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TRANSITION FROM INTERNAL COMBUSTION ENGINES TO ELECTRIC MOTORS – LEGAL AND ORGANIZATIONAL DIMENSIONS

PRZEJŚCIE Z SILNIKÓW SPALINOWYCH NA SILNIKI ELEKTRYCZNE – WYMIAR PRAWNY I ORGANIZACYJNY

***Abstract*:** The authors of the paper have studied the current tendencies in motor transport, threats to the ecological safety of people from the introduction of new technologies in this area and the main legal mechanisms to reduce the negative impacts on humans caused by vehicles. The main environmental problems in this area are: accumulation of used batteries from battery-powered vehicles as hazardous waste and the problem of their unified disposal; redistribution of emissions from transport operations, but not their reduction; focusing on only one technology – battery-powered electric vehicles; energy costs of transport and sources of their coverage. The authors offer the basis of legal mechanisms for overcoming the studied problems both in Ukraine and in the countries of the world.

***Zarys treści*:** Autorzy artykułu zbadali aktualne tendencje w transporcie samochodowym, zagrożenia dla bezpieczeństwa ekologicznego ludzi wynikające z wprowadzania nowych technologii w tym zakresie oraz główne mechanizmy prawne ograniczania negatywnych oddziaływań pojazdów na ludzi. Główne problemy środowiskowe w tym obszarze to: gromadzenie

zużytych akumulatorów z pojazdów zasilanych bateryjnie jako odpady niebezpieczne oraz problem ich jednolitej utylizacji; redystrybucja emisji z operacji transportowych, ale nie ich redukcja; skupienie się tylko na jednej technologii – pojazdach elektrycznych zasilanych bateriami; koszty energii transportu i źródła ich pokrycia. Autorzy przedstawiają podstawy prawne mechanizmów przezwyciężania badanych problemów zarówno na Ukrainie, jak i w krajach świata.

Key words**:** battery vehicles, motor transport, ecological safety, environmental protection, ecological legislation
Słowa kluczowe**:** pojazdy akumulatorowe, transport samochodowy, bezpieczeństwo ekologiczne, ochrona środowiska, przepisy ekologiczne

Society and countries began to pay more attention to sustainable development in the second half of the 20th century – a concept based on the principles of preserving the environment by the current generation in a state that makes it possible for future generations to use natural resources of no less quality. To realize this, various programme and legal documents were adopted at the international level, in each area or sphere of public life – socio-demographic, industrial, environmental, etc.

Each country can develop its own programme and legal documents and is free to use or not to use international recommendations while developing them, if such a country has not previously undertaken the relevant international legal obligations in a particular area.

The developed countries of the world are making more and more efforts for the ecologization of material production, energy and transport. This is most noticeable in the field of motor transport because the vast majority of the population of these countries own vehicles. Due to the high concentration of populations in cities and the daily use of automotive transport, the air quality decreases and harmful acoustic loads increase, etc. The unproductive loss of time increases due to traffic jams, which also affects fatigue levels and final productivity, as well as forcing people to work in hazardous conditions. Thus, according to road traffic monitoring services, on average the time spent in traffic jams in Kyiv is 46%.[1] This indicator ranges from 82% up to 103% during the rush hours, when the largest movement of commuters occurs, and can reach 130%.[2] Most importantly, a significant part of the working population spends a certain amount of time in areas with the highest concentration of pollutants – on highways. If a total of 40 minutes per working day, including scheduled stops, over a total of 220 working days per year is spent commuting, a person is exposed to these harmful conditions for 146 hours per year, which is the equivalent of 18 working shifts. This is prompting governments to impose increasingly strict requirements for vehicles.

Increasingly stringent conditions for the production and operation of vehicles are pushing carmakers to make significant investments in the development of more

[1] *Skolko vremeni kievlyane tratyat iż za probok*, https://nashkiev.ua/novosti/skolko-vremeni-kievlyane-tratyat-iz-za-probok.html?in_parent=novosti, [access: 08.12.2020] [in Russian].
[2] *Kyiv traffic*, https://www.tomtom.com/en_gb/traffic-index/kiev-traffic, [access: 08.12.2020, 2020].

advanced engines and equipment and, sometimes, outright fraud. This is confirmed by the recent 'Dieselgate' scandal, with the installation of vehicle software which detected whether or not a vehicle was being tested and, if so, underestimated the vehicle's emissions. 'Dieselgate' has become a catalyst for a series of bans on diesel vehicles in a number of European cities. However, the situation did not stop at the ban on diesel vehicles in some cities. A number of countries have announced the complete transition of vehicles to electric power plants and the abandonment of internal combustion engines. Thus, Norway plans to introduce a ban on internal combustion engines from 2025, Germany from 2030 and France from 2040.

The situation in Ukraine in this direction is mostly unchanged and diametrically opposite to that in Europe. Thus, Ukraine has adopted programmes of gradual introduction of environmental requirements for vehicles, which are known as 'Euro-4', 'Euro-5' and 'Euro-6'. Currently there is a requirement for the commissioning of vehicles that meet the requirements of the 'Euro-5' programme; the plan was to introduce the 'Euro-6' programme from January 1, 2020, but the introduction of these standards has been postponed to 2025. Moreover, as a result of a series of protests and the corresponding liberalization of customs legislation, it is possible to import and register in Ukraine used cars that do not meet the requirements of the 'Euro-5' programme as an exceptional, temporary measure. To stimulate the development of electric vehicles markets Ukraine has introduced customs clearance benefits, as well as initiating an independent series of state license plates with green inscriptions. Ukraine has not adopted the relevant standards with regard to the banning of internal combustion engines.

It should be noted that Ukraine, as well as the rest of the world, in order to reduce carbon dioxide emissions from vehicles, once stimulated and developed technologies for the use of mixtures including raw materials derived from renewable products (of animal or vegetable origin) as motor fuel, in particular bio-ethanol and biodiesel. There were attempts to mandate the addition of a certain proportion of ethanol to petrol, but that tendency has not been developed due to the small number of vehicles that have been adapted to run on such fuels.

Therefore, we can currently state that the use of internal combustion engines for individual transport is being gradually curtailed. Using motor fuel from renewable sources solves only one problem – reducing greenhouse gas emissions. Other problems remain unresolved. In the process of fuel combustion under ideal conditions, water and carbon dioxide should be formed, but in practice it is different. First of all, the fuel always contains impurities which do not only form water and carbon dioxide while being burned. All protein structures of living organisms contain sulphur and nitrogen, which inevitably get into the fuel, although in small quantities. The combustion of such impurities produces oxides of sulphur and nitrogen, which are part of exhaust fumes and cause acid rain. Secondly, atmospheric nitrogen is oxidized at high combustion temperatures in the engine and forms nitric oxide of different valences. Most of these compounds are neutralized in vehicle systems, in particular in catalytic converters. However, some of these compounds still enter the atmosphere.

Considering the significant concentration of vehicles in cities, even insignificant emissions are multiplied by the large number of vehicles, which leads to a high concentration of hazardous substances in small areas. Some cities, during windless weather, are covered with clouds of smog which are dangerous for all city residents, not only those who use transport.

In addition, the use of fuel containing products of animal or vegetable origin has faced certain ethical problems. Land is used for growing crops suitable for the production of bio-ethanol and biodiesel, i.e. part of the land is used for fuel production and not for producing food. Certain crops, in particular maize, can be used both as a food crop and as an energy crop for bio-ethanol production and this is happening while the world has not overcome the problem of hunger in many countries. Hunger is pushing people to migrate, which is further degrading the population in certain places and creating new environmental and social problems, including in developed countries. This ethical problem does not only affect the future of motor fuel made from renewable sources.

It is necessary to start the gradual transition from internal combustion engines to electric motors in the development of motor transport. In general, in supporting such a transition, it is necessary to pay attention to certain problems that every country will inevitably face on the path to electrification of motor transport.

The first problem is the energy of transport. Electric vehicles consume energy for movement and operation of onboard systems. The required amount of energy is taken from the battery, which must be charged from the existing power supply system. Without going into all the technical aspects of this issue, it should be noted that the use of batteries as a source of energy in vehicles incurs the following types of energy loss on:

- Conversion of alternating current to direct current, the losses are not significant here – 2-5%, associated with the operation of transformers and electronics.
- Conversion of direct current and energy of chemical bonds. This process is accompanied by a significant release of heat and accounts for much of the energy consumed from the network. The amount of losses depends on the model and technology of the manufacturer. Experience in the use of electric vehicles indicates that the difference between the metered electricity consumed from the grid and that stored in the battery of the electric vehicle can be 15–30% depending on climatic conditions and the degree of battery charge.
- Losses from the reverse conversion of the energy of chemical bonds into electricity are difficult to track, but purely technically they exist and can not be denied due to the very characteristics of the processes occurring in the battery.

These losses may increase over time due to battery degradation. In addition, such losses must be taken into account within technical and economic grounding of the introduction of electric vehicles in certain industries (emergency vehicles, public transport, etc.).

The ability of the existing power supply network to accept loads from chargers must be taken into account. It should be noted that there are certain advantages for

energy networks when citizens use them to charge electric vehicles. Charging usually occurs at night when the load on the network is minimal and the amount of unproductive losses of the grid from downtime is increased. Electric vehicles can minimize such fluctuations, but this is true only for a nationwide power generation system. However, private housing power supply systems, especially in Ukraine, were not designed to charge electric vehicles. Therefore, the mass transition to electric vehicles should be accompanied by the modernization of the energy network.

In addition to this there is the purely environmental problem of electricity generation. Most electricity in Ukraine is generated from fossil fuels or nuclear energy. Therefore, to consider electric vehicles as vehicles with zero emissions (zero vehicles) is quite presumptuous. Electric vehicles in Ukraine, as in most countries of the world, redistribute the place of emissions and their type, partially reducing them. From the point of view of protecting the health of the population and ensuring environmental protection, individual electric transport is really a compromise between the need for comfortable transport and emissions that affect humans. In terms of the overall emissions balance of a country, or the world as a whole, electric vehicles do not significantly reduce them. However, this is not so much a problem of electrified transport but rather the global energy sector as a whole. Indeed, the zero emissions from electric vehicles can be discussed in the event of achieving a complete replacement of nuclear energy or energy from fossil fuels by energy from renewable sources. There is progress in this direction and the level of emissions associated with the operation of electric vehicles is gradually decreasing.[3]

Legislatively, this problem is solved by introducing increasingly stringent energy regulations in terms of environmental pollution and stimulating the development of alternative energy sources. In this regard, a number of regulations and policy documents have been adopted and therefore it is impractical to pay detailed attention to them in this study.

The next problem that arises in the introduction of electric vehicles is called the emission balance during their manufacture. A study was conducted in Germany comparing the manufacturing greenhouse gas emissions of a Mercedes C220d and a Tesla Model 3. According to the results of the study, the extraction and processing of lithium, cobalt and manganese required for the manufacture of batteries are very energy-intensive. The production of one battery with a service life of 10 years leads to the emission of 11–15 tons of CO_2.[4] This problem is related to the industry and the ecologization of material production. The main legal mechanisms for influencing the solution to this problem lie in the area of environmental requirements for industrial facilities. The production of electric vehicles or batteries for them is not currently undertaken in Ukraine, but if this were to change, such facilities will be subject to the general requirements for industrial facilities set out in environmental legislation.

[3] *Wie umweltfreundlich sind Elektroautos?*, https://www.bmu.de/fileadmin/Daten_BMU/Pools/Broschueren/elektroautos_bf.pdf, [access: 08.12.2020].

[4] Ch. Buchal, H.-D. Karl, H.-W. Sinn, *Kohlemotoren, Windmotoren und Dieselmotoren: Was zeigt die CO_2-Bilanz?*, https://www.ifo.de/DocDL/sd-2019-08-sinn-karl-buchal-motoren-2019-04-25.pdf, [access: 08.12.2020].

We also did not find any specific legal requirements for EU countries for the electric vehicle manufacturing industry.

In our opinion the biggest existing problem of electric vehicles, which has not yet become critical, is the batteries of vehicles. A number of environmentally harmful chemical elements that require specific disposal are used in the production of batteries. Informational material on the responsible disposal of used batteries from household appliances indicate that one 'penlight battery' of AAA type, weighing 45 gr. pollutes 20 sq.m. of soil. If we mathematically scale up such a battery to that of an electric vehicle battery weighing 240–300 kg, we get an area of pollution of more than 10 hectares.

At the end of 2019 there was a collective article published in the journal Nature on 'Recycling lithium-ion batteries from electric vehicles'.[5] The authors of the article quite thoroughly raised the technological and environmental problems associated with the future fate of used batteries. Without going into a detailed analysis of their work, we would like to underline the main problems that were identified by the authors. Market analysis and tendencies of the introduction of electric vehicles indicate the unpreparedness for the environmental problem of the accumulation of used batteries. One million electric vehicles generate 250,000 tons of hazardous waste in the form of used batteries. The main problem for the disposal of such batteries is the different approaches of the production technology and industrial design of the batteries themselves. The authors point to the variety of both the forms of batteries and the methods of their production, which makes it difficult to automate the process of disassembly of the battery for separate disposal of substances contained therein. This will require workers to be involved in the disposal process and be exposed to the attendant hazardous conditions.

The authors also draw attention to the impossibility of the burial of such waste. The reason for this is the extremely high fire hazard of such waste, including due to the effect of 'thermal acceleration'. The danger for Ukraine is even greater due to the lack of a system for segregation of household waste. If such a battery is buried together with household waste and subsequently spontaneously combusts, a single landfill will burn from one battery. The tragedy of the fire in the Hrybovytska landfill near Lviv, which took the lives of several people and caused a problem for waste disposal in the whole region, showed how dangerous fires could be at such facilities. Nobody has calculated the overall environmental consequences.

Disposal of such batteries in the long run is not advisable at all due to the exhaustion of chemical elements and the complexity and energy consumption of their extraction. This is why systems should be developed to remove useful elements from used batteries and reuse such resources.

As one of the options for a partial solution to the problem of used batteries, manufacturers offer to include them into existing energy storage systems from alternative energy sources. Despite the expediency of such a step, it should be noted that this

[5] G. Harper, R. Sommerville, E. Kendrick and others, *Recycling lithium-ion batteries from electric vehicles*, https://www.nature.com/articles/s41586-019-1682-5 [access: 08.12.2020].

only delays the problem and will eventually exacerbate it. Therefore, it is necessary to agree with the need to develop a single industrial design of batteries. Restricting and forcing manufacturers to use only one technology will undoubtedly lead to patent complications and complicate (limit) the development of technologies. An example of such an association of manufacturers around a single product design is the use of a single standard for chargers for portable equipment. Everything is a bit more complicated with electric vehicle batteries. Every manufacturer has their own device architecture and structure and their own patents for the technology. All this complicates the introduction of uniform standards for the manufacture and disposal of electric vehicle batteries. The role of legislative acts of a programme nature in this context, which set certain requirements for the future, is growing. Examples of such directives are the establishment of the requirements for vehicles known as 'Euro-2,-3,-4,-5,-6' such as Regulation (EC) No. 715/2007, which established requirements for car emissions at the level of 'Euro-5'.

Currently, there are no legal requirements in any country in the world to bring the design of batteries to a state and architecture suitable for automated and complete disposal after the end of service life. All legal requirements for batteries of electric vehicles both in Ukraine and in most countries of the world are based on their nature of chemical power sources. In our country, it is the Law of Ukraine 'On Chemical Power Sources', which does not establish differences or special conditions for the disposal of electric vehicle batteries compared to other chemical power sources.

In this regard, it is necessary to develop and set a date for the introduction of a mandatory legal requirement to make the architecture of batteries suitable for automated and complete disposal, with a mandatory deadline for their introduction sufficient to adapt the production. This must be done by the governments of the countries where production of electric vehicles takes place or major car manufacturers are registered. Other countries should implement similar requirements in their legislation to establish generally accepted rules for the operation of electric vehicles. This step will provide additional incentives for technological development and competition since, if there is a single platform and requirements for such batteries, the market for electric vehicles will be available not only directly to car manufacturers but also to other companies with their own products. Additionally, single battery architecture will allow exchange of batteries at charging stations.

A number of regulatory requirements for the recycling of electric vehicle batteries should be additionally developed in Ukraine. There is simply no industry for recycling electric vehicle batteries at the moment. Practically all electric vehicles operated in Ukraine are not imported by car manufacturers, but by the citizens who bought them. Some car manufacturers only began official sales of electric vehicles in in Ukraine in 2020. This has led to car makers and dealers not addressing the need for disposal of used batteries. In the current realities of Ukraine and the rather low environmental consciousness of citizens, the creation of infrastructure for recycling electric vehicle batteries seems a remote prospect.

It is necessary to introduce legal mechanisms that would require the creation of structures and mechanisms for centralized collection and subsequent disposal of used batteries. This will require the introduction of mechanisms for the registration of the supply of batteries for electric vehicles. If an electric vehicle is imported, its owner must be held responsible for the proper disposal of the battery. If it is necessary to replace the battery or any of its components, suppliers must accept used batteries for disposal or notify the environmental control authorities that there is no exchange of battery taking place, which in turn should be a signal to check what happens to the battery in the future. The absence of a spent battery in the possession of the owner should be considered as environmental pollution and considered as improper disposal. There should be an additional financial instrument to encourage proper disposal – a disposal fee – an amount of money that corresponds to the cost of the battery, which is refunded to the owner when the battery is transferred to an appropriate operator.

Another problem that has to be addressed is the limited perception of the electrification process and the phasing out of internal combustion engines, which lies in the false perception of electric vehicles exclusively as battery-powered vehicles. This encourages the development of legal requirements based on this false perception and does not stimulate the development of alternatives such as fuel cells, which consume hydrogen to produce energy. There is no combustion process in fuel cells as the oxidation of hydrogen occurs as a result of another process, which produces current without electromagnetic generation and with water and heat as by-products. The efficiency of this process is up to 60%.

Hydrogen in fuel cells is an environmentally clean fuel due to the lack of combustion, which means there is no oxidation of atmospheric nitrogen. An obstacle to the widespread introduction of this technology is the lack of a developed system of hydrogen production and sale. However, the same problem occurred with chargers for electric cars a few years ago. Indeed, hydrogen production is a very energy-intensive process. However, production facilities can be built where there is access to significant amounts of renewable energy – solar energy in the deserts of Africa, Asia and Australia, geothermal sources, wind power on coasts, etc. Transporting such large amounts of electricity through conventional networks is a rather complex engineering task and it may be better to use energy at the site of its generation to produce hydrogen and then transport the hydrogen. Moreover, the existing gas pipeline network can be used for this purpose after the end of the hydrocarbon era, providing technical specifications can be met.

The advantage of introducing fuel cells in vehicles is that the generation of energy take place in the vehicle itself with the possibility of fast refuelling, just like cars with internal combustion engines. Moreover, such vehicles have a virtually unlimited drive range, which battery electric cars will never have without replacing the batteries on the drive. An additional advantage of vehicles with fuel cells is the possibility of their use as a mobile source of electricity generation, which can be useful for emergency services, and significantly expands the potential use of such vehicles.

Analysis of the legislation of Ukraine does not demonstrate support for developing vehicles which use fuel cells. All existing tax incentives are for 'vehicles equipped exclusively with electric engines'. Vehicles which use fuel cells are not on the classification list of goods for foreign economic activity.

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Summary

The requirements of environmental legislation from the 1960–1970s is one of the main factors in the technological development of material production. The introduction of increasingly stringent requirements for vehicles during the last 30 years has stimulated the development of vehicle transport technologies and has led to a total change in the type of power plants for cars. Currently it is insufficient to introduce prohibitive requirements alone. We need a strategic environmental assessment of the impact of technology and its integration into transport policy. Legislation should become the main programme factor in the development of vehicle transport technologies, but at the same time everything necessary should be done to avoid the transformation of one environmental problem into another, no less threatening one. Ukraine can be neither a pioneer nor an outsider in this area. We need to get involved in the European law-making processes and should implement the requirements adopted in the EU into our law.