives.

The model developed for assessing RES-driven vehicle promotion measures covers the main indicators that determine the relevance of particular measures. Based on this model, the efficiency and feasibility of particular financial and non-financial promotive measures, consumer choice and implementation costs can be assessed. The model also allows exploring the potential of RES-driven vehicle promotion measures in individual countries and form the sets of most appropriate measures when selecting alternatives. By applying this methodology, national governments and municipalities can plan and develop the entirety of RES-driven vehicle promotion systems.

Structure and volume of the dissertation

The volume of the dissertation excluding appendixes is 120 pages, 17 figures and 51 tables. 274 references were used. The structure of the dissertation comprises 3 main chapters reflecting the logical structure of the work (see Fig. 1). Chapter 1 "The Concept and Preconditions of the Use of RE Sources in the Transport Area" discusses the concept of RES in the context of a sustainable economy and analyses the use of three RES-based alternatives (hydrogen, biofuels and electric energy) in the transport sector. This section also discusses barriers to the development of the use of RES in the transport sector and market development determinants. In Chapter 2, titled "Development of the Model for Assessing RES-driven Vehicle Promotion Measures", RES-based transport fuel alternatives are compared, electric vehicle promotion measures are systematised and the model for assessing the promotive measures is developed. Chapter 3 presents the research methodology employed for assessing RES-driven vehicle promotion measures. It also provides a comprehensive report on the research consisting of the preliminary consumer survey, expert evaluation, consumer preference survey, estimation of promotive measure implementation costs and multi-criteria evaluation.

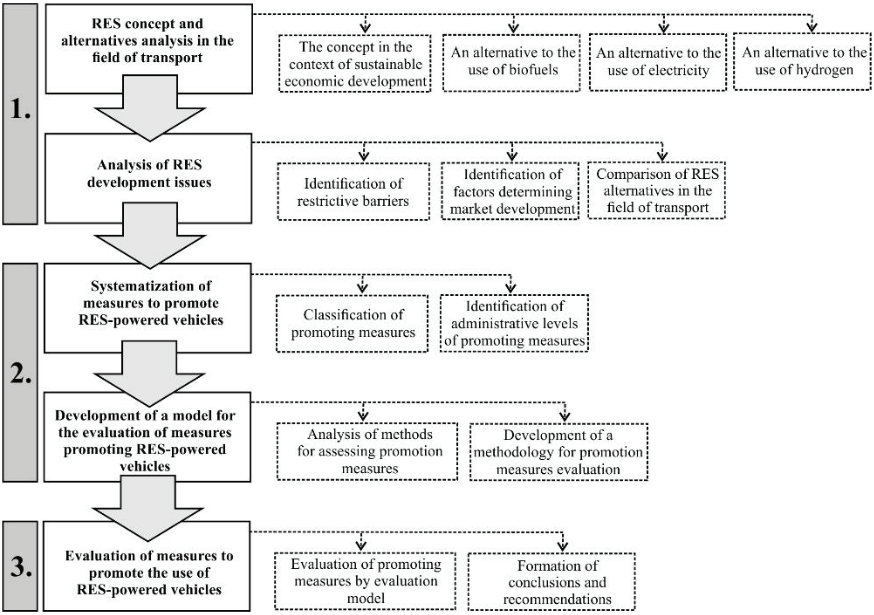

Figure 1. The logical structure of the dissertation (compiled by the author)

1. THE CONCEPT AND PRECONDITIONS OF THE USE OF RENEWABLE ENERGY SOURCES IN TRANSPORT SECTOR

1.1. The concept of RES in the context of sustainable economic development

Sustainable economic development is considered to be an integral part of the general concept of sustainable development along with other components, such as social and environmental dimensions. In this concept, economics is seen as an equivalent component, the sustainability of which presupposes the improvement of environmental conditions and social justice (Urmee and Md, 2016, Spangenberg, 2005, Barbier, 1987). The word 'sustainability' is usually derived from the term 'sustainable development'. This modern concept of sustainability was introduced to the world by the Brundtland Commission in 1987. Since then, the use of the concept of sustainable development as well as the number of sustainability studies has grown exponentially (Urmee and Md, 2016).

The global energy market is characterised by a steady increase in energy demand, and all long-term scenarios suggest that energy consumption is going to rise, even if market prices are high. Global energy demand is projected to increase by 35 per cent in 2030 compared to 2010 levels (Simionescu et al., 2017). The global energy demand growth in the medium and long terms is mainly determined by economic and population growth in developing countries (Miškinis et al., 2014). The main cause of carbon dioxide (CO_2) emissions into the atmosphere is fossil fuels used to produce electric energy and heat; CO_2 emissions cause an enhanced greenhouse effect called global warming. Among the GHG that contribute to global warming, almost three-quarters of emissions come from CO_2. In the last century, the use of fossil fuels has led to the highest CO_2 emissions, reaching unprecedented records (Pacesila et al., 2016).

In recent decades, the global focus on sustainable development has accelerated the use of RES. In response to these and many other related factors, states around the world are embarking on fundamental transformations of their energy systems. In doing so, these early pioneers demonstrate that a new energy paradigm is possible and the transition to a RE society can be positive in economic, social and environmental terms (Pacesila et al., 2016, Couture and Leidreiter, 2014). RES development can benefit local communities from the following perspectives: contributing to the creation of new jobs, increasing local tax revenues linked to energy sales, and reducing the cost of energy to consumers (Akella et al., 2009).

1.2. The use of RES-based alternatives in the transport sector

Based on the information provided in the studies conducted by Navas-Anguita et al. (2019), Dominković et al., (2018), IRENA (2016), IEA-RETD (2015), Ajanovic (2013), etc., this dissertation focuses on electric energy, hydrogen, and biofuels.

Biofuels. Biofuels are a RES, produced from natural (biological) materials, that can be used as a substitute for petroleum fuels. This type of fuel has become an attractive alternative not only because of the environmental benefits. The use of biofuels is promoted by the determinants that are related to energy security, environmental challenges and socio-economic issues that are relevant to rural sectors in many countries (Demirbas, 2009). Biofuels have another important advantage over fossil fuels: they are convenient to store, which can reduce dependence on imports due to the local production (Simionescu et al., 2017). Because of the unique characteristics of biofuels, their market integration can be gradual. Low-concentration mixtures can be added to the existing transport system using conventional energy infrastructure and vehicles (IEA-RETD, 2015).

Electric energy. Although electric vehicles can increase energy efficiency, contribute to diminishing the dependence on petroleum imports and reduce CO_2 emissions, there are a number of barriers to the sustainable development of the use of electric vehicles (Kley et al., 2010). The perspective of electric vehicles is closely related to the development of energy storage technologies (Navas-Anguita et al., 2019). When it comes to electric vehicles, there are many discussions about whether they can be classified as environmentally friendly. Fully electric vehicles can reduce local environmental impacts only if electric energy is produced without carbon sources (DeSimio et al., 2013). However, if batteries are charged with the electric energy produced from petroleum or carbon, CO_2 emissions can sometimes be higher than those produced by conventional petrol vehicles (Dominković et al., 2018).

Hydrogen. This type of fuel can be produced from all primary energy sources and is a universal energy carrier (Sherry et al., 2010). Hydrogen is best suited for the use in fuel cells with twice the efficiency of combustion engines. Hydrogen is also used as a production feedstock for various types of liquid fuels that can be blended with or replace conventional gasoline or diesel (Milčius, 2006). Storing hydrogen fuel for transport needs remains a major challenge (Larminie and Dicks, 2003). At the same time, it provides great potential to move to more modern filling options, e.g. by using very high pressure or liquid hydrogen. Nevertheless, legislation in most countries currently restricts the development of the clean hydrogen industry (IEA, 2019).

1.3. Barriers affecting the development of the use of renewable energy

According to Rogers (2013), investing in new technologies is associated with unprecedented benefits, so tested and clearly understood innovation means less uncertainty for potential consumers. Thus, it can be stated that the market penetration of electric vehicles is strongly related to how potential consumers understand their benefits and know the advantages and aspects of use. In other words, growing knowledge and experience contribute to product consumption growth (Eseonu and Egbue, 2014). The scientific literature contains various qualifications of the barriers to clean cars. First, these are general barriers linked to new technologies: lack of market understanding inherent to early-stage consumers, high initial costs and low-risk tolerance (Diamond, 2009). Banister (2005) proposed the classification of the barriers into seven categories, including:

- Financial barriers, incorporating additional costs for consumers, capital and operating costs for investors, and limited public finance resources;
- Technical and commercial barriers that limit market access and commercial feasibility;
- Institutional and administrative barriers;
- Public understanding and acceptance;
- Legal and regulatory barriers;
- Political failures and unintended results;
- Physical barriers.

In the opinion of the author of this dissertation, when analysing the specifics of electric cars, it is expedient to divide the barriers into three groups: technical and infrastructural barriers, economic barriers, and human-related barriers.

1.4. Determinants of the use of RES in the transport sector

According to Shamsuzzoha et al. (2012), the main determinants affecting the development of the use of RES are as follows: economic factors, sustainability, pollution control, energy price, and impact on health. Concerns about the volatility of the price of petroleum, dependence on foreign energy sources and environmental effects of CO_2 emissions are the main factors driving the interest in RES. The development of governmental policies, such as tax credits for RE production, rebates for the RES installations and RE standard and certificate market creation, have been an important constituent in promoting RES as promising energy and environmental protection component in different countries (Bowden and Payne, 2009).

1.5. Comparison of RES-based transport fuel alternatives

Environmental assessment of the alternatives. Comparing three alternatives in terms of environmental impact, it can be stated that electric energy and hydrogen driven vehicles have the highest potential for reducing pollution (CE Delft, 2011). In terms of lower engine noise, these two alternatives are also considered superior to biofuels (IEA-RETD, 2015). Pure electric cars are particularly suitable for urban use as they have to cover short distances (DeSimio et al., 2013). Semi-electric vehicles (e.g. rechargeable hybrid electric cars) possess a significant emission benefit, but only when driving in electric mode (CE Delft, TNO, 2012). Biofuels can also reduce GHG emissions, but the emissions are highly dependent on the type and feedstock used, and on whether the indefinite effects of the change in the indirect use of land are considered. When this change is considered, some biofuels (e.g. from waste and residues or sugar cane) can save a lot of emissions, while biofuels from crops can even raise net GHG emissions (IEA-RETD, 2015, Viesturs and Melece, 2014).

Economic assessment of the alternatives. Offer et al. (2010) analysed two transport fuel alternatives: electric energy and hydrogen. Their study focused on the impact of the alternatives on the sustainability of transport systems by employing a quantitative comparative analysis of the indicators throughout their entire lifecycle. In terms of capital costs, the two above-mentioned alternatives are significantly more expensive than conventional vehicles with internal combustion engines. High costs of building an entirely new infrastructure, as well as lower efficiency compared to electric vehicles can become too much of a burden for the development of a hydrogen-powered transport system (Dominković et al., 2018). Biofuels possess many consumption benefits, especially given the current state of the market and technological advancement. First, the costs of producing biofuels are much lower than that of electric energy or hydrogen, but still higher than that of fossil fuels (Čuček et al., 2014). Other benefits of biofuels are related to the impact on GDP (especially in rural areas), trade balance and employment, primarily in the agricultural sector, and also in vehicle production (IEA-RETD, 2015). This attitude is supported by Sobrino et al. (2010) who argue that the development of the use of biofuels raises the demand for agricultural commodities and thus can raise the income earned and the prices charged by agricultural producers (Sobrino et al., 2010).

Assessment of the alternative use development in the transport sector. Summarising the findings provided by Dominković et al. (2018), Daina et al. (2017), Nocera and Cavallaro (2016), IEA-RETD (2015), Sperling (2014), etc., it can be stated that in the context of the long-term perspective, electric energy has the greatest potential for development, and changes in the market depend on constantly improving batteries. In addition, electric cars offer the greatest benefits in terms of noise reduction and environmental protection, but only in case the production of electric energy is based on RES. The second alternative is hydrogen, but this type of fuel is currently facing technological and investment difficulties in installing the infrastructure that is needed to fill cars. The third alternative is biofuels which, while provide a gradual transition, offer significantly smaller advantages in terms of environmental performance than the other two alternatives. Based on this summary, in sections II and III of this dissertation, the author is going to focus on electric energy as an alternative from the total spectrum of RES available in the transport sector.

2. DEVELOPMENT OF THE MODEL FOR ASSESSING RES-DRIVEN VEHICLE PROMOTION MEASURES

2.1. Typology and grouping of electric vehicle promotion measures

Clean transport promotion measures can be differentiated by their nature. The simplest method, commonly found in scientific literature, is categorising the measures as financial and non-financial. There are also other options for segmentation. For instance, IEA/OECD (2016) distinguish three groups which are collectively called market development policies:

1. Regulatory measures (e.g. pollution regulations and fuel economy standards);
2. Financial leverage (e.g. differentiated vehicle taxation based on fuel economy or GHG emissions per kilometre and /or directly targeted at electric cars);
3. Other measures (e.g. exemptions from parking fees and charges, application of access restrictions).

Publications describe various disaggregation levels based on which electric vehicle promotion measures are classified by their nature, size or administrative level. IEA-RETD (2015) proposes segmentation into administrative levels and separation of three following dimensions: cars, energy infrastructure and energy carriers. Such division of the measures is most relevant because it sets the boundaries of responsibility and presupposes the question of the use of resources. All three above-mentioned dimensions (cars, energy infrastructure and energy carriers) are significant and inseparable from the entire system of the use of clean cars (Mačiulis et al., 2018).

2.2. Levels of implementation of electric vehicles promoting measures

Depending on the nature and purpose of a promotive measure, an appropriate administrative level for decision making, implementation and monitoring of electric vehicle promotion measures can be identified. The summary of the most common initiatives is presented below.

Table 1. Most common administrative levels for implementing electric vehicle promotion policies and measures (compiled by the author)

Administrative levels	Policy framework	
	Focus areas	Examples of measures
National	• Setting national goals • Standardisations • Regulations	• Exemption from VAT • Direct subsidies for vehicle consumers • Tax credits • Financial support for car manufacturers • Incentives in energy taxation • Incentives in vehicle registration taxes

	• Deployment of charging infrastructures • Financial initiatives • Marketing	• Annual vehicle tax reduction • Initiatives for public charging infrastructure • Regulation of charging infrastructure • Fuel regulation incentives • Cap and trade system • Green public procurement • Obligation for new constructions • R&D stimulation • Sales mandates • Promotion campaigns
Local	• Setting local goals • Marketing • Parking policy • Traffic management tools • Urban access restrictions • Fleets upgrade • Private and public partnerships • Deployment of charging infrastructures • Financial initiatives	• Initiatives for home charging infrastructure • Incentives for business charging infrastructure • Initiatives for public charging infrastructure • Regulation of charging infrastructures • Obligation for new constructions • Fleet tests and demonstration programmes • Incentives in parking policies • Bus lane incentives • Road pricing incentives • Congestion taxes • Low-emission zone incentives • Route/Access restrictions • Promotion campaigns • Consulting

2.3. The methodologies for assessing electric vehicle promotion measures

The methodologies proposed for assessing electric vehicle promotion measures can be grouped according to how the data analysed in the research are obtained. Mačiulis et al. (2019) distinguished three generalised groups:

1. The research based on market statistical analysis;
2. Survey-based research;
3. Other methods of researching promotion measures.

The research based on market statistical analysis. Sierzchula et al. (2014) were the first to use regression methods to research the impact of governmental promotive policies on the empirical data of the electric car market. They analysed the data of 30 countries for 2012 by employing regression analysis. Regression analysis was also employed by Li et al. (2017) and Diamond (2009). Other common methods include stepwise linear regression, hedonic regression and panel data.

Survey-based research. This group of research in scientific literature is usually based on willingness-to-pay methods. The main methods to assess consumers' willingness to pay are identified and stated preferences. The methods of identified preferences aim to use market-based monetary benefit estimates obtained by employing travel cost and hedonistic pricing methods (Štreimikienė and註Ališauskaitė-Šeškienė, 2014) as well as auctions, field and laboratory experiments (Breidert et al., 2006). Unlike the method of stated preferences, the method of identified preferences is not common in the context of electric vehicle promotion policy analysis.

Other methods of researching promotion measures. One of the methods to assess electric vehicle promotion measures and their implementation is a scientific literature review. This method was employed by Ahman (2006), Green et al. (2014), DeShazo (2016), Zhang and Bai (2017), Hardman et al., 2017, Zhang et al. (2017), etc. Promotion measures can also be researched by applying a multi-layer perspective, dynamic simulation modelling, and an agent-based model.

2.4. Structural parts of the model proposed for assessing RES-driven vehicle promotion measures and interaction among them

Scientific literature proposes a number of unique models for analysing electric car promotion policies. Many scientists base their research models on a combination of several methods. Mačiulis et al. (2019) believe that the development of complex models helps to assess the efficiency of particular promotive measures with consideration of different aspects, allows to research the measures in different terms or compare the results obtained by applying different methods. In countries with long-term experiences in developing clean car promotion policies, particular measures can be assessed by analysing the statistical information linked to the changes in the clean car market. This line of research is not, however, appropriate for the countries without any or only with the beginnings of comprehensive clean car promotion policies. This is due to the limited statistical information required for this type of research. For this reason, to develop a reliable assessment model, the author of this dissertation considers it necessary to include the analysis of the hypothetical promotion measures that are not currently used in the country under consideration, but can have a significant impact on the development of the use of clean cars. The sets of existing and hypothetical measures can be employed when assessing consumer preferences in terms of selecting one of the ready-to-pay methodologies (Helveston et al. 2015, Lee et al., 2016). The values of the hypothetical measures can be estimated by surveying customers or experts (Murphy et al., 2005, Lieven, 2015).

Nevertheless, the relevance of a promotion system is not limited to consumer preferences. According to Law (2009), effectiveness is measured by considering how successfully the system helps to achieve the desired results. Mačiulis et al. (2019) note that in order to comprehensively assess the relevance of particular promotive measures, a complex assessment must be invoked, i.e.

different methods need to be integrated into a single model. After analysing a number of studies focused on assessing various clean car promotion measures, it can be stated that literature does not provide any unequivocal agreement on what independent variables must be included in an assessment model as the development of the model depends on the research purpose, theoretical access, presumptions and data availability. The author of this dissertation is of the opinion that it is expedient to supplement the consumer preference research with the feasibility, efficiency and costs analysis which would reveal how much implementation of a particular measure (whether existing or hypothetical) costs. Measure feasibility indicates how difficult it is to implement a particular measure at political and administrative levels (Bakker and Trip, 2013). Measure efficiency assessment indicates which of the measures can more significantly contribute to the development of the use of electric vehicles (Zhou et al., 2016). Both feasibility and efficiency can be researched on the basis of a qualitative survey by involving experts (Bakker and Trip, 2013). After summarising the results of the previous theoretical and empirical studies, a model illustrating the author's of this dissertation systematic approach to the assessment of RES-driven vehicle promotion measures was developed. The model proposed for assessing RES-driven vehicle promotion measures is presented below. The parts that are recommended to be implemented through expert evaluation are indicated with dotted lines.

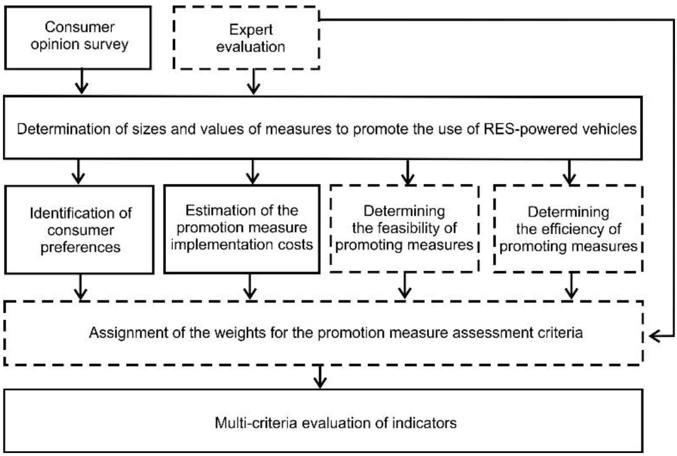

Figure 2. The model proposed for assessing RES-driven vehicle promotion measures (compiled by the author)

Based on this model and possessing the consumer preference survey and the feasibility, efficiency and costs analysis results, the weights of the assessment criteria need to be estimated for all of the four blocks mentioned above. These weights are recommended to be evaluated by the experts who can more objectively assess the environment for clean car promotion in an individual country or city and indicate various development factors and barriers. The proposed model is completed with a multi-criteria evaluation that summarises the results of all research blocks with consideration of the assessment criteria weights. The model reflects at least some of the promotion measure assessment methods analysed in the theoretical part of the dissertation. Nevertheless, unlike the models in most previous studies, this model covers the components that were previously analysed in different contexts (countries or cities) but not aggregated into a general assessment model. The assessment model highlights four parts that are aggregated for a comprehensive assessment of particular promotion measures: consumer preference identification, summing up a measure implementation costs, estimation of the measure feasibility and efficiency indicators. This model is proposed for assessing the promotion measures employed by a state or municipality; hypothetical promotion measures can also be included in the research.

3. EMPIRICAL RESEARCH OF THE RES-DRIVEN VEHICLES BY THE EXAMPLE OF ELECTRIC VEHICLES

3.1. Research methodology

Based on the defined purpose and objectives, the empirical research was conducted. The process and methodology of the empirical research as well as the relationship between the research parts and the model proposed for assessing RES-driven vehicle promotion measures are detailed below.

Table 2. Structural parts of the empirical research (compiled by the author)

First part	Estimation of the volumes and values of the electric vehicle promotion measures	Completed based on the preliminary consumer survey and expert evaluation. In this section, the values of the hypothetical car tax, VAT tariff and subsidy are estimated.
Second part	Estimation of the weights of the promotion measure feasibility, efficiency and evaluation criteria	This part is based on the method of expert evaluation. By employing the method of questionnaire survey for data collection, business representatives, scientists, representatives of non-governmental organisations and public authorities were surveyed. The author is this dissertation selected the experts with consideration of their professional specifics, competences and the relationship between an institution or organisation represented by a respondent and the issues of developing the use of electric cars and their infrastructure in different sectors. Consistency of the expert opinions and statistically significant differences were evaluated by employing Kendall's coefficient of concordance and the Kruskal-Wallis test.

Third part	Consumer preference identification	In this part of the research, discrete choice models were selected; the models were estimated by employing Probit and Logit regressions. The suitability of the logistic model for the research data was verified by using the classification table, maximum likelihood chi-square statistics, Hosmer-Lemeshow chi-square statistics, Wald test for regressors and pseudo-coefficients of determination. The suitability of the Probit regression for the research data was verified by employing Pearson's chi-square and regressor Z statistics.
Fourth part	Estimation of the promotion measure implementation costs	This part of the research focused on estimating how much implementation of a particular measure costs to the state (or a municipality) budget per year. Since a substantial part of the promotion measures is inseparable from the size of the electric car fleet and the volumes of sales of these cars in the country, the author of this dissertation projected three electric car development scenarios.
Fifth part	Multicriteria evaluation of the indicators	In this part of the research, the method of Simple Additive Weighting (SAW), which integrated all the criteria and weights of the dissertation research into a single quantity, was selected. The results are presented based on Probit and Logit regressions as well as by three different electric car development scenarios.

3.2. Research results on the relevance of electric vehicle promotion measures

3.2.1. Estimation of the volumes and values of electric vehicle promotion measures

The online questionnaire survey was being conducted over the period from 21 July 2018 to 14 October 2018. The online survey involved 292 respondents. The research employed a quantitative data collection method – a questionnaire survey. This part of the research is based on a random probabilistic sample. The research error rate is equal to 3 per cent, and the value of statistical reliability p is equal to 0.95. The aim of this survey was to estimate the volumes and values of electric vehicle promotion measures. The sample size was estimated by applying the Paniotto formula. A reliable sample required the inclusion of 256 respondents; the questionnaire was filled by 36 respondents more.

This part of the research helped to estimate the values of the hypothetical car tax, VAT tariff and subsidy. By integrating the results of the preliminary consumer survey and expert evaluation, data quartiles were found. Approximately every fourth respondent of the preliminary consumer survey (25.3 per cent) is in favour of a subsidy amounting to EUR 4,000 or less, while 30.6 per cent of the expert evaluation participants are in favour of a subsidy amounting to EUR 5,000 or less. A EUR 8,000 or less subsidy is supported by nearly half (52.8 per cent) of the expert evaluation participants, while a EUR 9,000 or less subsidy is supported by 56.2 per cent of the preliminary consumer survey participants. A subsidy not higher than EUR 12,000 seems sufficient for more than 75 per cent of all respondents (78.8 per cent of the preliminary consumer survey participants and 77.8 per cent of the expert evaluation participants, respectively).

To maintain the balance between the minimum subsidy and the maximum discount to VAT tariff, it is necessary to include a subsidy in the amount of EUR 0 into the consumer preference survey. Thus, the further parts of the research will contain an evaluation of the following subsidies: EUR 0; EUR 4,000; EUR 8,000; and EUR 12,000. The author of the dissertation points out that the above-mentioned options differ proportionally, i.e. by EUR 4,000; therefore, the same principle will be followed when defining VAT tariff options. At the time of the research, goods and services in Lithuania were taxed at the rate of 21 per cent. According to the majority of the expert evaluation and preliminary consumer survey participants, the state should apply a 0 per cent tariff when purchasing an electric car. This was indicated by 47.2 per cent of the expert evaluation and 54.1 per cent of the preliminary consumer survey participants, respectively. To maintain the balance among the options, the author of the dissertation selected dividing the VAT tariff into four following options: 21 per cent, 14 per cent, 7 per cent, and 0 per cent.

At the time of the research, no annual car tax was established in Lithuania, although there were many debates on this issue at the political level. Thus, this research proposes a hypothetical annual tax which was estimated based on the expert evaluation and preliminary consumer survey results. Electric car owners would be exempted EUR 10–30 per month tax (sufficient to affect the development of the use of electric cars). This attitude was expressed by 28.1 per cent of the preliminary consumer survey and 38.89 per cent of the expert evaluation participants, respectively. Considering the above-mentioned results, this research employs the tax average of EUR 20 a month, most commonly indicated in both surveys.

3.2.2. Estimation of the weights of the promotion measure feasibility, efficiency and evaluation criteria

Over the period from August 10 to October 14 2018, the author of this dissertation was conducting the expert survey based on the pre-designed questionnaire. The anonymous questionnaire was delivered by e-mail to 42 addressees; the data was provided by 36 respondents. The questionnaire consisted of an introduction and four question groups. The fourth part of the expert evaluation sought to find out how important each of the following criteria is when assessing electric vehicle promotion measures:

I. Consumer opinions about a particular promotion measure (how a consumer's decision to purchase an electric car is affected by a particular measure);

II. Promotion measure implementation costs (how much implementation of a particular measure costs);
III. Promotion measure feasibility (how difficult/easy it is to implement a particular measure at the political and administrative level);
IV. Promotion measure efficiency (what effect implementation of a particular measure can have on the sales of electric cars).

The majority of the survey participants (77.8 per cent of the respondents) represent public authorities and business organisations. 75 per cent of the respondents possess more than 10 years of work experience. The questionnaire asked to assess whether it is easy or difficult to implement a particular electric vehicle promotion measure in Lithuania at the political and administrative levels (1 point – it is very difficult to implement, 10 points – it is very easy to implement). The experts were also asked to assess what effects on the sales of electric cars in Lithuania could be observed in case a particular promotion measure is implemented, i.e. they were asked to indicate how efficient a particular promotion measure could be (1 point – completely inefficient, 10 points – very efficient). Summary of the promotion measure feasibility and efficiency assessments is presented below with the highest indicators marked in green, and the lowest – in pink.

Table 3. Promotion measure feasibility and efficiency indicators identified on the basis of the expert survey results (compiled by the author)

Promoting measures	Feasibility	Efficiency
VAT relief and subsidy for purchase	5.88	8.24
Road tax exemption	4.83	6.78
Free city centre parking	8.92	7.14
Free use of bus/fast lanes	8.72	6.67
Free charging at public parking	7.58	6.92
Financing the charging station near the home (in the garage or in the yard)	5.81	7.11
Financing of charging station installation near the workplace	6.47	7.08

3.2.3. Results of the consumer preference survey

In this part, consumer preferences were researched by employing a questionnaire survey which was being conducted over the period November–December 2018. The research employed a quantitative data collection method – a questionnaire survey. This part of the research is based on a random probabilistic sample. The research error rate is equal to 3 per cent, and the value of statistical reliability is equal to 0.95. The number of respondents amounted to 104 people; most of them live in the three largest Lithuanian cities. As proposed by Lieven (2015), 12 alternative sets were formed; each set contained three alternatives – A, B and C – available to a respondent. Alternatives B and C possessed different attributes which, in this case, represented particular electric vehicle promotion measures. The total amount of the attributes (in all sets) was the same. The results of the binary logistic regression are presented below.

Table 4. Estimates of the logistic model parameters (compiled by the author)

Promoting measures	B	S.E.	Wald statistics	p	Exp(B)	95% C.I. for exp(B)	
						Lower	Upper
0% VAT and EUR 4,000 sub.	0.539	0.218	6.093	0.014	1.714	1.117	2.628
7% VAT and EUR 8,000 sub.	0.860	0.161	28.676	0.000	2.362	1.725	3.236
14% VAT and EUR 12,000 sub.	0.879	0.201	19.146	0.000	2.408	1.624	3.569
Road tax exemption	0.224	0.099	5.073	0.024	1.251	1.030	1.521
Free city centre parking	0.737	0.097	57.696	0.000	2.089	1.727	2.526
Free use of bus/fast lanes	-0.251	0.094	7.104	0.008	0.778	0.647	0.936
Free charging at public parking	0.313	0.105	8.840	0.003	1.367	1.112	1.680
Financing the charging station installation near the home	1.634	0.111	216.767	0.000	5.124	4.122	6.368
Financing of charging station installation near the workplace	0.862	0.103	70.408	0.000	2.368	1.936	2.895
Constant	-2.685	0.112	578.216	0.000	0.068		

The data collected during the surveys were also analysed by employing a probit model. The results of the probit regression are presented below.

Table 5. Estimates of the Probit model parameters (compiled by the author)

Promoting measures	Parameters	S.E.	Z	p	95% C.I.	
					Lower	Upper
0% VAT and EUR 4,000 sub.	0.313	0.131	2.391	0.017	0.056	0.570
7% VAT and EUR 8,000 sub.	0.490	0.093	5.297	0.000	0.309	0.671
14% VAT and EUR 12,000 sub.	0.501	0.119	4.212	0.000	0.268	0.734
Road tax exemption	0.119	0.060	1.998	0.046	0.002	0.237
Free city centre parking	0.433	0.059	7.383	0.000	0.318	0.547
Free use of bus/fast lanes	-0.173	0.056	-3.102	0.002	-0.283	-0.064
Free charging at public parking	0.172	0.063	2.722	0.006	0.048	0.296
Financing the charging station installation near the home	0.963	0.065	14.733	0.000	0.835	1.091
Financing of charging station installation near the workplace	0.504	0.062	8.159	0.000	0.383	0.625
Intercept	-1.545	0.055	-28.011	0.000	-1.600	-1.490

3.2.4. Estimation of the annual costs of implementing electric vehicle promotion measures

Some of the electric vehicle promotion measures are inseparable from the size of the electric vehicle fleet and sales volumes of these vehicles in the country. Thus, to estimate the annual costs of implementing electric vehicle promotion measures, it is necessary to project the market size and sales. A summary of the scenarios that will be employed for estimating electric vehicle promotion measure implementation costs is presented below.

Table 6. Projection of the electric vehicle fleet and annual sales in Lithuania by three scenarios (compiled by the author)

	Number of EV in Lithuania	**EV sales per year in Lithuania**
NP20 scenario (forecast)	3359	134
NP30 scenario (forecast)	33589	722
EV30@30 scenario (forecast)	58910	8713

A summary table representing the annual costs of implementing particular electric vehicle promotion measures is presented below.

Table 7. Annual costs of implementing electric vehicle promotion measures by three scenarios (compiled by the author)

	NP20 scenario, EUR	**NP30 scenario, EUR**	**EV30@30 scenario, EUR**
0% VAT and EUR 4,000 subsidy for purchase	1,767,693	9,524,437	114,939,648
7% VAT and EUR 8,000 subsidy for purchase	1,780,479	9,593,328	115,771,012
14% VAT and EUR 12,000 subsidy for purchase	1,962,239	10,572,664	127,589,506
Road tax exemption	806,160	8,061,360	14,138,400
Free city centre parking	2,266,205	22,661,378	39,744,613
Free use of bus/fast lanes	0	0	0
Free charging at public parking	2,771,175	27,710,925	48,600,750
Financing the charging station installation near the home	227,964	1,228,288	14,822,816
Financing of charging station installation near the workplace	289,237	1,558,431	18,806,940

3.2.5. Integration of the research results by applying the multicriteria evaluation method

In this part of the research, by employing the Simple Additive Weighting (SAW) method, the multicriteria evaluation was conducted. The latter method allowed to integrate all the criteria researched in this dissertation into a single indicator. Summarised results from all three parts of the research are presented in the tables below (most relevant promotion measures are marked in green, least relevant – in pink) that represent consumer preferences, measure feasibility, efficiency and annual implementation costs, respectively. The results also cover criteria weights that were estimated on the basis of the expert evaluation and different electric vehicle promotion scenarios. In the case of both Probit regression and Logit regression, the normalised values of the indicators after reestimation fall into the interval [0,1] (Pollescha and Dale 2016), i.e. the best value of the indicator is set to 1, while the worst value is set to 0. In this case, a higher indicator represents a more relevant promotion measure.

Table 8. Promotion measure relevance indicators based on Logit regression by three electric vehicle promotion scenarios (compiled by the author)

	Relevance indicator by NP20	**Relevance indicator by NP30**	**Relevance indicator by EV30@30**
0% VAT and EUR 4,000 subsidy for purchase	0.44	0.50	0.38
7% VAT and EUR 8,000 subsidy for purchase	0.47	0.54	0.41
14% VAT and EUR 12,000 subsidy for purchase	0.46	0.53	0.40
Road tax exemption	0.20	0.20	0.24
Free city centre parking	0.49	0.49	0.61
Free use of bus/fast lanes	0.52	0.52	0.52
Free charging at public parking	0.28	0.28	0.42
Financing the charging station installation near the home	0.58	0.59	0.57
Financing of charging station installation near the workplace	0.47	0.48	0.46

The table above indicates that based on consumer preferences estimated by applying the Logit model, car tax exemption for electric vehicles is the least relevant electric vehicle promotion measure.

Table 9. Promotion measure relevance indicators based on Probit regression by three electric vehicle promotion scenarios (compiled by the author)

	Relevance indicator by NP20	**Relevance indicator by NP30**	**Relevance indicator by EV30@30**
0% VAT and EUR 4,000 subsidy for purchase	0.49	0.55	0.43
7% VAT and EUR 8,000 subsidy for purchase	0.52	0.59	0.47
14% VAT and EUR 12,000 subsidy for purchase	0.51	0.58	0.45
Road tax exemption	0.23	0.23	0.27
Free city centre parking	0.55	0.55	0.66
Free use of bus/fast lanes	0.52	0.52	0.52
Free charging at public parking	0.32	0.32	0.46
Financing the charging station installation near the home	0.58	0.59	0.57
Financing of charging station installation near the workplace	0.53	0.54	0.52

Conclusions

1. Scientific literature analysis proposes that sustainable economic development is considered an integral part of the general concept of

sustainable development alongside social and environmental dimensions. This concept treats economics as an equivalent component, the sustainability of which contributes to the improvement of the environment and social justice. Sustainable development can be defined as the development of a society that contributes to the achievement of universal well-being for current and future generations by reconciling environmental, economic and social objectives without exceeding the limits of the effect on the environment. Growing population, urbanisation and the dynamics of economic indicators determine the constant growth of energy demand. Sustainable energy use, based on sustainable energy resources, provides a cleaner environment, improves public health, helps mitigate climatic changes, and increases energy security. In addition, most of the previous studies revealed that the development of the use of RES affects economic growth, job creation and technological advancement.

2. Barriers to the development of the use of RE can be divided into three groups: technical and infrastructural barriers, economic barriers, and human barriers that are related to consumer expectations and preferences, misconceptions about technologies and the use of RES in the transportation sector. Economic barriers are related to the high cost of purchasing clean vehicles, uncertainty about the resale value and a lack of understanding of cost savings throughout the entire vehicle life-cycle. In terms of technical and infrastructural barriers, the use of biofuels is relatively least constrained as this technology can be adapted to the existing infrastructure exploited by cars with internal combustion engines. The direct determinants that promote the use of RES in the transport sector can be divided into four groups: environmental determinants, financial determinants, consumer preferences and promotion policies. The environmental determinants are related not only to the direct reduction of CO2 emissions but also to pollution control and public health. The economic determinants primarily include energy and fuel prices as well as a vehicle's life-cycle costs. The third determinants group covers promotion policies, while the fourth group incorporates consumer preferences that relate to social and demographic differences, personal attitudes, tendencies and loyalty to a particular technology. Economic growth and changes in the labour market, affected by the development of the use of RES, can also be treated as indirect RES-development determinants.
3. Summarising the scientific insights, three following RES fuel alternatives in the transportation sector have been identified: biofuels, electricity and hydrogen. Comparing these three alternatives in terms of environmental impact, it can be noted that the potential for reducing pollution and noise

from electric and hydrogen vehicles is the highest. The above-mentioned fuel alternatives also lead the way in assessing the life-cycle costs of a vehicle. Biofuels, however, have an advantage in terms of vehicle acquisition/adaptation costs: low-concentration biofuels can power conventional internal combustion engines and use existing refuelling infrastructures. Moreover, biofuels, unlike other fuel alternatives, offer a gradual transition from fossil fuels to RES. In the context of a long-term perspective, electric vehicles have the greatest development potential, though in terms of market expansion rapid changes depend much on the technological characteristics and prices of batteries.

4. The researched examples regarding the promotion of the use of electric vehicles show that complementing the national policy framework with appropriate municipal measures can create a favourable environment for the use of electric vehicles and reduce barriers to market development. The actions of the national government are extremely important in the initial stage of promoting the use of electric vehicles in a state. It is necessary to set policy goals that are important not only for general planning and coordination but also as a signal to manufacturers and service providers of the need for electric vehicles in the future. In addition to setting goals, the main instruments are standardisation, which ensures interoperability of electric vehicles inside and outside the country, economic mechanisms and regulation. The main purpose of financial instruments is to reduce the price or operating costs of an electric vehicle so that there is no critical difference between the prices of electric vehicles compared to those of conventional cars. Being closer to consumers, local authorities can communicate productively with all social groups and collaborate with businesses, thus creating synergies not only by providing appropriate financial and non-financial support but also by arranging marketing campaigns and advisory service to spread the basic information needed to change consumer perceptions of RES alternatives in the transportation sector.
5. The methodologies employed for assessing the relevance of electric vehicle promotion measures can be attributed to three groups, depending on the research method. In the countries where clean car promotion policies have many years of experience, particular measures can be assessed by conducting statistical analysis. The methodologies of such studies consist of different types of regression. However, this line of research is not suitable for countries with no or only the beginnings of comprehensive promotion policies. Survey-based research on the relevance of electric vehicle promotion measures usually addresses consumers' willingness to pay. The main methods to assess consumers'

willingness to pay include identified and stated preferences. Discrete choice models are commonly found in the scientific literature that addresses the efficiency of promotion measures. Other methods employed for assessing the relevance of electric vehicle promotion measures are as follows: agent-based model, dynamic modelling, multi-layered perspective, innovation diffusion, and literature review. A substantial number of researchers combine several methods to form a comprehensive research model. The development of complex models helps to assess the relevance of promotion measures in different aspects, from different perspectives or compare the results obtained by employing different methodologies. A comprehensive assessment of the relevance of various promotion measures requires an integrated approach, which, in its turn, calls for combination of different methods into a single model.

6. Based on the analysed promotion practice, the model for assessing the relevance of electric vehicle promotion measures was conceptualised. This model also allows the analysis of hypothetical promotion measures that are not currently used in the country under consideration but may have a significant impact on the development of the use of electric vehicles. The model is based on the research of preferences. The consumer preference method is complemented by a feasibility, efficiency and cost analysis that indicates how much implementation of a particular measure (whether current or hypothetical) costs. After receiving the results of the consumer preference, feasibility, efficiency and cost analysis, the weight of the assessment criteria is estimated for all four research blocks. These weights are recommended to be set by experts who can more objectively assess electric vehicle promotion environment, development factors and barriers. The model proposed for assessing the relevance of electric vehicle promotion measures is completed by a multi-criteria evaluation which summarises the results of all research blocks by considering the weights of the assessment criteria.
7. The expert survey showed that free parking in the city centre (feasibility indicator 8.92) and free bus lane driving (8.72) lead in terms of feasibility which reflects how difficult it is to implement a measure at the political and administrative levels. This can be explained by the fact that the above-mentioned promotion measures are among the most popular in many countries, including Lithuania, and their implementation only requires a relevant municipal decision. What is more, the implementation of these measures does not require any additional administrative resources. Meanwhile, according to the experts, the exemption of electric vehicles from car tax demonstrates the lowest feasibility indicator (4.83). Experts indicate that VAT relief and subsidies with the estimated indicator of 8.24 is a strong leading determinant when assessing the

efficiency of electric vehicle promotion measures, whereas exemption of electric vehicles from the annual car tax (6.78) and free bus lane driving (6.67) are least efficient measures. The expert survey also provided the evaluations of the four dimensions of this research: the efficiency of a promotion measure was ranked the highest (0.314), while implementation costs – the lowest (5.53) weight.

8. The survey of consumer preferences revealed that consumers best appreciate financing for the installation of a charging station near their homes: adding this measure to the set increases the choice of the alternative by 5.12 times. Thus, despite the relatively low implementation costs, practical implementation of this measure is a good incentive that gives potential users a sense of convenience that they will always be able to charge their cars. Free bus lane driving was rated worst, which reduced the probability of choosing the alternative by 22.2 per cent (this is the only measure with a negative indicator). When assessing the ratio of VAT tax relief to direct subsidies, the greatest consumer favourability (increasing the choice of the alternative by 2.41 times) went to the option a 14 per cent VAT tariff to a EUR 12,000 subsidy, while the lowest consumer favourability went to the option a 0 per cent VAT tariff to a EUR 4,000 subsidy (increasing the choice of the alternative by 1.71 times). Considering the results of the consumer survey, it can be concluded that a direct subsidy is a much more tangible and easier-to-understand measure for consumers than a VAT relief which is relatively dependent on the price of a vehicle.

9. After calculating the annual implementation costs of all promotion measures (according to the NPS scenario for 2020 and 2030) and summarising the research results by employing the multi-criteria assessment method, the most relevant measures in the case of Lithuania were identified. According to the NPS 2020, electric vehicle fleet and sales development scenario, the top three of the most relevant measures include financing for the installation of a charging station near homes (0.58), free bus lane driving (0.52) and free parking in the city centre (0.49). According to the NPS 2030 development forecasts, financing for the installation of a charging station near homes (0.59) remains the leader in the relevance area, a 7 per cent VAT tariff to a EUR 8,000 subsidy ratio being the second, and a 14 per cent VAT tariff to a EUR 12,000 subsidy ratio – the third by their relevance. The findings propose that financing for the installation of a charging station near homes is the most relevant electric vehicle promotion measure in Lithuania. This measure is best appreciated by consumers, and may, therefore, have the greatest impact on the promotion of the use of electric vehicles in the country; in

addition, the costs for implementing this measure are relatively low. It should be noted that the results of the research singled out a clear outsider: exemption of electric vehicles from the annual car tax is least relevant to the measures examined (0.20). One of the reasons for this tendency is the negative public attitude towards the introduction of a new tax, which greatly complicates the implementation of this measure.

Recommendations

- Although this empirical research considers individual electric vehicle promotion measures, it should be noted that there is no single measure that would radically change the situation of a state or a city in the context of RES-driven vehicles. The final result is determined by a set of measures rather than an individual measure. Systematicity, strategic planning, and assessment of promotion measures by employing cost-benefit analysis are the prerequisites for the sustainable development of the RES-driven vehicle market.
- The model proposed for assessing the relevance of RES-driven vehicle promotion measures can help identify the most relevant measures in terms of consumer preference, feasibility, efficiency and implementation costs. Having identified the measures with the highest relevance indicators, public authorities can develop a set of most relevant measures that would combine financial and non-financial, traffic regulation and car charging related incentives. However, when developing a set of most relevant promotion measures, it is recommended not only to take into account the indicators of relevance but also to coordinate the actions with other groups of stakeholders, consider local contextuality, economic situation, cultural aspects and other determinants transforming the car market.
- This model proposed for assessing the relevance of RES-driven vehicle promotion measures is designed to research the countries that do not have or have only fragmented RES-driven promotion measures. For the countries with long-term experience in the area of promotion of electric vehicles or the countries where RES-driven vehicles make up a relatively large share of the car fleet, assessment of the relevance of RES-driven vehicles promotion measures should additionally include the statistical analysis of market changes. The model for assessing the relevance of promotion measures as well as the methodology used in this dissertation can also be improved in the above-mentioned direction.

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