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Cars with electric drive and external costs of road transport

***Abstract**. The paper describes external environmental costs of road transport. Article presents also an assessment of the so-called reduction. "Marginal costs" such as the cost of fuel emissions, noise and greenhouse gas emissions, by the introduction into service, in the real perspective of 2020, electric cars. European project eMAP is described, in which are involved the authors of this article. The project is related to the assessment of demand and supply, in perspective 2030, of electric cars: Bartery Electric Vehicles (BEV), Plug-in hybrid electric vehicles (PHEV), Range extended electric vehicles (REEV) and Fuel cell hydrogen vehicles (FCHV). The analysis will be carried out for the EU countries, in particular for Finland, Germany and Poland and eastern EU countries.*

***Streszczenie.** W artykule odniesiono się do środowiskowych kosztów zewnętrznych związanych z eksploatacją samochodów osobowych. Dokonano w tym zakresie oceny redukcji tzw. „kosztów uniknionych" tj. kosztów emisji zanieczyszczeń z paliw, hałasu I emisji gazów cieplarnianych przez wprowadzenie do eksploatacji, w realnej perspektywie 2020 roku, w kraju elektrycznych samochodów osobowych. Przedstawiono też Europejski Projekt eMAP w którego realizację zaangażowane są ze strony polskiej, autorzy niniejszego artykułu. Projekt związany jest z oceną popytu i podaży, w perspektywie 2030 roku, osobowych samochodów elektrycznych Bartery Electric Vehicles (BEV), Plug-in hybrid electric vehicles (PHEV), Range extended electric vehicles (REEV) and Fuel cell hydrogen vehicles (FCHV) w krajach UE, w tym w szczególności Finlandii, Niemczech i Polsce oraz w krajach wschodnich UE. **Samochody o napędzie elektrycznym a koszty zewnętrzne transportu samochodowego**.*

Słowa kluczowe: samochody elektryczne, koszty eksploatacji
Keywords: electrical cars, costs of transport

Introduction

Every human activity directed at the environment, both positive and negative, brings with it the need to cover the cost of protecting it, as well as environmental losses, mainly economic ones, caused by that activity. It is, admittedly, quite idealistic statement because present economic activity and that in the future is largely contradictory with this environmental ideology. It is well known [1] that the negative impact of economic activity on the environment often eludes the market self-regulation mechanisms. Indeed, if some elements of the ecosystem, as a free good, have a market price equal zero, the use of them, either by the consumer or by the manufacturer is an uncontrollable phenomenon. Therefore, the active policy is required from each state to protect the environment.

In general it can be said that human activity causes external effects, which are apparent in cases where different entities use common resources, for which ownership has not been clearly defined. Areas that bear the effects of transport activities outside the transport market can be classified into three groups [2]:
- non-renewable resources / natural environment and non-productive human capital,
- public production and consumption,
- private production and consumption.

The man's use of all elements of the ecosystems with the market price equal to zero, has certain negative social and economic consequences, whose end, according to marginalistic theory comes only when the marginal productivity and usability of these elements becomes negative. Polish example can be cited in which about 25% of the country territory is covered by the Natura 2000 program, which with the orthodox approach to the issue of environmental protection would mean that not a single kilometre of motorway or expressway should be built, so there will be no issue of final marginal costs.

In addition, one must admit that the costs of natural environment protection are nowadays quite fashionable issue, and its value increases at a time when the budgets of the Member States of the European Union begin to look for sources of financial incomes. This can be seen, in particular, in Polish realities, where the introduction of high fees in the e-toll system bears no reflection on the quality of a transport infrastructure. It must also be noted that the rates for the use of road infrastructure in Poland should be taking into account at the financial capabilities of the Polish road transport companies and the state financial system, and should not be related to the rates in other EU Member States, especially those from the Euro zone

One of the most important human economic activity adversely affecting the environment is transport, widely described in the White Papers of the European Union.

External costs of the road transport

In the expert literature produces various definitions of external costs. One must admit that some of them are very general and the others contain an attempt to formulate some concrete facts, which are to be the determinant of these external costs. It can also be said that the concept of external costs is very general and relates more to the philosophy of economic functioning of modern economic market than to a specific market.

Now, taking into account the company, one can say that acting in a particular economic environment, both closer and further, its financial situation is mainly due to the impact of external costs such as: fuel, tires, tolls and insurance, as well as large investments appearing in the development of energy industry. These instruments have a major impact on the cost of the company, and will also influence the financial possibilities of introducing electric vehicles.

Use of the term – "external costs of transport" can be, according to the authors, used only in the consideration of environmental issues at the macroeconomic level. These considerations, in the consequence, will be reflected in the costs of the enterprises because only they are capable of generating these costs, trying to cover them with their activities by one hundred percent. It seems, therefore, that in talking about the external costs in transport one should, taking into account the basic economic unit, which the enterprise is, distinguish two categories of costs:
- external costs resulting from the principles and rules of operation of businesses on the market,
- environmental protection costs associated with the operation of transport.

This division seems to be logical from the point of view of economic calculation in the enterprise. The functioning of enterprises is based on the influence of the external instruments and these are, as mentioned earlier, dependent on the impact of the closer or further surroundings. It's obvious. Less obvious becomes the impact of environmental protection costs on the level of costs in the company because this level is often dependent on the general mood of environmental protection activists in Europe.

Ecological intention to reduce greenhouse gas emissions in the European Union may be a good one, but insoluble in the short term. It should also be taken into account that not only road transport is the emitter of carbon dioxide, but also all the economic sectors and supply chains that use electricity from coal. It is easy to say that, to a large extent, I do not produce, electricity from coal and I just only import it. It is after all a kind of hypocrisy that has taken root in the European Commission. This raises the question, if one needs to reduce carbon emissions, who should bear the costs if it, the state or the enterprises? Of course, if these costs will be covered by the state, it will still have to pass these costs on the electricity users, because the state is an abstract being with the real budget. So if it is to be the companies, in what amount, and depending on what the indicators? It should be recalled that the Polish road transport companies already pay an environmental levy, whose rates are annually determined by the Marshal Offices. This problem will be completely resolved in the future when humanity will produce electricity from sources not emitting carbon dioxide.

A.Tylutki and J.Wronka [4] state that the external costs of transport are the costs connected with negative for the environment and human life consequences of the activities of transport: air, water and soil pollution, noise emissions, traffic accidents, ground reclaiming and road congestion. While D.M. Newberry classified external traffic effects as [5]:

- costs associated with traffic congestion,
- costs associated with the deterioration of the technical condition of roads,
- costs associated with environmental pollution,
- the external effects of accidents.

These external effects are particularly evident in urban areas, because of their network of road infrastructure are the most intensively used, and spatial density is the highest [6].

In general, one can say that the external transport costs are the costs that are and will be covered by the general public and businesses today and in the future. It is possible to single out here, first of all, the costs associated with the impact of transport, such as: air, soil, water pollution, noise, climate changes, accidents, reclaim of land, landscape degradation and the time lost in traffic jams / congestion /. These costs can generally be called the social costs of transport. These should also include all the expenses to be incurred on a modern energy infrastructure that allows the future use of electric cars.

External costs of transport can not be precisely calculated, and their levels can be the result of a consensus between businesses and economic policy of the state. It was only in 2011, that the research subject of the European Commission under the name COFRET (Carbon Footprint of Freight Transport) began, which is to show the impact of carbon dioxide emissions on the costs of supply chain and thus the companies [7]. The fact is that the transport does not pay the full social costs, including the environmental ones, which may lead to disturbances of the competition on the transport market. It should be noted though, that this is not the fault of transport. Well, at the moment when you the state became a participant in the market / excluding demand, supply and price / it takes on the responsibility for the effective functioning of the socio-economic market. This means that pushing environmental protection policy it must be responsible for the level of environmental costs in the situation when it shifts them entirely onto the companies. It can be assumed that as a result of distorted price mechanism, the absence of the full environmental protection costs / the transport does not fully bears these costs, but one has to take into account the fact that other sectors of the economy should be involved in covering these costs, if only the chemical one/.

External environmental costs of road transport

The air pollution is today one of the very serious environmental problems. Needless to say, that the emission of these pollutants adversely affects the quality and length of human life, disturbs the balance of ecosystems and causes also irreversible socio-economic consequences for the future of humanity. It is worth to mention here a worldwide debate on the issue of climate change in the Earth where it is assumed that, so-called, greenhouse effect of the climate change, is caused by carbon dioxide [8]. It is assumed that the main culprit of this emission - 25% is transport, out of which from 80 to 90% of the road transport. The EU policy on reducing exhausts emissions assumes that by the 2030, member states are expected to reduce carbon dioxide emissions by 20%, and by the 2050 - by (80 – 95)% [9].

In Poland, the biggest environmental problems creates the large scale of road transport activities. In the period 2000 - 2008 there was an increase of emissions from the road transport sector, classified as greenhouse gases, i.e. carbon dioxide, by 37.7%, methane by 23.1% and nitrous oxide emissions by 38.3% [10, 11].

In Poland, for example, the cost of the negative impact of transport on the environment represent approximately 28 - 29% of the external costs of transport, including [10, 11]:

- costs of air pollution, about 11%,
- costs of climate change, around 5%,
- costs of noise, about 11%,
- other environmental costs, about 1 - 2%.

The remaining 71% of the external costs of transport are the effects of human and material transport accidents [10], [11]. In total, it is estimated that the external transport costs are now equivalent to 6% of GDP and are not included in the accounting [10, 11].

It is estimated that the individual domestic motorism will have the largest share in the passenger transport, increasing demand in 2020 by 26 - 35% compared to 2009 and by 36 - 54% in 2030 [10, 11].

The European Commission’s vision of an integrated strategy of the European transport sector development until 2050, assumes a reduction, by at least 60% till the 2050 of the greenhouse gases emissions from the transport sector compared to 1990 level, through a transition to alternative and "green" propulsion technologies in vehicles and the creation of a Single (Uniform) European Transport Area. By 2030 the greenhouse gas emissions are to be reduced in this sector by about 20% compared with the level in 2008 [10, 11, 12].

The direction is and, as it can be assumed, will be the electrification of vehicles. It is expected that the share of electric vehicles equipped with rechargeable batteries in the new cars market, sales will increase from 1 - 2% in 2020 to 11 - 30% in 2030. For the hybrid vehicles with plug in charging, the share is expected to be about 2% in 2020 and 5 - 20% by the 2030 [10, 11]. According to the European Commission's strategy, by the 2030 there will be eliminated 50% of vehicles from the public transport with conventional internal combustion engines, and by 2050 they will not be present in European cities [10, 11]. In Poland, the above course of action in terms of electrification of vehicles, also seems to be inevitable.

To estimate the external environmental costs of road transport (passenger cars only) in Poland, by the 2020 it was assumed that in the absence of active government policy in relation to the road transport sector, in 2020 there will be, in operation, approximately 25,000 electric cars. This will be only 0.12% of the total number of passenger cars, forecast at 20.9 million [13]. The expected increase in the activity of government policy resulting from the provisions of the "EU White Paper" of 2011 [12], on the impact of the road transport sector on the environment, may contribute to an increase in the number of electric cars in the country, to about 100,000 in 2020.

The impending time to introduce stricter pollution charges for polluting the environment in 2020 may result in a sharp increase in the interest, as part of the transport policy, in the change of passenger cars fleet structure, particularly in terms of increasing the share of vehicles powered by alternative fuels, which would increase the number of electric vehicles to around 300,000.

It can be assumed that during the analysed period there will be drastically tightened rules on the technical condition of passenger cars in operation, which in turn will shorten the life time limit for the operating cars to, e.g. about 10 years old, and the eliminated cars, with environment-friendly government policy, can be replaced by electric cars.

With a projected increase of the national fleet of electric cars to 300,000, it justifies a claim that the benefits, known as "avoidable costs" will be reached, that would have occurred in the operation of passenger cars powered by internal combustion engines.

To perform a economic simulation accounting of the amount of "avoidable costs", the category of external costs not occurring in the case of electric passenger cars, was included, namely [14-17]:

- unit cost per of air pollution (PM (PM_{10} and $PM_{2.5}$) NO_x, NMVOC, SO_2, i.e. 0.0256 PLN / paskm,
- unit cost of noise, i.e. 0.0235 PLN / paskm,
- unit cost of climate change (cost of greenhouse gases emission, such as CO_2, CH_4 and N_2O) i.e. 0,0370 PLN/pas-km, which together makes up the environmental external costs in 2012.

It was assumed that in Polish realities of 2020 the electric passenger cars will replace mainly carriage conducted by passenger cars with combustion engines in urban and suburban traffic in the proportion of 50% -50% for every mentioned traffic area. The authors are of the opinion that in 2020 electric passenger cars will not be used in the significant numbers.

In order to calculate abovementioned unit costs for 2012 the output cost data was used, from the available literature, and first of all, [14-17], taking into account both the relationship of GDP for the EU-27 countries and Poland, as well as the annual inflation rates. It was assumed that:

- average annual passenger car mileage - 15 thousand km,
- average number of people travelling in a passenger car - 1.5.

With the above assumptions, the "avoidable costs" for 300,000 electric cars will reach in 2020 (adjusted for inflation) about 844 million PLN, it would be about 2% of the cost of air pollution, noise, climate change, caused by the passenger cars fleet in 2020. These are tangible sums for the national economy.

It should be born in mind that equally important, in the introduction of electric cars to be used, are intangible benefits associated with improving the health of urban residents, where the concentrations of both pollutants and noise intensity is relatively high. It can be estimated that the spending on health care related to a group of “civilisation” diseases, (air passages, allergies, etc.) would be reduced by about 20%.

Technical progress forces a change in thinking and actions of those responsible for the policy in relation to the entire national economy, including the road transport sector, which will cause the increase in the number of electric cars. It is obvious that now this figure, for 2020, may be determined only by the estimates.

It should also be borne in mind that technological progress will create gradual decrease in the purchase prices of electric cars, which will cause the increase in the number of their potential buyers.

The European eMAP project as a support in the evaluation of external environmental costs of the road transport

The advantage of the electric drive is a zero carbon dioxide emission from the vehicle itself. A very important problem are the limitations in the energy storage by batteries [11]. Important are also determinants of the implementation of an integrated system e- mobility, both in the European Union, as well as in Poland.

Studies on the possibilities of implementing electric vehicles appear in a number of international projects and programs, for example, [18-23]. One such European project currently implemented in the framework of the ERA - NET Plus Electromobility + is a European eMAP project (**E**lectromobility – scenario based **M**arket potential **A**ssessment and **P**olicy options) carried out with the participation of the Motor Transport Institute and the authors of this article.

The main objective of the eMAP European Project (2012-2015; total budget: app. 1.24 mio. Euro) is to analyse feasible deployment paths of electric vehicles for the time horizon until 2025-2030. This will be done using a scenario based market model which specifies consumer demand and market supply of electromobility [24]

Socio-economic impacts of deployment of electromobility on greenhouse gas emissions, local emissions, transport costs, energy supply safety and technological change in industry and economy will be evaluated under various scenarios. Political supporting actions and strategies of electric vehicles will be identified and their impacts on the deployment paths analyzed and evaluated. In the end, recommendations for optimized political strategies will be derived [24].

The regional scope of the project focuses on Europe, most importantly the three partner countries Finland, Germany, and Poland. These vehicle markets will be analyzed in detail with regard to demand structure and supply of electric vehicles and necessary infrastructures for example in mega cities (Berlin), major cities (Cologne, Helsinki) and dense populated areas (Rhein/Ruhr, Warsaw) [24].

The main objectives of the eMAP project are [24]:

- to identify the main characteristics of drivers and pinpoint impediments on side of the customers and the suppliers of electromobility,
- to quantify the demand for electric vehicles given different scenarios,
- to quantify supply of electric vehicles in different market segments,
- to make a forecast of development paths of electromobility based on scenarios,
- to make a thorough socio-economic evaluation of the

deployment path of electric vehicles given the different scenario outcomes,
- to determine and evaluate measures and strategies to increase speed of the adaption of electric vehicles,
- to provide policy options and recommendations for optimized deployment programs.

Partners of eMAP are: Federal Highway Research Institute (BAST), Institute for Transport Economics/University of Cologne (UOC), Institute of applied social sciences (INFAS), German Aerospace Centre (DLR), Institute of Vehicle Concepts, Technical Research Centre of Finland (VTT) and Motor Transport Institute (ITS).

In the focus of the project are vehicle concepts which use only electrical energy or use electrical energy in addition to petroleum fuel or gas. The considered power train concepts include Battery electric vehicles (BEV), Fuel cell hydrogen vehicles (FCHV), Plug-in hybrid electric vehicles (PHEV) and Range extended electric vehicles (REEV)) are included which can be driven with electricity alone [25].

In general, electric vehicle demand decisions of customers will depend on the relative attractiveness of electric vehicles compared to vehicle types with conventional power train concepts (Fig.1). Differences in comfort and flexibility of usage of EV will play an important role in this respect. Also the higher upfront costs, but lower running costs of EV mainly caused by relatively low electricity costs and relatively high efficiency of batteries and motors are feeding into the decision making process of customers [25].

Beside comfort, upfront and running costs, attractiveness of electromobility for consumers depends for Plug-in vehicles on availability of charging and service stations. Therefore, also the availability of infrastructure for electromobility for loading and service, including the integration of electric vehicle storage capacity into the electricity grid has to be integrated in the demand analysis [25].

Market supply and the market introduction of further variants and models of EV will depend on technological developments, economies of scale, learning curve effects etc. The structure and volume of market supply of EV will be addressed by trend analysis of observable vehicle market trends in Finland, Germany, and Poland. In addition, expert interviews of the automotive stakeholders will be used to forecast technological development of components, and time, volume, and type of market introduction of EV [25].

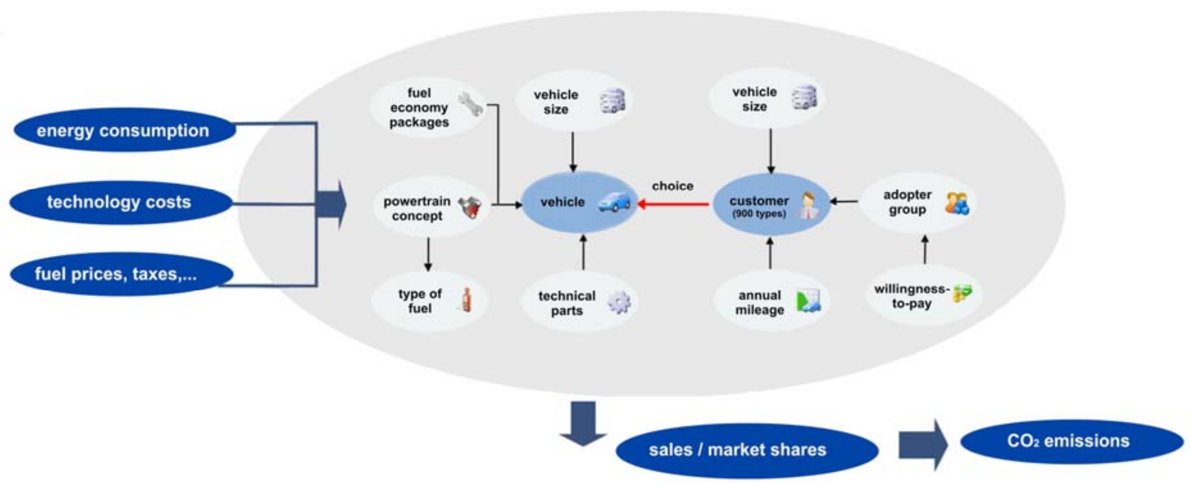

Fig.1. Influence of various factors on the choice of the electric car

For the German passenger car market several forecasting studies based on scenarios were done. For example : AT Kearny, Bain & Company, McKinsey, Boston Consulting Group, Roland Berger. The Fraunhofer study provides a scenario model based on comprehensive desktop analysis of vehicle usage patterns which is then used to derive demand potential of electric vehicles in Germany [26]. The following two models are also based on comprehensive analysis of consumer and vehicle data to derive demand potential and vehicle cost development [25]:

- The Institute of vehicle concepts (DLR) has developed a computer based scenario model (VECTOR21 (Fig.2)) to predict market shares of new power train concepts (HEV, BEV FCV etc.) for Germany between 2010 and 2030,
- With focus on battery electric vehicles (BEV) (16 kW, 24kW) the Institute for Transport Economics (UOC-model), which will support the work of the project coordinator BAST as a subcontractor, has done a market forecast for the time horizon 2015 – 2020 for Germany.

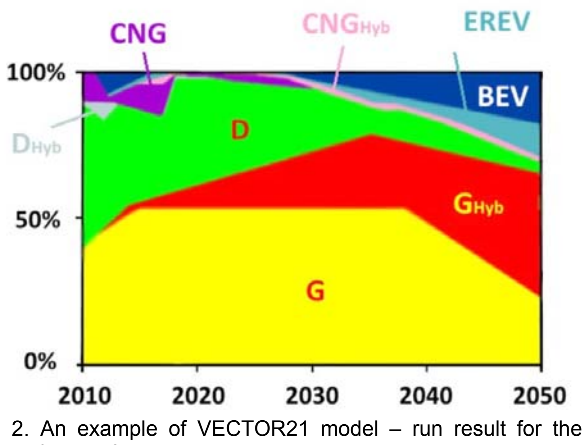

Fig. 2. An example of VECTOR21 model – run result for the new vehicle fleet in Germany

Abbreviations: CNG (Compressed Natural Gas) – car running on Compressed Natural Gas, DHyb (Diesel hybrid) – hybrid car with a self ignition engine, CNGHyb (Compressed Natural Gas, hybrid) – hybrid car with an engine running on Compressed Natural Gas, G (gasoline) – car running on petrol, GHyb (Gasoline hybrid) – hybrid car with a spark ignition engine, D (diesel) – car running on diesel oil, BEV (Battery Electric Vehicle), EREV (Extended Range Electric Vehicle)

The eMAP project will use especially the VECTOR21 model, but will also follow the UOC-model and the Fraunhofer study as a starting point for a scenario model on deployment of electromobility. The eMAP project will make progress in the following directions [25]:

- The conclusions of the VECTOR21 model are restricted to the German passenger car market. On a contrary, in the eMAP project a transnational approach is used. Scenario based forecasts will be done for three national markets: Finland, Germany, and Poland, but also for the remaining part of EU-27,
- In the VECTOR21 model and also in the UOC-model the customer purchase decision is modelled with focus on the vehicle market. However, a more comprehensive approach for consumer decision making will be provided in eMAP. Because electromobility opens new possibilities for modal split, especially in urban travelling, the decision making process has to be broadened. Therefore, the step-wise process of consumer decision making already shown in the VECTOR21 model will be further enlarged by an additional step of modelling mobility decisions about travelling modes,
- The scope of the supporting political actions considered in the framework conditions will be broadened. In the studies analyses about financial incentives dominate. However, beside financial support, also different research funding schemes, infrastructure investments, special e.g. priority rules for EV, and information and awareness campaigns for electromobility have to be included.

The Institute for Transport Economics (UOC) has done a socio-economic assessment of electromobility. The assessment is based on the forecast of market volume of BEV (24 kW) and City-BEV (16 kW) for Germany for the time horizon 2015 – 2020. The assessment comprises impacts of electromobility on local (noise, PM, NO_x) and global emissions (CO_2) which are transferred to monetary benefits by using environmental damage cost-unit rates [25].

The eMAP project with regard to socio-economic impact evaluation will be based on the UOC-model, but enlarges the assessment further in the following directions [25]:

- A socio-assessment is done for Finland, Germany, Poland, and also for the remaining part of EU-27,
- The shift to electromobility has strong effects for fuel based tax income, and thus on the public budgets. Therefore based on the scenario results of fleet penetration of EV a financial analysis will be done. A financial analysis covers monetary transfer payments and tax revenues which are not considered in the cost-benefit analysis,
- A usual cost-benefit assessment is restricted to an assessment of impacts which can be expressed in monetary values like transport costs changes and environmental benefits. Therefore, structural effects of the deployment of electromobility for employment, less dependency from crude oil, competitiveness of automotive industry etc. are not part of the cost-benefit assessment. To make a thorough assessment of the impacts the shift to electromobility will have on society a broader approach is used integrating monetary, quantitative and qualitative effects in the assessment. This is done by a multi-criteria analysis.

In eMAP project the final set of strategy will be presented in a easy interpretable graphic design, which shows the share of private and public commitment to boost electromobility and to overcome the various challenges in the market development [25].

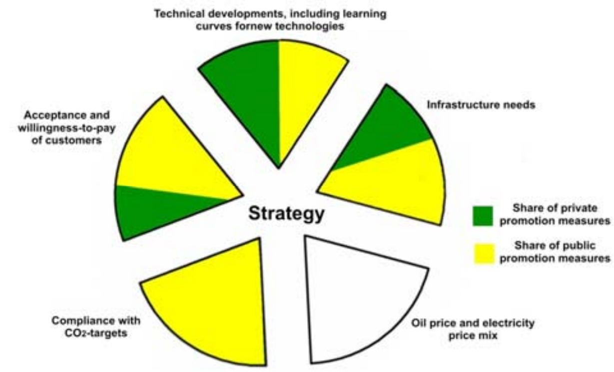

Fig. 3. Share of public and private promotion measures in strategy for promotion of EV

Conclusion

The European Union is conducting research studies to identify opportunities for tackling the problem of carbon dioxide emissions from cars in favour of gradual entry into service of electric cars. This is a very complex problem due to the issues such as.:

- production capacity of the energy industry,
- technical infrastructure for charging batteries,
- technical capabilities to produce a new generation of batteries,
- servicing electric cars,
- level of costs of operating electric cars.

It should be stressed that solving these problems will be associated with a significant financial expenditures, which will fall to the external costs of transport, and their levels will be one of the decisive application factors for the modern electric vehicles. On the other hand "avoided costs" incurred by the replacement of conventional vehicles powered by internal combustion engines with these vehicles will not be meaningless.

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