ECOLOGICAL EFFECT OF ELECTRIC VEHICLES ON CO_2 EMISSIONS IN LATVIA

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Abstract. Road vehicles are one of the largest sources of pollution in Latvia. Such an alternative type of fuel as biofuel is introduced and electric drive is used because of this reason. The paper analyses the distribution of road vehicles by fuel type, employs an algorithm for identifying an amount of CO_2 emissions and a total amount of the emissions for a group of road vehicles depending on the type of the fuel used. The paper compares the amounts of emissions from electric vehicles and internal combustion vehicles.

Keywords: number of electric vehicles, emissions, ecological effect, emission reduction, fuel consumption, electrical energy consumption.

Introduction

The number of automobiles increases in the world from year to year. This trend is observed in Europe and Latvia as well. The EU legislation envisages exhaust emission reductions, introducing automobiles running on alternative fuels and electric automobiles. The use of electric automobiles is considered to be the most effective way of reducing exhaust emissions and noises.

Although exhaust emission standards become stricter with every relevant legal act adopted, it is difficult to reduce some exhaust emission components for internal combustion engine automobiles, as their structure has to be considerably changed. A few exhaust emission components, for example, CO_2 cannot be reduced multiple times with the current technologies for internal combustion engine automobiles. This exhaust emission component is not toxic; yet, it can impact the greenhouse effect and the balance of gases in the atmosphere.

Estimates of the amount of exhaust emissions from internal combustion vehicles may be based on a number of assumptions. One of the methods involves the average annual kilometrage of a particular vehicle fleet and maximum exhaust emission limits for this vehicle fleet. Calculation of exhaust emissions from electric vehicles is more complicated, as electrical energy production involves both zero-emission or low-emission technologies (hydro power plants, wind generators and solar energy plants) and technologies that produce emissions in the cogeneration process, the biogas processing process or in thermal power plants.

The EU directive 2014/94/EU envisages that until 2020 the member states have to establish infrastructure for electric vehicles in cities and in their vicinities [4], which could foster the expansion of the electric vehicles. It would ensure that electric vehicles can freely move across larger territories, doing battery charging operations fast and comfortably. The directive prescribes supportive measures for establishing charging stations that are not publicly available.

At present, a little more than 200 electric automobiles are exploited in Latvia. The greatest increase in the number of electric vehicles in Latvia was observed after government financial support was granted in 2014.

The key aim of the paper is to develop a calculation methodology for estimating CO_2 emissions from electric vehicles and analyze the emissions produced currently and in the future.

Materials and methods

Distribution of automobiles by engine type in Latvia and changes in the distribution

The key segment in the use of electric vehicles is light passenger vehicles (M1 category) and light lorries (N1 category). Therefore, only such vehicles are analyzed further in the paper. The changes in the number of cars and light lorries in Latvia for the last 8 years, broken down by fuel type [9], are presented in Figure 1. Based on the trend in the number of automobiles over the last years, Figure 1 shows also a forecast for the period until 2020.

The total number of automobiles reached 932828 in 2009. Over the next years, a sharp decrease in the number of petrol engine automobiles was reported – from 677096 in 2009 to 402136 in 2011. Such a decrease in the number of petrol engine automobiles may be explained by the fact that Soviet-period vehicles, which were not exploited for a number of years, were excluded from the register. During the next years, the total number of petrol engine automobiles decreased, whereas that of diesel engine automobiles increased. In 2015, the total number of diesel engine automobiles was greater by 5488 units than that of petrol engine automobiles, while in 2016 this difference increased to 38240. A steady increase was observed for the number of automobiles running on gas (LPG) – from 28919 automobiles in 2009 to 57083 in 2016. Such an increase in the number of diesel and LPG engine automobiles indicates the tendency of auto drivers to use economical automobiles with lower fuel costs.

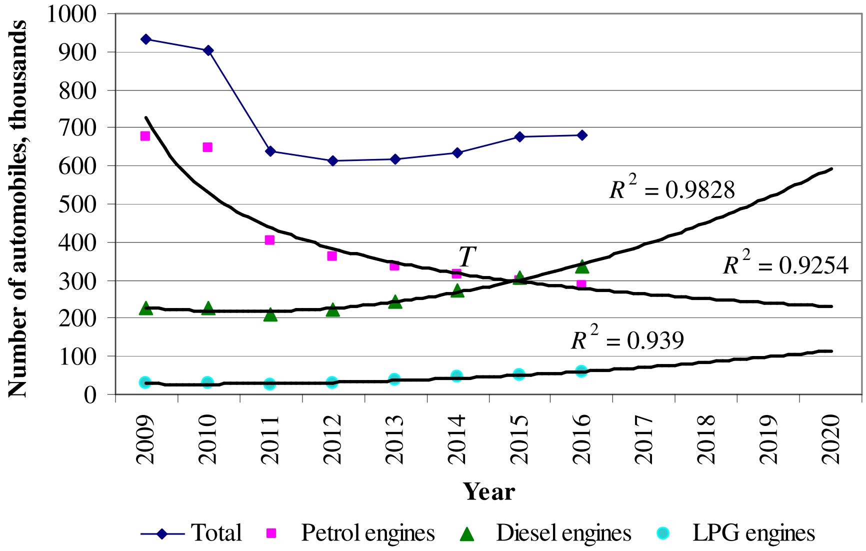

Fig. 1. **Changes in the distribution of cars and light lorries by engine type**

In Latvia, the use of electric automobiles began with two electric cars Fiat Fiorino purchased by the enterprise Latvenergo in 2012. Until 2014, the number of electric automobiles rose insignificantly and reached 17 units. In 2015, the number of electric automobiles increased twelve times, totalling 194. Such a trend could be observed owing to governmental financial assistance for purchase of electric automobiles. The changes in the number of electric automobiles [9] are presented in Figure 2.

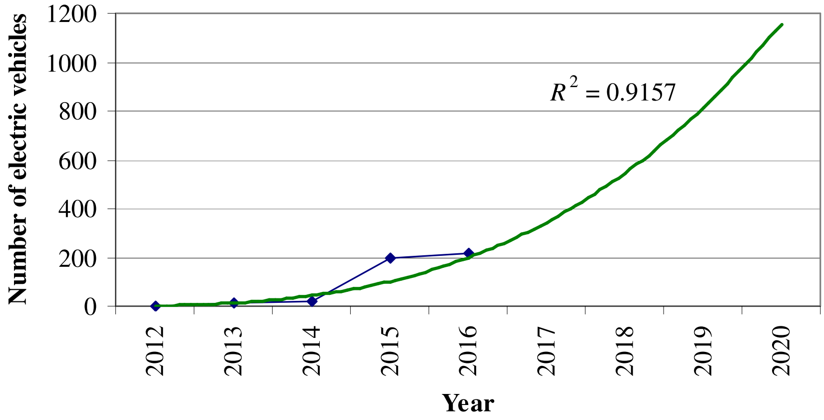

Fig. 2. **Changes in and forecasts of the number of electric vehicles in Latvia**

Figure 2 also shows a forecast for an increase in the number of electric automobiles, according to it, their number might exceed 1000 in 2020. However, such an increase most likely is possible in case the government financially supports the purchase of electric automobiles, as within a year from 2015 to 2016 their number rose by only 24. Part of these electric automobiles was purchased owing to the government support.

Algorithm for calculating ecological effect

According to the European Automobile Manufacturer Association (EAMA), the average age of cars in Europe in 2014 slightly exceeded 9.6 years. In 2016 in Latvia, the average age of automobiles, according to the Road Traffic Safety Directorate (RTSD), was 14.2 years [11]. Besides, like in Europe, the average age of cars in Latvia increases as well.

Relevant exhaust emission standards that were in force at the moment of manufacture of automobiles that are now 14 years old may be used to calculate the amount of emissions from internal combustion engine automobiles. It means that the standards being in force in 2002 have to be taken into consideration. This year, the Euro 3 standard is effective for new automobiles [3; 7; 8].

The regulation 443/2009 sets the average CO_2 emission limit for cars at 130 $g \cdot km^{-1}$. Automobiles that exceed this limit have to pay an extra tax for every CO_2 gram above the set limit [5]. It is envisaged to adopt even stricter limits on CO_2 emissions in 2021, reducing the CO_2 level to 95 $g \cdot km^{-1}$ [5]. The CO_2 emission component correlates strongly with the average consumption of fuel.

One of the methods of calculating CO_2 emissions is based on the quantity of fuel sold in a country or a region. The key imperfection of the method is its low accuracy, as it is not clear what kinds of vehicles have consumed the fuel sold in the country. This method may be employed to estimate the total amount of emissions. Petrol is a fuel used for various cars, small garden and forest machinery, a few kinds of lorries as well as motorboats. However, diesel fuel is used for cars, lorries and tractors. Therefore, the method of calculating CO_2 emissions, which is based on the quantity of fuel sold, may not be used for analyses of a particular group of vehicles.

The air pollutant emission inventory guidebook provides data on the mass of CO_2 per kg of fuel burnt [6]. However, it is difficult to find a methodology for calculating this value. Besides, the values given for the average fuel combustion technology in internal combustion engines for vehicles exploited in Latvia could differ from the values given in the literature owing to the old vehicle fleet.

To analyse the exhaust emissions from the automobile fleet of Latvia, the authors of the paper have already developed a method for calculating the following toxic components: CO, CH+NO, THC, NO_x and PM components [1; 2]. However, the previous calculations involved too high proportion of electric automobiles and no CO_2 emissions were estimated. An algorithm for estimating CO_2 emissions will be analysed in the algorithm suggested by the authors.

To estimate the amount of exhaust emissions from the automobile fleet of Latvia, it is assumed that the average kilometrage of automobiles was 20000 km in 2016. The amount of CO_2 emissions was calculated excluding large engine capacity vehicles, the proportion of which is insignificant. The kilometrage of the entire fleet of the analysed internal combustion automobiles may be calculated by the equation:

$$L_{ICE} = A_{ICE} l_g \text{, (km)} \tag{1}$$

where A_{ICE} – number of internal combustion engine vehicles in the n-th group;
l_g – respective average kilometrage for the group of internal combustion engine vehicles a year, km.

The specific values for the CO_2 component for respective automobile groups are not given; therefore, the calculations were performed dividing automobiles into groups with an engine capacity increment of 0.4 litres. The analysis employed the RTSD data on the average CO_2 emissions from automobiles with diesel and petrol engines for 2002 and 2006, obtaining the average amounts of emissions for each group [10]. The data are summarised in Figure 3.

The CO_2 calculations give average amounts of emissions for various engine capacity groups and take into account all the groups. However, given the proportion of automobiles with an engine capacity of more than 2.8 l is low in Latvia, average CO_2 emission amounts will be used in further calculations, excluding the mentioned automobile category. The amount of CO_2 emissions from internal combustion automobiles is calculated by the following equation:

$$m_{CO_2} = L_{ICE} M_{Av-CO_2} = A_{ICE} l_g M_{Av-CO_2} 10^{-6} \text{, t,} \tag{2}$$

where $M_{Av\text{-}CO2}$ – average CO_2 emissions for the group of vehicles running on a particular fuel, $g \cdot km^{-1}$.

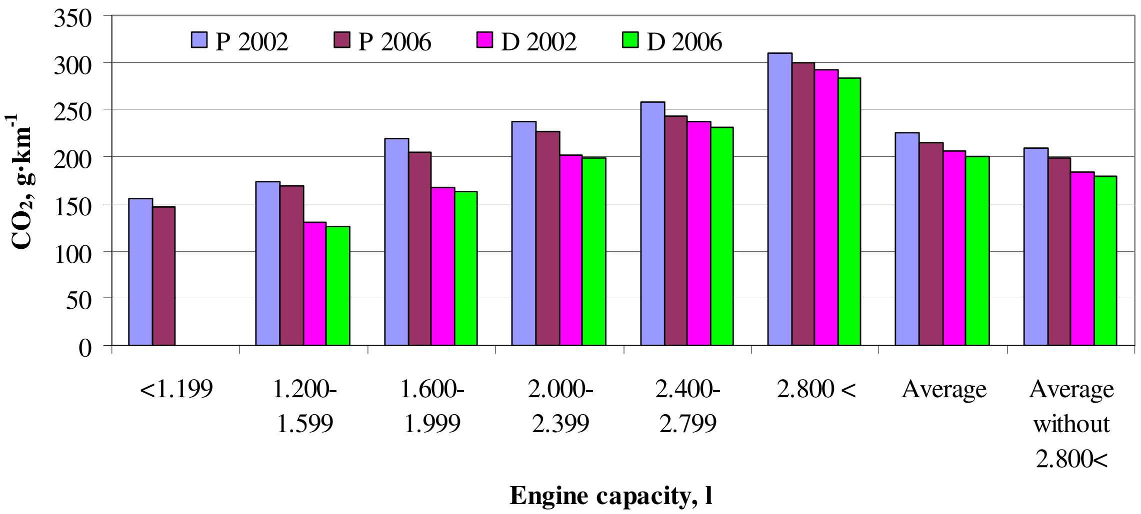

Fig. 3. **Average amount of CO_2 emissions by vehicle group**

Indirect emissions from electric automobiles may be also estimated, which depend on the specifics of production of electrical energy in a country. The average annual kilometrage of electric automobiles, using the current technologies, is smaller than that of internal combustion automobiles. A transitional factor, which ranges within $k_{l\text{-}EV}$=0.6-0.8, is employed to specify the kilometrage. With the charging infrastructure establishing and battery technologies developing, this factor may increase. Given equation 1, the annual kilometrage of the fleet of electric automobiles is calculated by the following equation:

$$L_{EV} = A_{ICE} l_g k_{l-EV} \text{, km,} \tag{3}$$

where $k_{l\text{-}EV}$ – transitional factor for the kilometrage of electric automobiles.

The amount of electrical energy needed for an electric automobile to cover a distance of 1 km is calculated by the following equation:

$$E_{1km} = \frac{E_{CH}}{l_R} \text{, kWh}\cdot(1 \text{ km})^{-1}, \tag{4}$$

where E_{CH} – amount of electrical energy needed to fully charge the battery of an electric automobile kWh;
l_R – kilometrage of the electric automobile per full battery charge, km.

Given equations 3 and 4, the indirect amount of CO_2 emissions for the annual kilometrage of an automobile group may be calculated as follows:

$$m_{EV-n} = L_{EV} E_{1km} M_{El-n}, \tag{5}$$

where $M_{El\text{-}n}$ – emissions for the n-th component of electrical energy production, g·(kWh)$^{-1}$.

Results and discussion

Employing the developed algorithm, the amounts of CO_2 exhaust emissions are calculated for diesel engine cars, petrol engine automobiles and electric automobiles for 2016 as well as for the forecasted number of automobiles for 2020. For internal combustion automobiles, the calculations used the average amounts of CO_2 emissions.

The forecast of the number of automobiles by type of fuel used for 2020 employed the data of Figures 1 and 2; however, some corrections were made for the total numbers of diesel and petrol engine automobiles, so that the trend of increase in the total number of automobiles fits the real changes over the last four years. It is also forecasted that the annual kilometrage of internal combustion automobiles will increase by 2000 km in 2020. The kilometrage factor for electric automobiles for 2016 is assumed to be equal to 0.7, while for 2020 it is 0.8, which may be explained by the establishment of the charging infrastructure.

For electric automobiles, the calculations used the average amount of CO_2 emissions from electrical energy production in Latvia in 2016, which was estimated at 115 g·(kWh)$^{-1}$. Since electrical energy production tends to exploit renewable sources, it is forecasted that the amount of CO_2 emissions should decrease to 113 CO_2 g·(kWh)$^{-1}$. The kilometrage of electric automobiles per full charge in winter and in summer are different; therefore, the calculations used the average kilometrage of electric automobiles, 120 km per full charge. The average electric energy consumed per charge was assumed to be 20 kWh.

The contribution of electric automobiles to the CO_2 emission balance is very insignificant, and, for example, in 2020 it is more than 4155 times smaller than that of diesel engine automobiles. Such a trend can be observed both owing to the insignificant indirect emissions from electric automobiles and owing to the small total number of the electric automobiles.

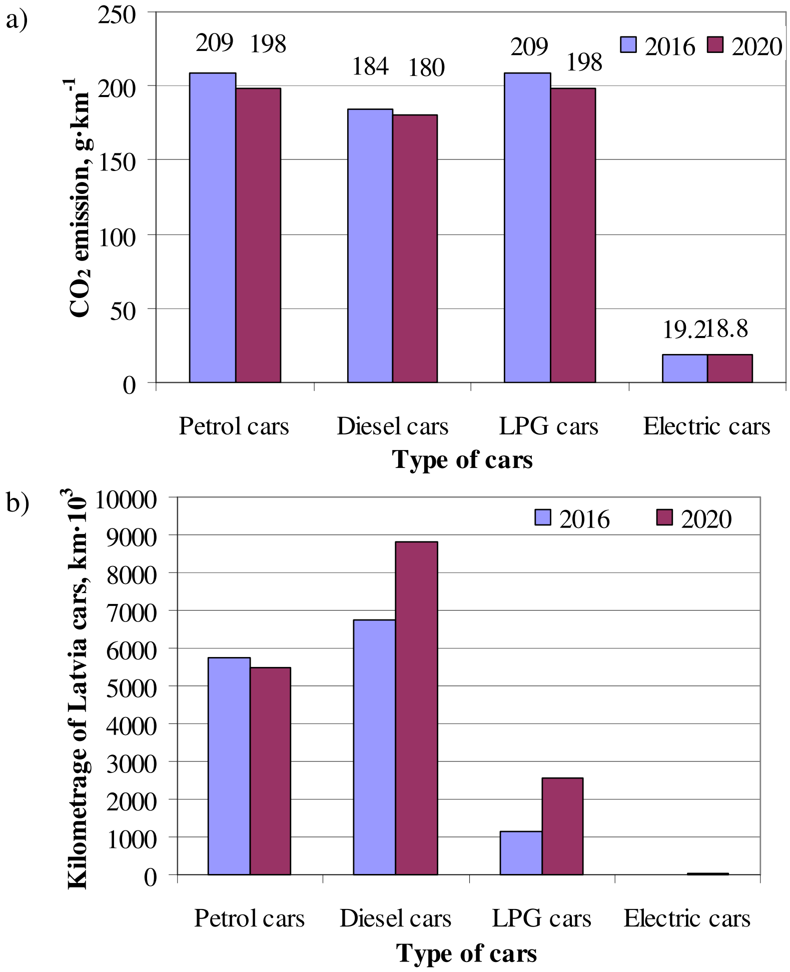

Fig. 4. **Emission-related characteristics of automobiles in Latvia in 2016 and a forecast for 2020:**
a – average amount of CO_2 emissions, g·km^{-1}, depending on the type of fuel used;
b – kilometrage of cars in Latvia, km, depending on the type of fuel used

The amount of CO_2 emissions, g·km^{-1}, and the amount of indirect CO_2 emissions per km from electric automobiles are from 12 to 13.7 times smaller than those from internal combustion automobiles. The calculations do not include fuel consumption for warming up the cab of electric automobiles because such a technology is rarely used in modern electric automobiles. Compared with the proportion of internal combustion automobiles, the proportion of electric automobiles is very small; therefore, their total kilometrage in 2016 was 4468 times smaller. In 2020, the situation should slightly improve; yet, the total kilometrage of electric automobiles is 833 times smaller than that of internal combustion automobiles.

The total amounts of CO_2 emissions for all the analysed automobile groups are summarised in Fig. 5.

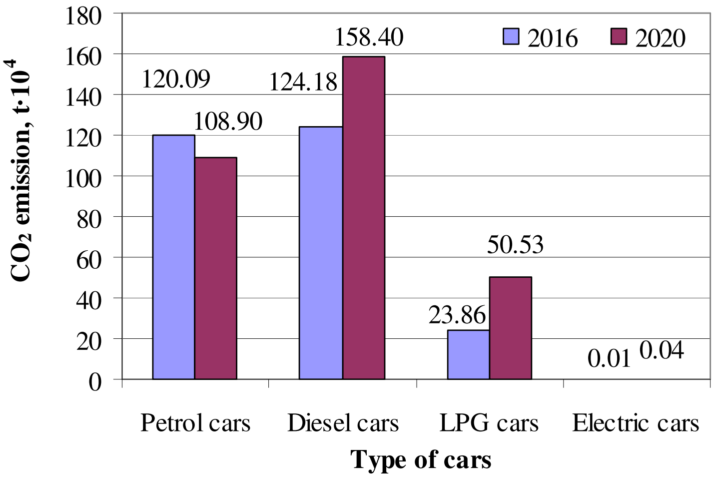

Fig. 5. **Total CO_2 amount, t a year, depending on the type of fuel used**

Due to an increase in the total number of diesel engine automobiles, their CO_2 emissions are greater and reached 1241827 t in 2016, while in 2020 the emissions are estimated at 1584000 t. The amount of indirect CO_2 emissions from electric automobiles are insignificant – 58 t in 2016 and 381 t in 2020. Even though the indirect emissions are small, they have to be taken into account if examining the entire fleet of automobiles.

Conclusions

1. In the period of analysis, the number of petrol engine automobiles has tended to decrease since 2009, whereas the number of diesel engine automobiles has gradually increased. In 2015, the number of diesel engine automobiles exceeded that of petrol engine automobiles by 5488, while in 2016 by as many as 38240.
2. Since 2009, a steady increase has been observed for the number of LPG automobiles. The numbers of diesel and petrol engine automobiles indicate the tendency to choose automobiles incurring lower fuel costs. Such a trend is positive for introduction of electric automobiles, as the general principle – the use of cheaper energy – remains if exploiting the electric automobiles.
3. A forecast of an increase in the number of electric automobiles for 2020 has to take into account the fact that government support is necessary due to the high costs of the electric automobiles that are considerably higher than those of internal combustion automobiles of the same class.
4. As the structure of automobiles develops, CO_2 emissions from each internal combustion automobile group analysed tend to decline, which indicates the use of more efficient and economical engines.
5. An algorithm for calculating CO_2 emissions from various internal combustion automobiles and electric automobiles was designed and approbated.
6. The amount of indirect CO_2 emissions from electric automobiles, $g \cdot km^{-1}$, is from 12 to 13.7 times smaller than that from internal combustion automobiles. This amount may greatly vary depending on the amounts of electric energy produced at hydro, wind and solar power plants in a country.
7. Over the next years in Latvia, the total kilometrage of the fleet of electric automobiles will be several hundreds of times smaller than that of internal combustion automobiles. The trend will improve if the number of electric automobiles considerably increases.
8. The total amount of CO_2 emissions from electric automobiles is small both due to the low proportion of electric automobiles in the total number of automobiles and due to the small amount of indirect CO_2 emissions from electrical energy production. If introducing electric automobiles intensively, it is possible to considerably reduce CO_2 emissions in the country, nearing the set limit of 95 $g \cdot km^{-1}$.
9. A considerable reduction in CO_2 emissions from the road transport sector may be achieved by replacing the existing internal combustion automobiles with at least 8-10 % electric automobiles instead of adding electric automobiles to the existing fleet of automobiles. It requires significant government support for the purchase and exploitation of electric automobiles.

10. The advantage of the method developed is the possibility to calculate CO_2 emissions in a relatively simple and direct way. High accuracy may be achieved if analysing and assessing individual vehicles or their groups. An analysis of a larger group, which consists of diverse makes of vehicles, may yield greater dispersion of the research results. The dispersion is associated with the proportion of particular motor vehicles in the group analysed and the difference in the average weighted kilometrage among the motor vehicle groups.

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