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ECOLOGICAL AND ECONOMIC ASPECTS OF ELECTRIC MOTOR VEHICLE EXPLOITATION

EKOLIGINIAI IR EKONOMINIAI ELEKTRA VAROMŲ TRANSPORTO PRIEMONIŲ EKSPLOATACIJOS ASPEKTAI

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The resources of the fossil energy in the world become exhausted, due to this reason necessity for research in different alternative energy resources arises. One of these kinds of energy is electric energy. It is possible to use electric energy in individual motor vehicles accumulating it in accumulators. It is possible to cover 120-150 km with an up-dated electric car what is sufficient for every day usage, especially in the conditions of cities. For application in Latvian conditions rebuilt electromobiles are advisable. The operation costs of such electromobiles are 3-4 times lower than for fossil energy automobiles, but CO_2 emissions are localized in the place of energy production and globally reduced at least 10 times.

Electric energy, electric motor vehicles, electromobiles, economic efficiency, ecological contribution.

Introduction

Energy resources of the world fossil fuels sharply decrease, yet the demand for them increases. The number of population grows with the rise in living standards, simultaneously requiring additional energy resources.

Several scenarios are developed for the calculations on the time period for the sufficiency of energy resources for the world population, if the rates of fossil fuel resource usage remain constant, although mostly the considerations on the sufficiency of resources embrace the next 50 – 70 years.

The first electric motor vehicles were known already since 1830. Still, their application was limited as there were not rechargeable batteries invented. Wider usage of electric motor vehicles was observed only at the beginning of the 20th century when the New York electric cabs appeared. Electric motors compared to internal combustion motors at the beginning of the 20th century had several advantages, for example, they did not need to be specially started, they were not noisy, and they did not have exhaust gases and fuel smell. With the development of the internal combustion motor constructions introducing the electric starter and other innovations application of internal combustion motors in motor vehicles developed fast but electric motor vehicles were used comparatively seldom.

Every motor vehicle is suitable for specific exploitation conditions. There are not completely universal motor vehicles suitable for all exploitation conditions. So also electric motor vehicles in spite of their drawbacks can occupy and have occupied their market niche and their application. This application can be related to the specificity of this kind of motor vehicle – localisation of pollution in the place of production of electric energy and noiseless operation.

Recently also in Latvia attention is paid to the possibilities of application of electric motor vehicles of different kinds. Nevertheless, wider application is limited by the high prices of electric motor vehicles, their production and sales limitations, weak infrastructure.

Electric motor vehicles, their kinds and application in Latvia

According to their kinds the electric motor vehicles can be divided into several groups that are summarized in Figure 1. Electric motor vehicles can be divided in two large groups – autonomous and with outer energy source. Let us discuss the main advantages and disadvantages of the classified motor vehicles.

Already for several decades for passenger transportation such outer energy source electric motor vehicles as trams, trolleybuses, electric trains and underground trains are used. The main advantage of these motor vehicles is their ability to move without accumulator charging for unlimited length. Also the weight of the motor vehicle has not been added with heavy accumulator batteries. The main drawback is the necessity for the expensive infrastructure, disability of these motor vehicles to move freely without connection to outer energy by means of wires.

This drawback has been eliminated in autonomous motor vehicles. They depending on the construction have higher or lower autonomy that today can be in the range from 20 – 200 km. This autonomy is ensured by accumulator batteries that can also be of different constructions and materials used, starting with lead accumulators even up to the expensive but energy capacious lithium ion accumulator batteries. Low speed electric motor vehicle driving speed usually does not exceed 50 km/h, but most often it is 20 – 30 km/h.

The autonomous electric motor vehicles can be divided into low speed and high speed motor vehicles. The low speed motor vehicles can have or not the rights to participate in the street traffic depending on the fact if they have been certified for street traffic. Three wheel and four wheel low speed motor vehicles are applied for different specific purposes, for instance, serving the golf games for moving along the field. In the developed European countries low speed electric motor vehicles are used also for shopping. Electric motor vehicles with direct usage of solar energy are scarcely common due to their limited application [1].

The main disadvantages of these motor vehicles:

- solar energy can ensure the movement of these motor vehicles only on very sunny days;
- the area of solar batteries has to be very large;
- the body weight of the motor vehicles has to be as possibly small;
- it is possible to use only limited power electric motors.

The power of four wheel low speed electric motor vehicles usually is in the range from 2 – 5 kW, autonomy up to 75 km. For these motor vehicles most often the standard lead deep charge accumulators are used. At present in Latvia ten low speed electromobiles produced by Melex are used. Most of them are used for tourist transportation in Sigulda and Jurmala. People who have used these tourism trips are satisfied for the senses and impressions during these rides.

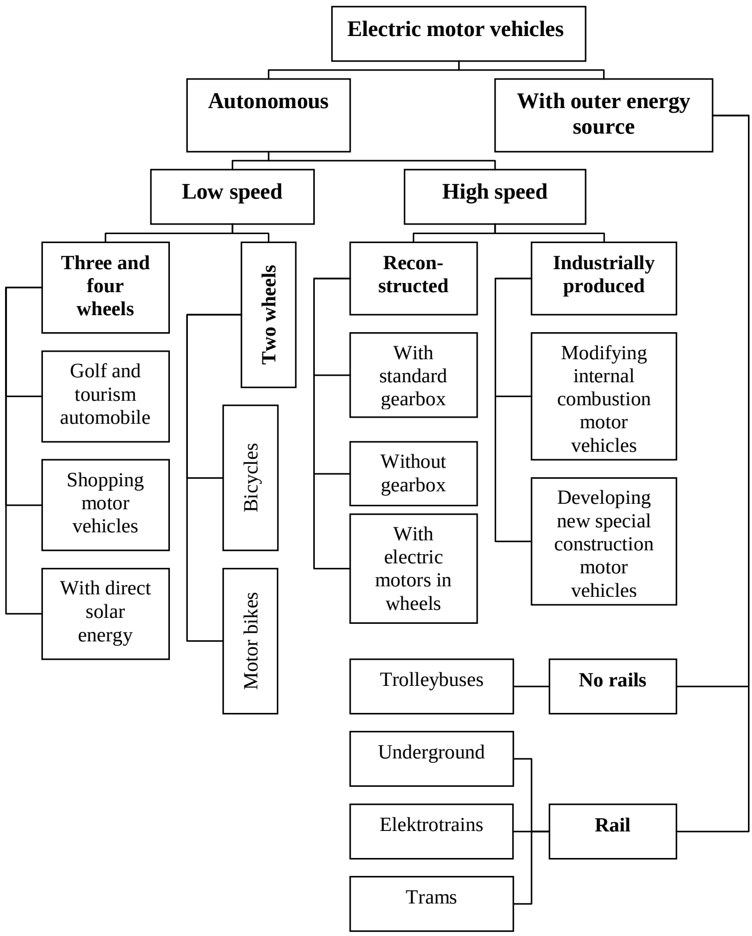

Fig. 1. Electric motor vehicle classification
1 pav. Elektros variklių klasifikacija

In the Latvian market a comparatively wide range of electric bikes is offered. Electric bikes are two wheel motor vehicles the power of the engine of which usually is in the range from 0.25 – 0.35 kW, the maximal riding speed 20 – 30 km/h and autonomy with one charging 25 – 40 km. For electric bikes most often lead deep discharging accumulators are used but it is possible to use also lithium ion accumulators. According to the European normative documents the electric bike power cannot exceed 0.25 kW. For starting the electric bike motor two kinds are used: traditional accelerator handle or starting of the motor in the moment when the rider has pedaled with definite speed, the electric motor helps ensure the movement. The application of electric bikes can be rather wide as their price is in the range from 300 – 700 Euro. On of the main electric bike advantages is the possibility to get home also after complete discharging of the accumulator. It can be done using the electric bike traditionally pedaling. No other electric motor vehicles have this ability.

Electric mopeds usually have higher power than electric bikes and they do not have pedals. Their power is in the range from 1 – 2.5 kW, riding speed up to 40 km/h, autonomy up to 60 km. Due to high power the motor bikes need to have also accumulators with higher capacity that ensures good enough dynamic properties. Electric mopeds are expensive, usually the price is 2000 – 3000 Euro that decreases their purchasing possibilities.

High speed electromobiles can be self reconstructed or industrially produced. Modifying the internal combustion automobiles envisaged for street traffic has been done already for 30 years. The automobile production plant concludes a contract with the reconstruction plant where the electric motors are installed. In the first 20 years of the development of these electromobiles usually 20 kW electric motors were installed in Europe. For these electromobiles lead deep discharging accumulators were used but recently also lithium ion batteries. There is no information on exploitation of these first generation automobiles in Latvia; it allows for a judgment that there are not such automobiles in Latvia. The second generation industrially produced motor vehicles usually have power above 20 – 50 kW, the maximal driving speed 100 – 140 km/h, autonomy 140 – 160 km. Their mass production is planned only in 2010. Their most essential disadvantage is their high price that exceeds 30000 Euro. In Latvia the company Latvenergo has planned to buy some of these motor vehicles for purpose of advertising.

In Latvia application of the reconstructed internal combustion automobiles could be prospective, still the main limiting factor is the inconvenient certification in compliance with the EU normatives for street traffic. The certification procedure in Latvia is not only very expensive but also time consuming and complicated.

Electromobile purchasing costs or costs for rebuilding internal combustion automobiles into electromobiles

In order to promote application of electric motor vehicles it is necessary not only to have the necessary infrastructure – accumulator charging places as well as their fast exchange units – but also their price should be much more lower. At present prices for electricity in Latvia an electromobile can pay back not sooner than after 100000 km run. If it is assumed that 20000 km are covered per year the period of repayment is at least five years.

Considering the prices at present rebuilt automobiles are considered to be most perspective. One of the most expensive elements of such electromobiles is lithium ion batteries the price of which can reach even 10000 Euro. If it is assumed that we have a private car with a damaged motor, buying an electric motor, control units and other parts, it is possible to build such an automobile in total for 15000 – 20000 Euro. Also certification expenses are needed. With this, such rebuilding can be ineffective individually. It would be simpler to certify a group of automobiles that could be equipped with the standard automobile reconstruction set.

Electromotor and internal combustion motor vehicle technical service and repair costs

The highest motor vehicle costs can be dividend in the following groups:

- technical service and repair costs;
- fuel and electric vehicle battery charging costs;
- costs for taxes related to participation in street traffic – technical inspection, road tax, compulsory third person vehicle insurance.

If the government does not promote introduction of electric motor vehicles, the third group costs for electromobiles as well as for internal combustion motor automobiles are equal. Therefore this group of costs will not be analysed.

The technical service costs are easy to prognosticate as they are planned. Let us compare them for small cars if they are used as electromobiles or internal combustion motor cars. According to the price offer of the dealers the car with 1.4 l internal combustion engine technical service costs are in average 900 Euro per 100000 km. These costs are comprised mainly by work, lubricants and such service parts as air, fuel and oil filters, motor camshaft driving belt with rollers, aggregate driving belt. Electromobiles do not have most of these parts therefore no servicing of them is needed.

The electromobile service costs are assumed to be 400 Euro per 100000 km. The current repair costs are calculated according to the correlation:

$$C_R = C_{TA} \times 0{,}5\,, \qquad (1)$$

where C_{TA} – technical service costs.

Calculating the current repair costs for internal combustion motor automobiles we get 450 Euro per 100000 km. The electromobile repair costs will be 200 Euro per 100000 km. Of course, these are provisory calculations and in actual exploitation conditions they can vary.

Economic evaluation of electromobile application

There are several production companies that have developed electromobiles, for instance, Renault, Mitsubishi etc. The „fuel" or charging costs for there automobiles are envisaged 1.50 – 2.00 Euro per 100 km at the existing prices for electricity in Latvia. The calculations will be performed for an ideal case if all Latvian cars are rebuilt into electromobiles. The average consumed amount of fuel by the Latvian car fleet per year:

$$\sum Q_d = \frac{Q_d \times l_g \times A}{100}, l \tag{2}$$

where Q_d – average yearly automobile fuel consumption, l/100 km;

l_g – average yearly automobile coverage, km;

A – number of cars with valid technical inspection registered in Latvia.

The information according to the Road Traffic Safety Department (RTSD) [2] data on the cars registered in Latvia on May 1, 2010 is summarised in Table 1.

Table 1. Number of cars in Latvia.
1 lentelė. Automobilių skaičius Latvijoje.

Automobiles according to the kind of motor	Number of automobiles	
	Automobiles	With valid technical inspection
With Otto motor	640559	377930
With Diesel motor	220275	129962
Total	860834	507892

In calculations we assume that only cars with valid technical inspection participate in road traffic that is 59% of the total number [2]. Let us assume that the average coverage of these cars is l_g=20000 km and average fuel consumption is Q_d =7.5 l/100 km. In such case this Latvian car fleet will consume:

$$\sum Q_d = 761838000 l \text{ fuel.}$$

The cost of this fuel assuming that in the average one liter of fuel costs C_d =1.10 Euro:

$$\sum C_d = C_d \sum Q_d = 838021800 \text{ Euro.} \tag{3}$$

Operating an electric automobile, according to the provisory data in literature [1], full charging of accumulators costs 2.0 Euro. It is possible to cover up to 150 km with such charging. Due to this 100 km coverage costs approximately C_e=1,33 Euro. In total the costs for operation of the whole Latvian car fleet with electric drive:

$$\sum C_e = \frac{C_e l_g A}{100} = 135099272 \text{ Euro.} \quad (4)$$

So, economy for this kind of transport in Latvia is:

$$\sum C_{ekon} = \sum C_d - \sum C_e = 702922528 \text{ Euro.} \quad (5)$$

Thus, global fuel economy per year could be 702.9 millions Euro per year. This is the maximal effect at the present moment without evaluating the versions if only a part of the whole auto transport net is operated using electrodrive. In this case the effect will be accordingly by the corresponding percentage less, for example, 10% of the calculated maximal effect.

If the economic effect obtained by saving fuel is calculated per one automobile, it is 1384 Euro per year. Comparison of different motor vehicles covering 20000 km can be seen in Figure 2.

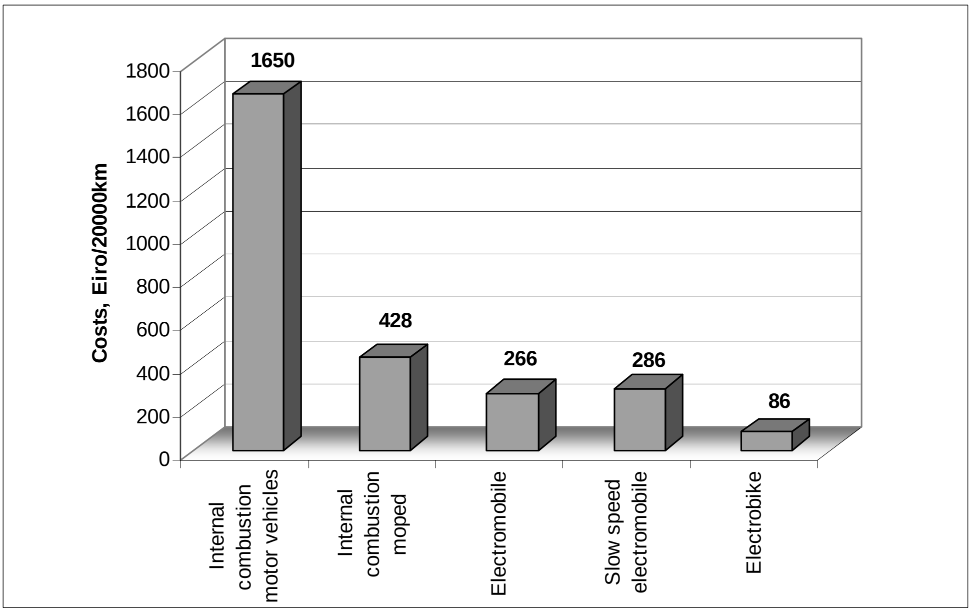

Fig. 2. Fuel and charging costs of different motor vehicles Euro/20000 km
2 pav. Degalų ir elektros įkrovos kainų kitimas skirtingų transporto priemonių variklių rūšims Euro/20000 km

In the graph given in Figure 2 calculations are performed considering:

- internal combustion automobile fuel consumption 7.5 l/100 km;
- internal combustion moped average fuel consumption 2 l/100km;
- electromobile electroenergy costs – 1.33 Euro/100 km;
- low speed electromobile electroenergy costs – 1.43 Euro/100 km;
- electrobike full electroenergy costs – 0.43 Euro/100 km.

It is possible to prognosticate also the increase of labour productivity, especially in the mental sphere, as well as the decrease in the sickness rate caused by automobile exhaust gases. With improvement of the living environment using electric motor vehicles and their emission free operation, and the decrease of pollution the increase of productivity is possible in all spheres of production in cities. It is assumed that the sickness rate of lung diseases, especially chronic, can reduce by P_{ps}=5%. Operation of electric motor vehicles is without considerable noise of the motor. It is assumed that reduction of noise in the city can ensure increase in productivity at least by P_{pt}=5%, especially in the spheres of mental work where noise interferes with concentration for fruitful work. The total effect from usage of electric motor vehicles if assumed that the productivity will increase based on the above assumptions ΣP=10%. Assuming that in formation of the Latvian gross product (18920458571 Euro in 2009) [3] the specific proportion of cities is 50%, calculations are done with ΣP=5%, getting 946 million Euro. Due to this the total effect from global electric transport introduction in Latvia could be 1.464 milliard Euro.

Ecological evaluation of electromobile application

Due to using of fossil energy in transport and the large number of vehicles recently the problems with the total warming of the Earth have essentially reduced. One of the reasons of total warming is the CO_2 gas that has been produced on different burning processes; it is not toxic but in a longer period of time unskillfully and wastefully using the resources of fossil fuel the Earth heat balance can be destroyed by gases producing the greenhouse effect.

A large part of the world population live in cities (more than 3.1 milliard or 49%). In Latvia in cities even a larger number of residents live – up to 68%. Lately exactly in the cities using transport vehicles ignoring the strict exhaust gas norms the negative influence of motor vehicles can be observed. These problems become topical also in Latvia. We will roughly determine what amount of emissions would get into the atmosphere if all cars are rebuilt into electromobiles.

To calculate the amount of emissions the method of the admissible amount of emissions can be used performing a new automobile certification procedure. As the Latvian car fleet is not new, we will assume that automobiles in Latvia in the average correspond to the Euro – 3 standard and we will evaluate the parameter worsening factor after 80000 km run – 1.2. In this case automobiles with Otto motors get the following emission values for 1 km run that are summarized in Table 2 [1].

Table 2. Exhaust gas values used for calculations considering the worsening factor.
2 lentelė. Deginių sudėties reikšmės panaudotos skaičiuojant nagrinėjamą bloginantį veiksnį.

Kind of motor	Exhaust gas values, g/km				
	CO_2	**CH**	**NO_x**	**PM**	**CO**
Otto motor	210	0.24	0.18	0.01	2.76
Diesel motor	155	-	0.50	0.06	0.71

Calculating the amount of emissions of the corresponding components *G* (CO_2, CH, NO_x, PM, CO) for the Latvian car fleet based on the assumptions of chapter 4 on the average yearly coverage and the data of Table 1 on the number of automobiles the following correlation is used:

$$\sum I_G = \sum I_{GO} + \sum I_{GD} = \frac{A_O \times l_g \times M_{GO} + A_D \times l_g \times M_{GD}}{10^6}\text{, t/year,} \qquad (6)$$

where A_O – number of Otto motor automobiles;
A_D – number of Diesel motor automobiles;
l_g – automobile coverage per year, km;
M_{GO} – amount of the corresponding emission component g/km for Otto motors;
M_{GD} – amount of the corresponding emission component g/km for Diesel motors.

To calculate how much for the Latvian state the corresponding pollution costs the average CO_2 trading quotas are used but for the other exhaust gas components the costs are assumed based on their possible influence on people and the surrounding environment. The CO_2 costs according to the average quota trading costs are 10 Euro/t. The costs of the Latvian auto fleet exhaust gas emissions are calculated according to the correlation:

$$C_G = \sum I_G \times C_{KV} Eiro / year\ , \qquad (7)$$

where *G* – index designating the corresponding emission component;
C_{KV} – costs of the corresponding exhaust gases, Euro/t.

The calculation results are shown in Table 3.

Table 3. Amount and costs of Latvian car exhaust gases per year.
3 lentelė. Latvijos automobilių deginių kiekiai per metus ir kaina.

Character value	Exhaust gas components				
	CO_2	CH	NO_x	PM	CO
Amount of exhaust gas component, t/year	1990188	1814	2660	232	50970
Exhaust gas costs, Euro/t	10	200	200	500	200
Exhaust gas component costs, Euro/year	19901880	362800	532000	116000	10194000

The amount of the above calculated components will not be emitted if electric motor vehicles are used. The amount of exhaust gas components is clearly shown in Figure 3.

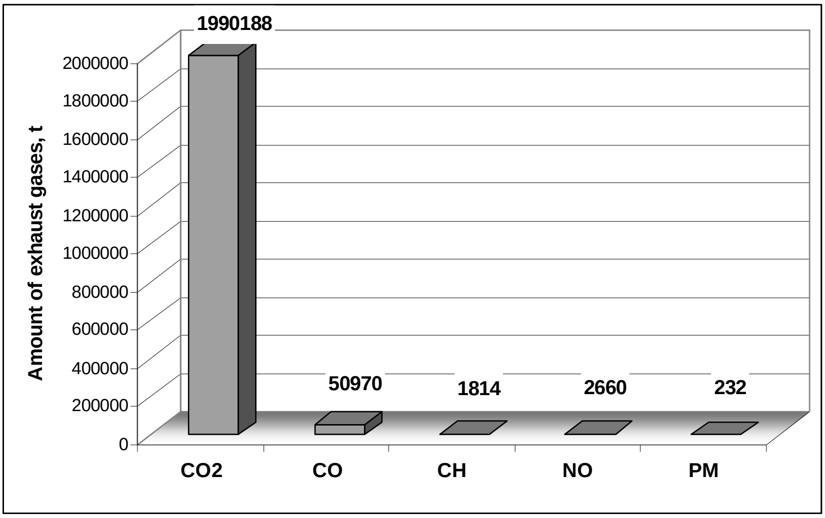

Fig. 3. Approximate amount of exhaust gases for Latvian cars
3 pav. Apytiksliai deginių kiekiai išmetami Latvijos automobilių

All above mentioned benefits are possible if for obtaining of electric energy renewable resources are used, for instance, it is produced in hydroelectrostations or by wind energy. In case if electric energy is produced using nonrenewable resources, evaluation of the full electroenergy production cycle is necessary.

Conclusions

1. In the Latvian market at present low speed electromobiles, electrobicycles and electric mopeds are available. Their charging is possible only at their owner homes as there is no infrastructure developed.

2. Electric motor vehicles are classified according to autonomy and the driving speed.
3. Bulk purchasing of high speed electromobiles could be hindered by the high price and weak infrastructure. The rebuilt electromobiles replacing the car internal combustion engine by the electric motor could be most perspective for a wider range of users.
4. Wide distribution of the rebuilt electromobiles could be limited by the extremely strict rebuilding certification requirements in Latvia.
5. At the present fuel and electric energy princes in Latvia the electromobile charging price is 6 times lower than the costs of fuel for analogous internal combustion motor automobile.
6. Exploitation of electric moped is up to 5 times cheaper than exploitation of the internal combustion moped.
7. The maximal possible economic effect for the Latvian cars can exceed 700 millions Euro per year.
8. Savings due to the exhaust gas costs in Latvia can exceed 31 million Euro per year.

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EKOLIGINIAI IR EKONOMINIAI ELEKTRA VAROMŲ TRANSPORTO PRIEMONIŲ EKSPLOATACIJOS ASPEKTAI

Reziumė

Pasaulyje mažėjant iškastinių energijos šaltinių, būtina ieškoti alternatyvių energijos šaltinių. Viena iš alternatyvių energijos rūšių yra elektros energija. Akumuliuotą elektros energiją galima panaudoti kaip energijos šaltinį individualioms transporto priemonėms varyti. Naudojant akumuliuotą elektros energiją elektra varomuose automobiliuose galima nuvažiuoti 120-150 kilometrų. Tokius automobilius tikslinga naudoti miesto sąlygomis, kiekvieną dieną pakraunant akumuliatorių baterijas. Būtų tikslinga tokius elektromobilius naudoti Latvijos Respublikoje. Elektromobilių eksploatacinės išlaidos yra 3-4 kartus

mažesnės nei tradicinių naftos produktais varomų automobilių. CO_2 emisija į atmosferą būtų tiktai elektros gamybos vietoje ir bendroje sumoje sumažėtų 10 kartų.

Elektros energija, elektrinės transporto priemonės, elektromobiliai, ekonominis efektyvumas, ekologija.

Дайнис Берьеза, Инара Юргена

ЭКОНОМИЧЕСКИЕ, ЭКОЛОГИЧЕСКИЕ АСПЕКТЫ ЭКСПЛУАТАЦИИ ЭЛЕКТРИЧЕСКИХ АВТОМОБИЛЕЙ

Резюме

С уменьшением в мире энергетических ресурсов, становится необходимо искать новые источники энергии. Одна из альтернативных источников энергии является электрическая энергия. Аккумулированную электрическую энергию можно использовать как источник энергии для продвижения индивидуальных транспортных средств. Используя аккумулированную электрическую энергию можно проехать 120 – 150 километров без дополнительной зарядки аккумуляторов. Такие электромобили можно использовать в городских условиях. Такое транспортные средства можно использовать в условиях городов Латвийской республики. Цена эксплуатации таких электромобилей 3-4 раза дешевле, и эмиссия газов CO_2 сосредоточенна на месте производства и в сумме 10 раз меньше, чем автомобилей использующих традиционное нефтяное топливо.

Электрическая энергия, электрические транспортные средства, электромобили, экономическая эффективность, экология.