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Comparison of the environmental impact of an electric car and a car with an internal combustion engine in Polish conditions using life cycle assessment method

Abstract: The paper presents results of a comparative analysis of the environmental impact of an electric car and cars with spark ignition and compression ignition engines. The investigations were carried out with the use of the life cycle assessment (LCA) method, with the processes related to the manufacturing, operation, and disposal of the vehicles when worn out being taken into account in the analysis. The life cycle assessment was made according to the ReCiPe method, with taking into account ten impact categories. The results obtained have indicated very high susceptibility of the ecological properties of electric cars to the electricity generation technology used. In Polish conditions, where most of the electric energy is obtained from coal and lignite combustion processes, the use of electric cars may result in a higher environmental load than it is in the case of motor vehicles with internal combustion engines.

Keywords: *electric vehicles, internal combustion engine vechicles, life cycle assessment (LCA), electric energy*

Porównanie oddziaływania na środowisko samochodu z napędem elektrycznym i samochodu z silnikiem spalinowym w warunkach polskich z zastosowaniem metody oceny cyklu istnienia

Streszczenie: W pracy przedstawiono wyniki analizy porównawczej oddziaływania na środowisko samochodu elektrycznego i samochodów z silnikami spalinowymi – o zapłonie iskrowym i o zapłonie samoczynnym. Do badań wykorzystano metodę oceny cyklu istnienia (LCA). W analizie uwzględniono procesy związane z wytwarzaniem, eksploatacją, a także zagospodarowaniem pojazdów po zużyciu. Oceny wpływu cyklu istnienia dokonano metodą ReCiPe biorąc pod uwagę dziesięć kategorii wpływu. Uzyskane wyniki ukazują bardzo dużą wrażliwość właściwości ekologicznych samochodów elektrycznych na technologię wytwarzania energii elektrycznej. W warunkach polskich, w których większość energii elektrycznej pochodzi z procesu spalania węgla kamiennego i węgla brunatnego, użytkowanie samochodów elektrycznych może powodować większe obciążenie środowiska niż użytkowanie samochodów z silnikami spalinowymi.

Słowa kluczowe: *samochody elektryczne, samochody z silnikami spalinowymi, ocena cyklu istnienia (LCA), energia elektryczna*

1. Introduction

The dynamic development of electric cars that can be observed in the recent years reflects the hopes put on them for solving the basic problems related to the harmful environmental impact of motorization, i.e. air pollution and depletion of non-renewable natural resources, especially the resources of the raw materials used for the production of engine fuels. In this respect, electric cars may seem to be a very attractive solution: they do not emit pollutants when being used, which is of special importance for air quality in central parts of big cities; they are characterized by low noise emission; and the efficiency of electric motors is much higher than that of the internal combustion (IC) engines being in common use [8, 12, 18].

Actually, however, the assessment of environmental impact of electric cars, especially when aimed at comparing them with motor vehicles with IC engines, is a very complex issue and it requires considering many factors that operate outside of the area of vehicle use.

As regards electric cars, an issue of particular importance is the method of generation of the electric energy used to charge vehicle batteries [8]. This is because the environmental load caused by power plants is very much diversified, depending on the raw materials used and the energy carrier processing technologies employed. As an example, Fig. 1 shows the specific carbon dioxide, sulphur dioxide, and nitrogen oxides emissions accompanying the electricity generation processes based on the combustion of fossil fuels such as coal, fuel oil, and natural gas and on the use of renewable energy sources such as water, wind, and solar radiation [8]. As it can be seen in the graph, the most unfavourable solution among those presented is, in terms of environmental protection, the variant with power plants fuelled with coal, while hydroelectric and wind power plants are most environment-friendly.

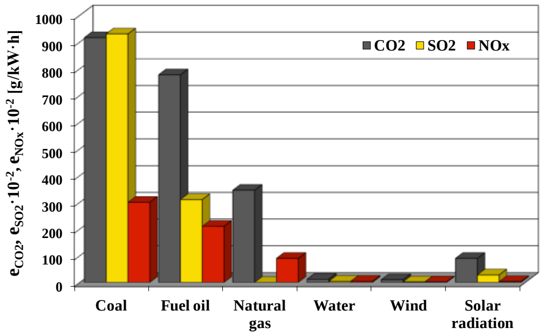

Fig. 1. Specific carbon dioxide, sulphur dioxide, and nitrogen oxides emissions resulting from electricity generation with the use of various energy carrier

The structure of electric energy in selected OECD countries, by energy sources (power plant types) [15], has been presented in Fig. 2. At present, nuclear power plants, which supply 25% of the total amount of the electricity generated, predominate in Europe. They are followed by the power plants where energy is obtained, in descending order, from natural gas (23% of the total), water (16%), coal (14%), and lignite (9%). Of course, these shares vary within very wide ranges when taken separately for individual countries. The Polish power industry is almost exclusively based on the combustion of coal and lignite, from which, taken in aggregate, about 87% of all the electric energy is obtained. In Norway, by contrast, as much as 95% of all the electric energy comes from hydroelectric power plants; in Switzerland and Sweden, this figure is 55% and 47%, respectively. It is also worth emphasizing that even in one specific country, the shares of electricity obtained from different sources are not constant, because they vary depending on region, season, or even time of the day [18, 26].

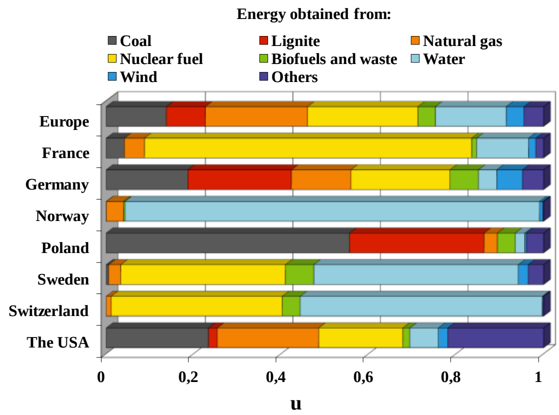

Fig. 2. Structure of electric energy in selected countries, by energy sources

Due to high susceptibility of the environmental impact assessment of electric cars to the method of electricity generation, there are only a limited number of countries at present where vehicles of this kind may be considered attractive in terms of environmental protection. In this study, the potential environmental impacts of an electric car and a car with an internal combustion (IC) engine used in Poland were assessed and compared with each other. This was done with the use of the life cycle assessment (LCA) method. In the investigations, the approach presented by Hawkins *et al.* [13] was adopted. Differences in the construction of drivetrains of both vehicle types were taken into account. Special stress was put on the processes of electricity generation with the use of different technologies.

2. The life cycle assessment method

The life cycle assessment (LCA) method is an analytical tool for quantitative determining of the potential environmental impact of the processes related to the whole conventional period of existence ("life cycle") of a specific object [5, 16]. In the case of motor vehicles, this period consists of four stages: designing, manufacturing, operation, and disposal when the vehicle is worn out. However, the designing is usually skipped in analyses because of difficulties in the quantification of the environmental load caused by this stage [5, 12].

General guidelines concerning the investigations carried out with the use of the LCA method have been provided in standards ISO 14040 and ISO 14044. The LCA begins with defining the goal and scope of the analysis, which is followed, in succession, by the "life cycle inventory" (LCI), "life cycle impact assessment" (LCIA), and interpretation of results [5, 16].

The life cycle of the vehicle is presented in the form of a system of interrelated processes, for which sets of input and output quantities are defined together with the units of measure of these quantities. A "functional unit" is also selected (e.g. kilometre – km], passenger-kilometre – pkm, or ton-kilometre – tkm), to which the analysis results will be subsequently referred. Then, quantitative data on all the input and output quantities are collected. Based on this information, material and energy balances are compiled and potential environmental impacts are assigned to their results.

The environmental load in the life cycle assessment method is classified with taking as a basis individual impact categories and areas of protection, with the latter being defined as combinations of several impact categories. Examples of the impact categories may be climate change; ozone layer depletion; eutrophication; acidification; smog formation; damage to ecosystem quality; damage to human health; depletion of fossil fuel, mineral raw material, and water resources; or changes to areas with natural ecosystems [5, 16]. According to ISO, there are three major types of the areas of protection, i.e. human health, natural environment, and resources. To calculate values of the indicators of individual environmental impact categories, a number of impact assessment methods may be used, such as: CML 2002, Eco-indicator 99, EDIP, EPS2000, Impact 2002+, LIME, LUCAS, MEEup, ReCiPe, Swiss Ecological Scarcity, TRACI, or USEtox [5, 16].

3. Assumptions and input data for the LCA analysis

The main objective of the LCA analysis was to compare the environmental impacts of an electric car and a car with an IC (compression-ignition or spark-ignition) engine. A secondary detailed objective was to investigate the susceptibility of the results obtained to the environmental load connected with the electricity generation method.

In this study, partial results of the works presented by Hawkins *et al.* [13] were used.

The analysis was carried out on two passenger cars: Nissan Leaf with an electric drivetrain and Mercedes Benz A-Class with two engine versions i.e. with a compression-ignition (CI) and spark-ignition (SI) engine. These cars are similar to each other in terms of their size, mass, engine power rating, and performance characteristics (Table 1).

The scope of the LCA analysis included the vehicle manufacturing, operation, and end-of-life as well as the processes related to electricity generation and production of engine fuels, i.e. petrol and diesel oil.

For the two types of vehicle drivetrains to be effectively compared with each other, all the important differences in their construction must be taken into account. For this reason, the general model of the vehicle was divided into assemblies which included elements specific to each of the versions under consideration, e.g. engine, power transmission system, or batteries, and universal assemblies, including vehicle body, undercarriage, brakes, wheels and tyres, vehicle interior trim components, and external parts (Fig. 3).

The model of the vehicle except for its drivetrain (for both the solutions assessed) was built with the use of the GREET 2.7 model [2], which was adapted to the characteristics of the Mercedes Benz A-Class car [6]. Detailed quantitative data on the construction and manufacturing of the major car assemblies were taken from the literature ([2, 6, 29, 31] for the vehicle body, [2, 25] for the undercarriage, [2, 14] for the interior trim components and external parts, [2, 9, 24, 30] for brakes, and [2, 14, 20, 21, 25] for wheels and tyres).

Basic assumptions concerning the electric drivetrain were made on the grounds of technical specifications of the Nissan Leaf car [22]. The information about the life cycle of its individual components was sourced from commercial reports of ABB [1] and literature [2, 14, 21, 24, 25, 29]. From among several battery types available, a lithium-ion battery pack with nickel manganese cobalt oxide cathode (Li-NCM) of 214 kg total mass was selected. The lithium-ion batteries are expected to predominate in automotive applications in the nearest years [13]. The data on the life cycle of the batteries were sourced from publication [19].

Table 1. Basic technical specifications of the Nissan Leaf and Mercedes Benz A-Class cars

Description	Unit	Nissan Leaf	Mercedes Benz A-Class
Body type		5-door hatchback	5-door hatchback
Number of seats		5	5
Curb weight	kg	1 521	1 225–1 365*
Length	mm	4 445	3 838
Width	mm	1 770	1 764
Height	mm	1 550	1 593–1 595*
Engine power rating	kW	80	60–142*
Acceleration time (0–100 km/h)	s	11.9	11.5–13.5*
Range (NEDC)	km	175	750–1 102*
Energy storage capacity of the battery pack	kW·h	24	
Electric energy consumption (NEDC)	kW·h/100 km	17.3	
Fuel tank capacity	dm^3		54
Fuel consumption (NEDC)	dm^3/100 km		4.9–5.4 (CI), 6.2–7.2 (SI)*

* Values for models CDI A160, A170, A180

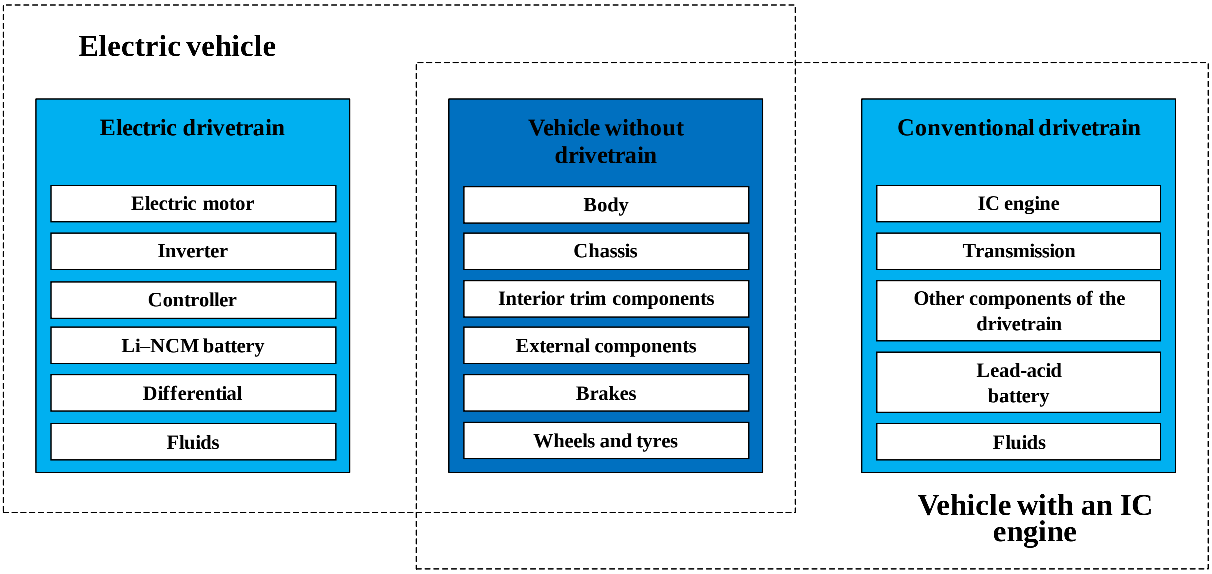

Fig. 3. Vehicle structure models considered, representing the electric vehicle and the vehicle with an IC engine

The model of the conventional vehicle drivetrain with an IC engine was based, first of all, on the GREET 2.7 model and on the materials, energy, and pollutant emissions balance for the engine of the Volkswagen Golf A4 car [25]. Information about the lead-acid battery may be found in publications [7, 23]. The other quantitative data on the power transmission system and the operating fluids were also taken from the literature [14, 17, 21, 29, 31–33].

The vehicle operation stage was considered with taking into account the electric energy consumption for the electric vehicle and the fuel consumption and pollutant emissions for the vehicles with an IC engine. These quantities were assumed on the grounds of results of testing the Nissan Leaf car [22] and the Mercedes Benz A-Class car (models CDI A160, A170, and A180) [6] according to the NEDC (New European Driving Cycle) type-approval driving test in compliance with the procedures specified in UN ECE Regulations Nos. 83 and 101. The NEDC test consists of four cycles simulating the vehicle driving in urban traffic conditions and one cycle simulating the driving in extra-urban traffic conditions. In the case of the electric vehicle, the 12 hour battery recharging (referred to as normal night-time battery recharging) and the related energy losses are taken into account.

It should be stressed here that the type-approval driving tests do not fully represent the actual vehicle operation conditions; hence, the values of the quantities measured during such tests may differ from those occurring in the reality. Due to the key role of the vehicle operation stage in the life cycle assessment of a motor vehicle, the assessment is very susceptible to the assumptions made with respect to pollutant emissions and energy consumption [5]. The fact that data obtained from NEDC tests were used for this analysis was caused by unavailability of results of testing the vehicles under investigation in road driving conditions. Such an approach, however, may be considered acceptable in the case of comparative analyses of different engineering solutions.

Apart from the IC engine, which emits particulate matter with exhaust gases, important sources of dust emissions from motor vehicles are tribological pairs (brakes, clutch), tyres and road surface material, materials of other vehicle parts that undergo wear, and road dust stirred up by moving vehicles [4]. In this analysis, the wear of friction brake materials [9] and tyres [24] was taken into account.

The assumptions concerning the vehicle operation, including the replacement of worn out components, were based on literature data [13].

The processes related to the preparation of fuels, i.e. petrol and diesel oil, pertain to general European conditions. As regards the electricity generation, the following variants were considered: technologies based on the combustion of fossil fuels, i.e. coal, lignite, natural gas, and fuel oil; wind utilization technology representing the renewable energy sources; and a mixed variant, covering various power plant types typical for Europe. The necessary data were obtained from the Ecoinvent database.

The end of life of a vehicle includes dismantling, waste landfilling, and recycling in accordance with the approach adopted in the Ecoinvent database [28]. The duration of the battery service life, expressed by a distance of 150 000 km travelled by the vehicle, was adopted on the grounds of the literature [13, 19]. The information about the battery recycling was obtained from the same source.

The functional unit for the LCA analysis was assumed as a distance of 1 km travelled by the motor vehicle. According to data published by the Central Statistical Office [11], the average period of existence of a passenger car in Poland is 15.5 years. The average number of kilometres annually travelled by a passenger car operated in Poland was estimated in a Motor Transport Institute's (ITS) report [34] at 12 016 km and 5 876 km for vehicles with CI and SI engines, respectively (based on data of 2010). The averaging of these data worked out at the total average number of kilometres travelled by a passenger car in Poland being 138 663 km. For the analysis, a distance of 150 000 km was assumed. This figure is most frequently adopted in LCA analyses [6, 13, 25, 33], although other values, ranging from 100 000 km to 300 000 km are also met [12].

The life cycle assessment was made according to the ReCiPe method [10], which combines together the advantages of the midpoint and endpoint approach. The investigation results were expressed at the endpoint level, for ten selected impact categories presented in Table 2. The unit of measure of the impact category indicators is gram – g. Hence, the LCA results related to the functional unit will be expressed in grams per kilometre – g/km.

Table 2. The impact categories selected for the analysis from the ReCiPe method [10]

Impact category	**Reference substance**	**Reference substance symbol**	**Unit**
Climate change	Carbon dioxide	CO_2	g
Terrestrial acidification	Sulphur dioxide	SO_2	g
Particulate matter formation	PM10	PM_{10}	g
Photochemical oxidant formation	NMVOC (Non Methane Volatile Organic Compounds)	NMVOC	g
Human toxicity	1,4–Dichlorobenzene	1,4–DCB	g
Freshwater ecotoxicity	1,4–Dichlorobenzene	1,4–DCB	g
Terrestrial ecotoxicity	1,4–Dichlorobenzene	1,4–DCB	g
Freshwater eutrophication	Nitrogen	N	g
Mineral resource depletion	Iron	Fe	g
Fossil resource depletion	Crude oil	Oil	g

4. Results of the LCA analysis

The following symbols were used for the presentation of analysis results. Vehicle symbols:
- Electric vehicle – EV;
- Vehicle with an internal combustion engine, compression-ignition – ICEV CI;
- Vehicle with an internal combustion engine, spark-ignition – ICEV SI.

Electric energy source symbols:
- Wind power plants – W;
- Power plants fired with natural gas – NG;
- Power plants fired with fuel oil – FO;
- Power plants fired with coal – C;
- Power plants fired with lignite – L;
- Miscellaneous power plants with a share typical for Europe – M.

The environmental loads caused by electric vehicles and vehicles with internal combustion engines in the ten impact categories have been shown in Figs. 4–13. The graphs were built with distinguishing the vehicle manufacturing processes, where separate attention was paid to the vehicle components present in both vehicle types (i.e. the components except for the drivetrain) and to the parts being specific to one of the vehicle types (i.e. electric motor or IC engine, power transmission system, and batteries); the processes of vehicle operation; the processes of electricity generation or fuel preparation and of electric energy or fuel consumption; and the disposal of the vehicle when worn out. The analysis results for the vehicle manufacturing stage have been presented with so high a degree of minuteness because of an intention to investigate the environmental impact of the battery pack of the electric vehicle. The area marked as "fuel" represents the fuel preparation process and the pollutant emissions from the IC engine during the vehicle use. Thus, this area may be compared with the electric energy generation, which, in most cases, is also a source of pollutant emissions.

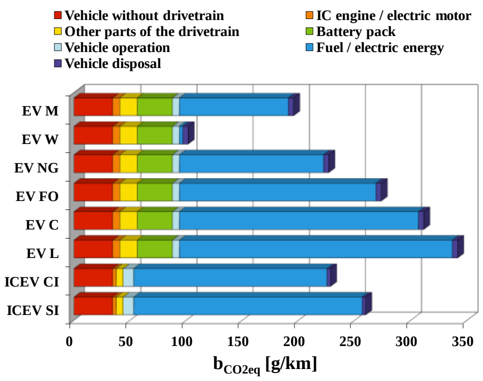

Fig. 4. Environmental loads caused by the vehicles in the "climate change" impact category

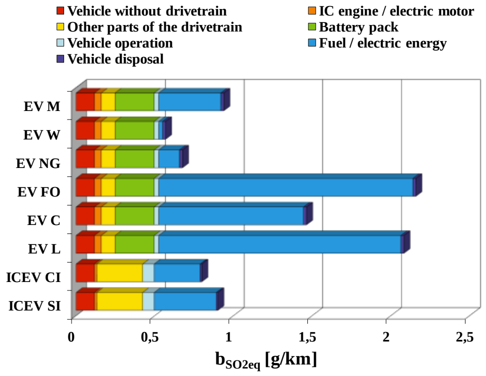

Fig. 5. Environmental loads caused by the vehicles in the "terrestrial acidification" impact category

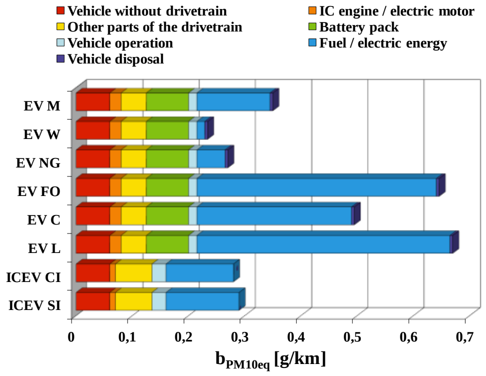

Fig. 6. Environmental loads caused by the vehicles in the "particulate matter formation" impact category

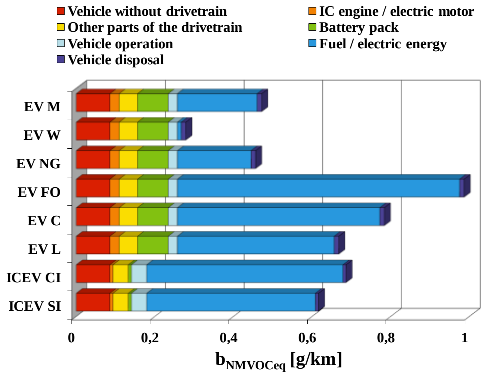

Fig. 7. Environmental loads caused by the vehicles in the "photochemical oxidant formation" impact category

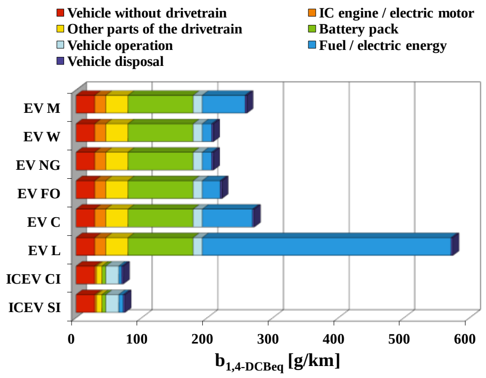

Fig. 8. Environmental loads caused by the vehicles in the "human toxicity" impact category

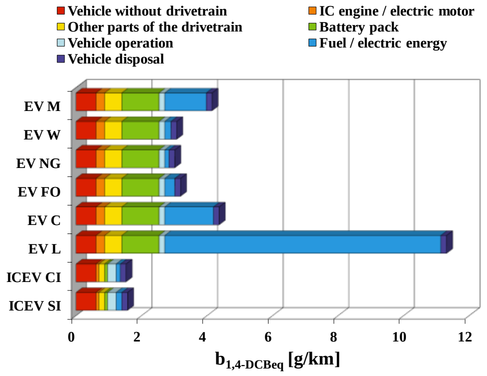

Fig. 9. Environmental loads caused by the vehicles in the "freshwater ecotoxicity" impact category

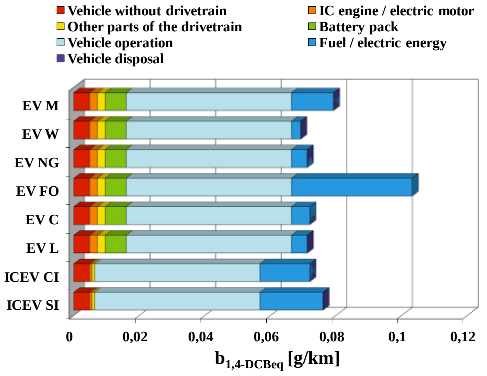

Fig. 10. Environmental loads caused by the vehicles in the "terrestrial ecotoxicity" impact category

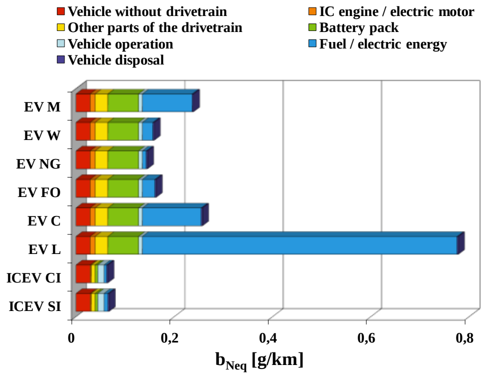

Fig. 11. Environmental loads caused by the vehicles in the "freshwater eutrophication" impact category

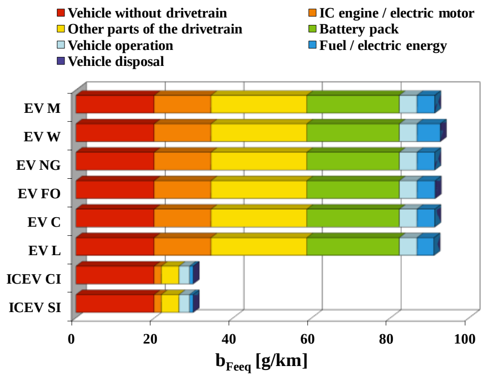

Fig. 12. Environmental loads caused by the vehicles in the "mineral resource depletion" impact category

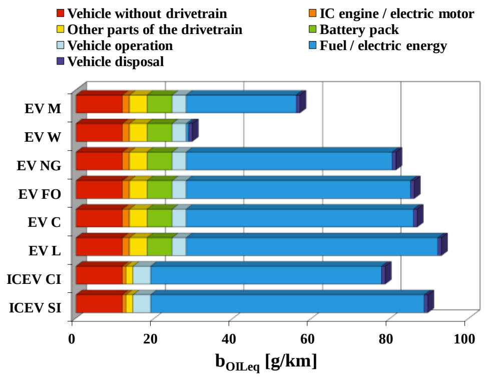

Fig. 13. Environmental loads caused by the vehicles in the "fossil resource depletion" impact category

For all the versions considered, the vehicle manufacturing stage constitutes a predominating source of environmental load with respect to the mineral resource depletion, human toxicity, and freshwater ecotoxicity (in the last two categories, an exception is the case where the electric vehicle uses electricity obtained from the combustion of lignite). The stages of vehicle operation together with fuel or electricity preparation play the greatest role in the categories of climate change, terrestrial ecotoxicity, and fossil resource depletion. The vehicle disposal is of minor importance in all the impact categories.

The manufacturing of electric vehicles exerts definitely stronger environmental impact than the manufacturing of vehicles with IC engines, with the processes related to the manufacturing of electric drivetrain and batteries having a significant share in this impact. This unfavourable situation is compensated by lower pollutant emissions when the electric vehicles are in use, but this only applies to some of the impact categories, depending on the electric energy source at that.

In the "climate change" impact category (Fig. 4), the vehicle use is the issue of primary importance, because of both the direct greenhouse gas emissions due to fuel combustion in the engine and the indirect emissions connected with electricity generation. The potential total greenhouse gas emissions for the electric vehicle fed with the "European" electric energy are lower by 25% and 14% than those for the vehicle with an SI and CI engine, respectively. In the case of using electricity obtained from wind power plants, even greater benefits may be expected, as the greenhouse gas emissions may be then reduced by 61% and 56%, respectively. On the other hand, if electric energy obtained from the combustion of coal is taken into account in a similar context, then the greenhouse gas emissions for the whole life cycle of the electric vehicle exceed those for the motor vehicle with an SI and CI engine by 20% and 36%, respectively. The least beneficial situation takes place when electricity generated by the combustion of lignite is used: in such a case, the greenhouse gas emissions for the electric vehicle are higher than those for the vehicle with an internal combustion engine by 32% (SI) and 50% (CI).

The greenhouse gas emissions related to the manufacturing of the electric vehicle are almost twice as high as those for the motor vehicle with an IC engine, with the production of electric batteries being accountable for 35% of the total. It is worth emphasizing here that when the "European" electric energy is used then as much as a half of the greenhouse gas emissions for the life cycle of the electric vehicle are related to the vehicle manufacturing stage.

The impact of the vehicle manufacturing stage on the terrestrial acidification (Fig. 5) is similar to that of all the other solutions under assessment. In this respect, the acquisition of some metals such as nickel, copper, aluminium, or platinum-group metals is particularly harmful to the environment [12]. In the electric vehicle, such metals are present in the motor and batteries; in the vehicle with an IC engine, they are present in the catalytic reactor.

In the ReCiPe method, the main indicator of terrestrial acidification is the emission of sulphur dioxide. For this reason, the biggest differences between the solutions assessed are observed for the vehicle operation stage, when this substance is directly emitted by a vehicle with an IC engine or indirect emission of this substance takes place in connection with electricity generation. In respect of protection of the environment from acidification, electric vehicles are not a favourable solution in the countries where a significant part of electric energy is generated by the combustion of coal, lignite, and fuel oil, because such processes cause very high sulphur dioxide emissions. This situation may be expected to improve with an increase in the proportion of electric energy obtained from natural gas and, above all, from renewable energy sources such as wind or water.

The analysis results concerning the particulate matter emission in the vehicle life cycle (Fig. 6) are similar to those obtained for the acidification and they are based on identical dependencies. In this respect, the electric vehicles in combination with electricity obtained from wind and gas-fired power plants constitute the best solution. The second and third position is occupied by motor vehicles with spark-ignition and compression-ignition IC engines, respectively. The particulate matter emissions from the combustion of coal and fuel oil are too high for electric vehicles supplied from these energy sources to be considered an attractive solution from the environmental protection point of view. On the other hand, the harmful impact of power plants of such types is usually exerted on areas of low population density, where the power plants are located.

The "photochemical oxidant formation" impact category, related to the formation of photochemical smog, sometimes referred to as Californian smog

(Fig. 7), is among the impact categories in which electric vehicles may be superior to vehicles with IC engines. An exception is the case with coal or fuel oil being used for electricity generation, where the photochemical oxidant formation indicator value exceeds those for motor vehicles with SI and CI engines by 44% and 60%, respectively.

The LCA results for the "human toxicity" impact category (Fig. 8) constitute an example of the problem referred to as "environmental burden shifting," encountered when electric vehicles are compared with motor vehicles with IC engines. At both the manufacturing and operation of electric vehicles, the value of this indicator is much higher than that for vehicles with IC engines, by about 180% in the best case for electricity obtained with the use of wind or natural gas but even by 696% for the version with lignite. The toxic impact of electric vehicles is chiefly caused by the processes related to the production of copper and nickel and to the extraction of some raw materials, including the extremely harmful processes of lignite extraction and disposal of the wastes simultaneously generated [12]. Similar trends are also observed in the "freshwater ecotoxicity" and "freshwater eutrophication" impact categories (Figs. 9 and 11, respectively).

In the "terrestrial ecotoxicity" impact category (Fig. 10), the heavy metal emissions resulting from the wear of brakes and tyres predominate. In this respect, the results obtained for all the solutions under assessment are similar to each other.

The "mineral resource depletion" (Fig. 12) for electric vehicles is about three times as high as that for vehicles with IC engines, because the construction of the former requires the use of much more metals of various kinds. Many of these metals occur quite rarely, which means that a problem with short supplies may be encountered in the future.

The use of electric vehicles may result in a reduction in depletion of the fossil fuel in comparison with vehicles with SI and CI engines (Fig. 13) by 27% and 36%, respectively, for the version with "European" electricity and even by 62% and 67%, respectively, for wind power plants. Of course, this is not applicable to the cases where electric energy is predominantly obtained from fossil fuels, as it is currently in Poland.

5. Conclusions

Based on the investigations carried out, the following conclusions may be formulated:

1) For unbiased comparison between the environmental impacts of vehicles driven by electric motors and IC engines to be possible, the whole conventional life cycle of such vehicles, especially the fuel production and electricity generation processes, must be taken into account. The results of analyses where only the energy consumption and efficiency of such vehicles during their operation are taken into account may be misleading.
2) Electric cars may only be considered an effective method of reducing the harmful environmental impact of motorization on the condition that the energy used for powering such vehicles is generated with the use of technologies that do not cause excessive environmental load. Examples of such solutions are wind, hydroelectric, solar, and nuclear power plants. In contrast with them, the power plants where fossil fuels, i.e. hard and lignite and fuel oil, are used have a very harmful environmental impact.
3) The vehicle manufacturing stage is an important factor for comparing and assessing the ecological properties of electric cars and motor vehicles with IC engines. In this respect, electric vehicles are characterized by higher environmental load, in particular by doubled greenhouse gas emissions, trebled mineral resource depletion, and almost four times as high human toxicity and water ecotoxicity.
4) Electric cars have only been mass-produced for quite a short time and the technical and technological solutions applied to them are being continuously improved (say, new types of battery packs may be mentioned here as an example). Therefore, the values of some parameters important for the LCA analysis, e.g. the range of vehicle operation, efficiency of the drivetrain, or battery charging efficiency, change very quickly. With progress in the field of electric vehicles, further improvements in their ecological properties may be expected to appear in the nearest future.
5) In this analysis, batteries of only one type were taken into consideration; moreover, an assumption was made that the battery service life was equal to the total vehicle's period of operation. Therefore, further investigations are needed for the environmental impact of electric cars with batteries of other types to be determined, with the actual durability of the batteries being taken into account.

Results of the analysis carried out suggest that the promotion of electric cars in the areas where a large part of electric energy is obtained from the combustion of coal, lignite, and fuel oil is not recommendable from the environmental protection point of view. Unfortunately, Poland is among such areas. On the other hand, electric vehicles virtually do not emit pollutants at the places where they are used. Therefore, the replacement of motor vehicles driven by IC engines with electric vehicles would mean the elimination of a very large number of mobile pollutant emission sources from roads with replacing them with isolated ones (i.e. power plants), which are easier to be controlled and optimized. It is not an unimportant fact, either, that the promotion of electric vehicles may be an incentive to undertake actions aimed at raising the share of electricity obtained from renewable sources in the total energy market in Poland.

Nomenclature/*Skróty i oznaczenia*

LCA Life Cycle Assessment/*ocena cyklu istnienia*
LCI Life Cycle Inventory/*analiza zbioru*
LCIA Life Cycle Impact Assessment/*ocena wpływu cyklu istnienia*
EV Electric Vehicle/*samochód elektryczny*
ICEV Internal Combustion Engine Vehicle /*samochód z silnikiem spalinowym*
CI Compression Ignition engine/*silnik o zapłonie samoczynnym*
SI Spark Ignition engine/*silnik o zapłonie iskrowym*
C Coal powerplant/*elektrownia wykorzystująca węgiel kamienny*
FO Fuel oil powerplant/*elektrownia wykorzystująca olej opałowy*
L Lignite powerplant/*elektrownia wykorzystująca węgiel brunatny*
M Miscellaneous power plants with a share typical for Europe/*różne rodzaje elektrowni, struktura typowa dla Europy*
NG Natural gas powerplant/*elektrownia wykorzystująca gaz ziemny*
W Wind powerplant/*elektrownia wiatrowa*

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