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Review

Electromobility Market: Perspectives and Risks

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Abstract: The widespread adoption of electromobility is now considered as one of the possible approaches to reduce greenhouse gas emissions into the atmosphere. However, the implementation of this task requires not only the development of a coordinated policy of different countries in this area, but also significant subsidies for the implementation of relevant activities. The article is devoted to the consideration of various (including environmental) aspects related to the widespread introduction of electromobility. Based on a broad base of up-to-date data, the review focuses on the risks of this process, which will help to understand the basic principles of the electric mobility market and its trends. The studies presented in the article can become a starting point in the search for balanced solutions in the development and implementation of the principles of electromobility.

Keywords: electromobility, electric car, plug-in hybrid

JEL Codes: P18, Q52

1. Introduction

To create a competitive and resource-efficient transport system, the European Union transport policy provides by 2030 achieving almost zero carbon dioxide emissions of vehicles used in large urban centers, and gradually phasing out the use of vehicles using traditional fuels-by 2050. The need to achieve these goals is confirmed by the agreement recently reached at a meeting of leaders of 21 most industrialized countries (Paris, France). The large-scale and accelerated development of the principles of electric mobility in Europe can make a significant contribution to the realization of these goals, has a positive impact on the ecological friendliness of the environment, and can also improve the situation of employment in Europe.

Humanity annually emits greenhouse gases into the atmosphere, the amount of which is equivalent to 39 billion tons of CO_2. It is believed that it is possible to stabilize the Earth's climate only if global emissions are close to zero. At the same time, it is assumed that the amount of carbon dioxide released into the atmosphere in 2020 compared to the previous year decreased by the equivalent of 2.4 billion tons (7%), which is the largest decrease in the entire history of observations (Friedlingstein et al., 2020). This is due to the fact that due to the spread of COVID-19 pandemic in the world, the volumes of industrial production, automobile traffic and many other sources of greenhouse gases have sharply decreased. In absolute terms, this decrease is several times greater than the consequences of the economic crises of 2009, 1981 and 1992.

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The COVID-19 pandemic has very differently affected different sectors of the economy of the countries in the world. In particular, the most significant decrease was observed in the USA and European countries (by 11-12%). China was practically unaffected by this drop-emissions were decreased by only 1.7%.

In terms of industries, the largest decrease in emissions was observed in aviation and road transport: they produced 10 to 40% less greenhouse gases. On the other hand, the metals and energy sectors recovered their typical emissions after a sharp drop in April 2020 and almost reached 2019 values. Climatologists believe that after the end of the COVID-19 pandemic, this figure will return to the values of previous years (Ozherelyev, 2020).

The widespread adoption of electromobility is now considered one of the possible approaches to reduce greenhouse gas emissions into the atmosphere. However, the implementation of this task requires not only the development of a coordinated policy in different countries, but also significant subsidies for the implementation of relevant activities. As a result of the work already carried out until March 2020, sales of electric vehicles and plug-in hybrids in the global market grew steadily (+16% in February 2021), despite the almost widespread closure of production facilities.

However, in the conditions of almost total quarantine in Europe and the United States, as well as the crisis of overproduction in China, the situation with electromobility has become more complicated. Therefore, in mid-2020, experts from Wood Mackenzie (consulting and analytical agency for energy, renewable energy, chemicals, etc.) started talking about a possible peak in the decline of the market for electric vehicles, equal to 43%. At the same time, experts believed that the COVID-19 pandemic can be not the only reason for such a massive decrease in sales: the ultra-low prices for oil (and, accordingly, for gasoline) and the disruption of plans for the release of new models of electric vehicles, scheduled for 2020, could also contribute to the narrowing of the electric mobility market.

Nevertheless, the main problems for the electric vehicle market were associated precisely with the COVID-19 pandemic. The consequences have become dire, and it will take some time for the market to achieve even the former positions in Europe and the United States. In addition, those who buy an electric car for the first time (and such people are the majority), due to a sense of uncertainty, are wary of new technologies, including electric mobility.

Experts predict an upturn in the electric car segment, which, in their opinion, will begin in 2022, when prices for cars with internal combustion engines and electric vehicles are expected to approximately equalize. It is expected that in 2022, sales of electric vehicles will grow to up almost 10 million, and in 2028 up to 40 million electric vehicles will be sold globally, which will make up about half of the market for all cars.

2. Transport and environmental pollutions

Remaining one of the main sources of greenhouse gases (Figure 1), transport requires the implementation of innovative solutions.

Governments of many countries try to minimize by administrative measures the environmental damage caused by transport (the introduction of severe restrictions on the movement of cars with internal combustion engines (ICE), subsidies for the purchase of electric vehicles, etc.). It should be noted that electric transport (trolleybuses, metro, electric cars, electric buses, etc.) in developed countries is the main carrier of passengers within the city (it accounts for more than 50% of transit). However, due to the significant market capacity, the main focus is still on passenger cars and the problems associated with their transfer to electric traction.

Electric vehicles are driven by an electric motor powered by an energy source (batteries, fuel cells, capacitors, etc.). There are two main types of electric vehicles (EVs):

- rechargeable batteries that only use batteries for energy storage and must be connected for recharging (BEV);
- plug-in hybrid, having both batteries and liquid fuel storage/ refueling systems (PHEV).

The main advantages of BEV electric vehicles are:

- easy usage;
- high efficiency (the efficiency of an electric motor can reach 90-95%, which is much higher than the corresponding indicator of gasoline engines (25%) and diesel ones (40%));
- low maintenance costs (due to the relative simplicity of the design-high reliability; an electric car can be charged at night, when electricity is especially cheap);
- increased stability when driving (the batteries are located at the bottom of the car in many models-as a result of using this design solution, the center of gravity of the car is located very low, which increases the controllability and

stability of the vehicle);

- increased safety (electric vehicles do not have any heavy parts under the hood that could threaten passengers in the event of an accident, therefore, namely electric cars show the best results during crash tests);
- quiet driving (there are almost no mechanical transmissions in electric vehicles, which are a source of noise, therefore, for the safety of pedestrians, many models are specially equipped with sound amplifiers);
- lack of vibrations;
- fast acceleration (the electric motor, even at low speeds, develops maximum power, while the internal combustion engine can only achieve it in a very narrow speed range);
- smooth running (the frequency of rotation of the shaft of the electric motor is directly controlled by changing the voltage);
- improved aerodynamics (electric vehicles do not have an exhaust pipe, and they also do not need a radiator, which is designed to cool the internal combustion engine; all these features of EV's construction expand the possibilities of ensuring minimum air resistance), etc.

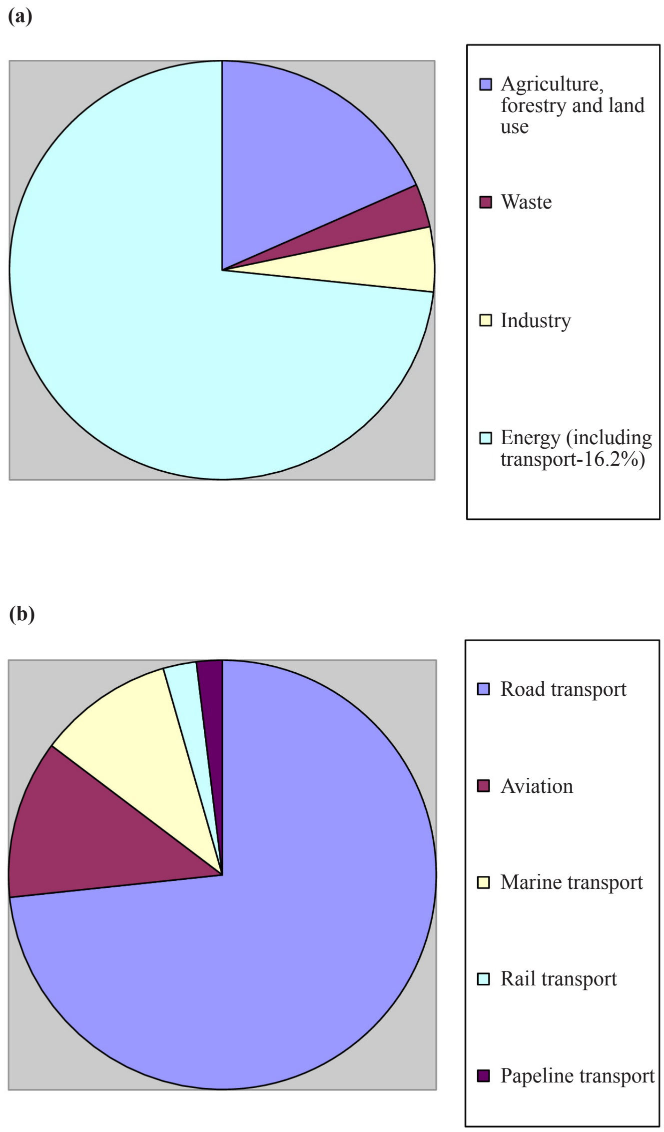


Figure 1. Global greenhouse gas emissions by economy sectors (a) and transport sectors (b)
Source: Statista, 2020

Almost all major automakers, in making efforts to rely on electric vehicles, are actively introducing BEV and PHEV into their model lines. This is due not only to the desire to develop new technologies, but also to the very measures to fight for the cleanliness of the environment, which are actively promoted by the governments of many countries. When choosing a car, Europeans carefully study the data on harmful emissions, including in their own interests, because the less a car generates CO_2, the greater the chance of getting a tax break from the government.

At the same time, the damage caused to the environment is measured not only by the amount of CO_2 emitted directly during the movement of the car, but also by the value of the "carbon footprint", which is the aggregate of all harmful emissions and greenhouse gases produced by an object during its life cycle. In the case of a single car, the carbon footprint is defined by not only CO_2 emissions directly during fuel combustion, but also all environmental pollution during the production of a car and the electricity it consumes.

At the same time, it was found that electric and hybrid engines give increased CO_2 emissions already at the stage of production (Figure 2) due to using additional electrical and power components in alternative power circuits. At the same time, the worst indicator of global warming potential (GWP) at the production stage was shown by an electric vehicle on fuel cells-a negative contribution is made by a high-voltage battery and a hydrogen tank. A standard drive, even with a gasoline internal combustion engine, shows in this rating itself far from the worst way. However, this rating can be adjusted with a change in the energy cycle, entry into the market of environmentally friendly sources of electricity, the development of new technologies, etc.

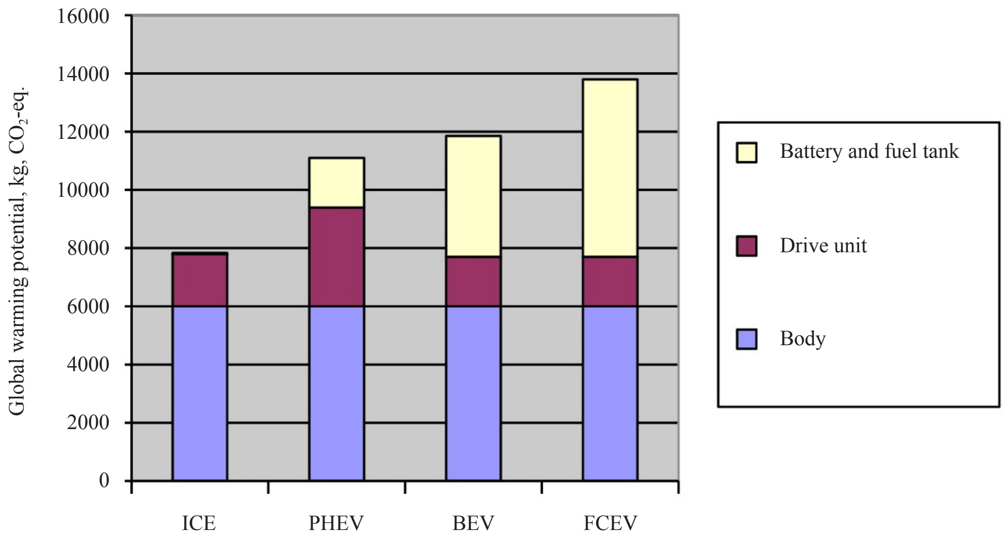


Figure 2. Structure of CO_2 emissions at the stage of car production (ICE-cars with an internal combustion engine, PHEV-plug-in hybrid, BEV-battery electric car, FCEV-fuel electric cell car) (Ozherelyev, 2020)

If one calculates the hydrocarbon footprint released during the production of fuel, then the most harmful is gasoline, and the most neutral is compressed natural gas (Figure 3). Perhaps that is why today namely the compressed natural gas is considered the best solution for commercial vehicles on public roads. Interestingly, steam reforming, used to produce pure hydrogen from light hydrocarbons, is extremely energy intensive, which makes fuel cell vehicles not inherently green. In addition, the conversion of hydrocarbon mixtures contributes to the formation of CO_2.

There are many questions about power generation. However, in this aspect, the carbon footprint has an obviously regional distribution. For example, coal-fired energy dominates in China (its share is 65%), and the coal and gas power plants have equal shares in the United States (33%). France relies on nuclear power (77% of the energy balance), and almost 100% of electricity in Norway is generated by hydroelectric power plants. In Germany, both wind power plants and solar panels are actively developing. However, unfortunately, wind and solar energy cannot become the main source of global generation. For developed countries, this is purely technically impossible: almost all developed countries of the world are located in those parts of the globe where the winter output of solar power plants is several times lower than the summer one. It is impossible to store energy for six months in advance: the required amount of batteries, for example, for the United States will cost the same as the annual GDP. Wind power plants will not be able to cope with the same task due to long frosty anticyclones, when their production can drop to zero altogether (Ozherelyev, 2020). Therefore, the priority use of battery electric vehicles, where the bulk of the energy is generated by coal-fired power plants, makes little sense from an environmental point of view, at least, until there is a major change in the energy balance (Sidorovich, 2020).

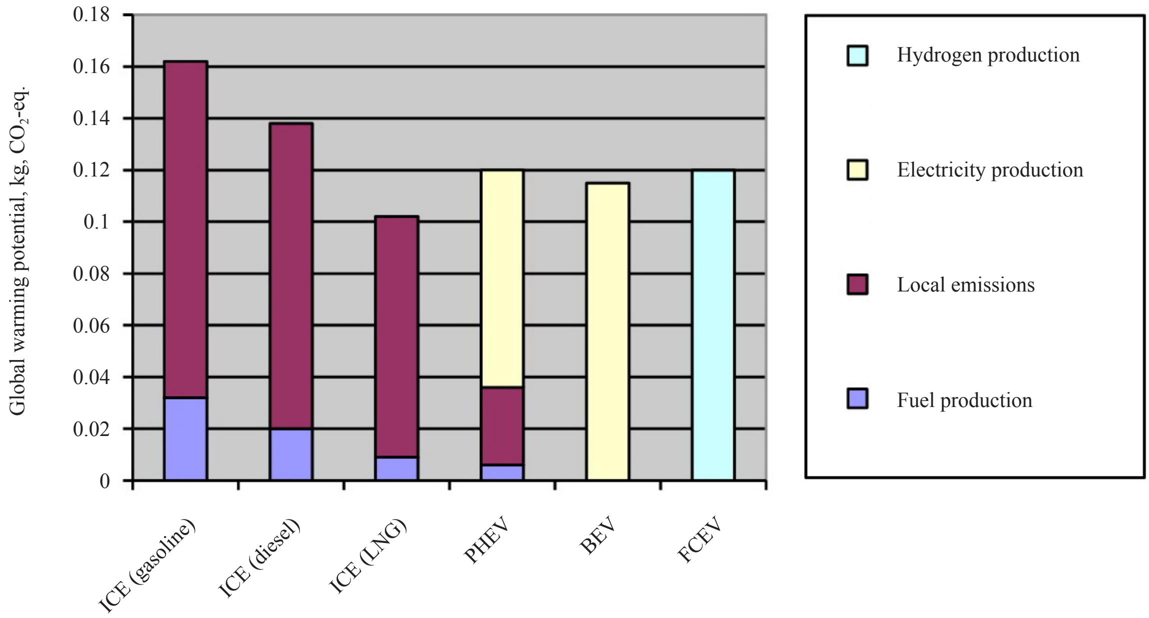


Figure 3. The structure of CO_2 emissions during the production of fuel and electricity of a car (ICE-cars with an internal combustion engine, PHEV-plug-in hybrid, BEV-battery electric vehicle, FCEV-electric vehicle on fuel cells) (Ozherelyev, 2020)

Electric vehicles are beginning to influence the structure of hydrocarbon consumption: analysts at Bloomberg NEF have calculated that 1,000 electric buses “replace” 500 barrels per day, and 1,000 electric vehicles-15 barrels (the reasons for the difference in data lie in high mileage and constant use).

According to forecasts, by 2040, the development of electric vehicles will lead to the fact that hydrocarbon consumption will decrease by 6.4 million barrels per day. An additional 7.5 million barrels per day will be reduced due to technologies that reduce fuel consumption in the internal combustion engine. However, now the world spends 100 million barrels a day, and therefore there can be no talk of a complete rejection of hydrocarbons.

Reducing the carbon footprint of cars is one of the many measures to improve the environment, including the reduction and recycling of waste, water protection, air quality control and reduction of its pollution in large cities, the introduction of new technologies, the preservation of biodiversity and forests, etc.

At the same time, it should be noted that there is still no clear understanding on which energy source the car of the future should drive. Toyota specialists rely more on hydrogen, while BMW specialists believe that by 2050 none of the technologies of the future will become the main one, but will share the market among themselves. This uncertainty is forcing automakers and oil and gas companies to invest in various areas of research, which may lead to some dissipation of funds (Kharitonov, 2020).

3. World cars production and sales

Table 1. World cars production in 2019-2020, units

Country	2019	2020	+/-, %
China	25,699,314	25,171,259	-2.05
USA	10,920,670	8,772,648	-19.67
Japan	9,509,347	7,973,211	-19.67
Germany	4,997,959	3,713,147	-25.71
South Korea	3,950,589	3,506,878	-11.23
India	4,515,823	3,393,019	-24.86
Mexico	3,750,750	3,031,874	-19.17
Spain	3,016,524	2,266,777	-24.85
Brasilia	2,804,012	1,905,173	-32.06
Thailand	2,013,710	1,427,074	-29,13
Canada	1,922,312	1,377,356	-28.35
France	2,070,106	1,327,727	-35.86
Russia	1,723,376	1,286,380	-25.36
Turkey	1,430,186	1,112,505	-22.21
Czech	1,314,723	1,020,213	-22.40
United Kingdom	1,364,424	986,765	-27.68
Iran	732,832	860,959	+17.48
Slovakia	1,079,978	819,188	-24.15
Italy	881,604	735,665	-16.55
Indonesia	1,286,848	690,150	-46.37
Malaysia	572,335	485,218	-15.22
Hungary	544,217	440,067	-19.14
South Africa	597,515	438,861	-26.55
Romania	490,412	438,207	-26.66
Poland	524,141	389,857	-25.62
Total production	90,864,533	76,075,528	-16.28

Source: Autoversity (2019-2020)

The number of cars in the world is growing at an ever faster pace every year. It is almost impossible to determine their exact figure, because vehicle registration and reporting rules vary widely from country to country, and some vehicles may remain unregistered. Therefore, only the volumes of production and official sales of new cars can be estimated reliably.

About 76,075,528 cars were produced in the world in 2020, which corresponds to the production of about 2.34 cars per second (Table 1). The largest number of cars (25.17 million units in 2020) were manufactured in China (production decline compared to 2019-2.05%). The United States of America ranks second in terms of annual motor vehicle production. About 8.77 million cars were produced in the United States in 2020 (a drop in production compared to 2019-19.67%). The third place in this ranking is occupied by Japan, where about 7.97 million cars were manufactured (a drop in production compared to 2019-19.67%) (New car production statistics, 2019; 2020).

Table 2. World sales of new passenger cars in 2019-2020, million units

Country	2019	2020	+/-, %
China	21,409	19,790	-7.6
USA*	17,053	14,451	-15.3
Japan	4,301	3,810	-11.4
Germany	3,607	2,918	-19.9
India	2,962	2,455	-17.1
Brasilia	2,665	1,955	-26.6
South Korea	1,781	1,855	4.2
France	2,214	1,650	-25.5
United Kingdom	2,311	1,631	-29.4
Russia*	1,759	1,599	-9.1
Canada	1,972	1,586	-19.6

Source: Autoversity (2019-2020).
*Light commercial vehicles (LCV) are partially taken into account in the USA and Russia. European statistics are based on new vehicle registrations reported by the European Automobile Manufacturers Association (ACEA).
China statistics is according to the China Association of Automotive Manufacturers (CAAM). Japan statistics according to JADA data.
India statistics is according to the Society of Indian Automobile Manufacturers (SIAM).
Brazil statistics is according to Anfavea.

According to the LMC Automotive consulting company, 77.6 million new passenger cars and light commercial vehicles (LCV) were sold in the world in 2020, which is 13.9% less than in 2019. China, which controls almost a third of world sales, is in the first place. The United States, which lost first place in 2009, is the second. The top three are closed by Japan. Russia, with a drop in sales by 9.1%, moved from 12th to 10th place. The only country among the world leaders that showed positive sales dynamics in South Korea, 7th place (+4.2%) (Table 2, New car sales statistics, 2019; 2020).

The most popular brands in 2020 were: Toyota-8.1 million cars (-8.2%), Volkswagen-5.7 million (-11.0%) and Honda-4.3 million (-6.5%). However, the breakthrough of the year was the American brand Tesla, which moved up to 39th position, having sold 538,038 vehicles (+46.2%). It should be noted that Toyota's strategy is to concentrate the world's most powerful model line within one brand (Toyota has only a small diversification: Lexus-premium segment and Daihatsu-a segment of small inexpensive cars). Other manufacturers aiming to reach more customer segments tend to concentrate many brands in one brand. Volkswagen lost a lot in this crisis year due to its heavy dependence on the Chinese market, which accounts for more than 40% of global sales. Volkswagen's share in the global market was 7.1%, down by 0.4 points. Honda managed to move up to 3rd place, ahead of the continuing decline of Ford. Model leaders: Toyota Corolla-1.10 million cars (-11.2%), Toyota RAV4-1.00 million (+7.2%) and Ford F-Series-0.97 million (-9.5%).

4. World electric cars production and sales

(a)

(b)

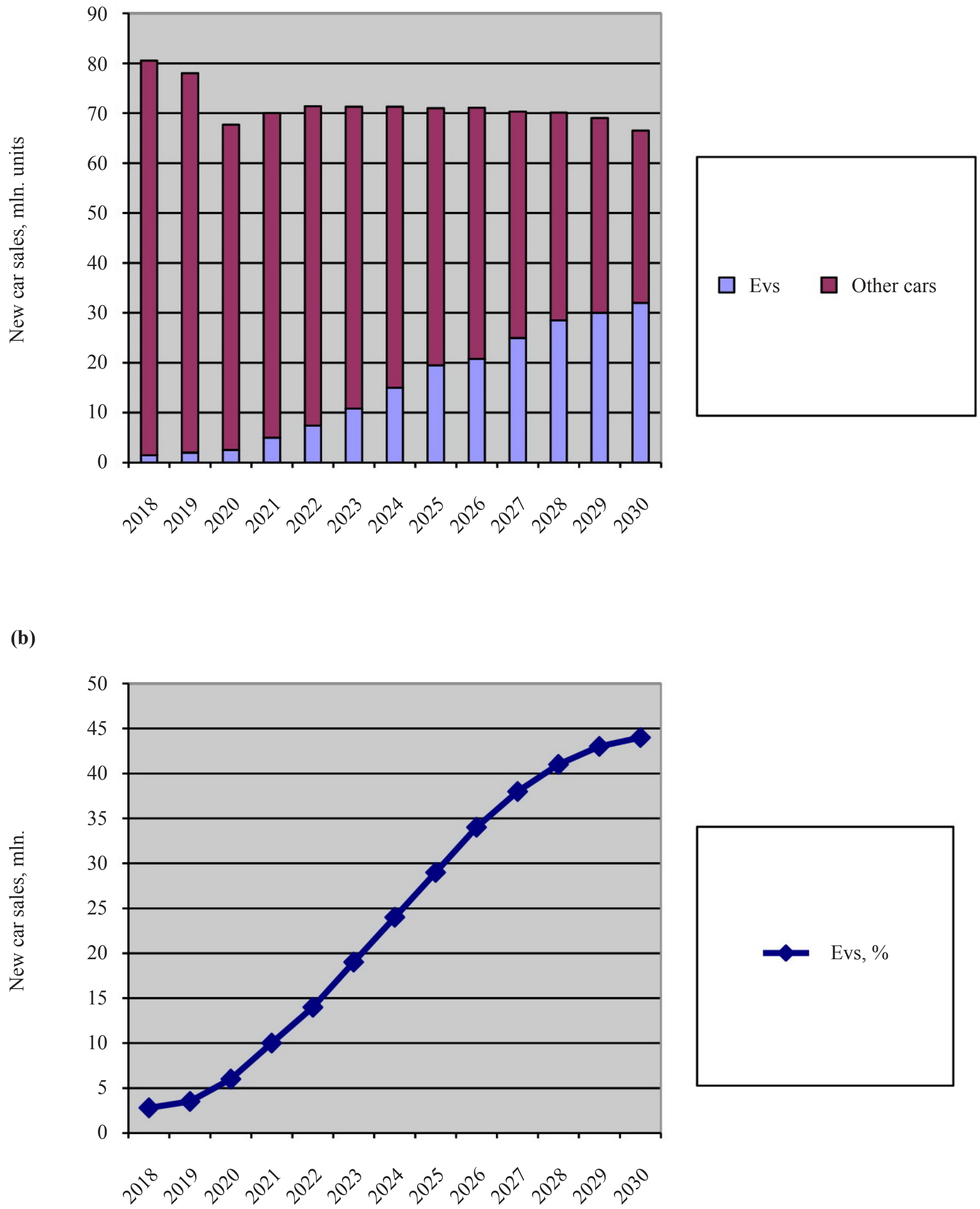


Figure 4. Sales forecast for passenger cars and electric vehicles (excluding commercial vehicles, source: Canalys estimates, January, 2021): a) projected quantitative indicators, b) projected growth of electric vehicles in % of the total number of vehicles)

According to analyst firm Canalys, global EV sales in 2020 increased 39% year-on-year to just over 3 million units, while the total passenger car market saw a 14% decline in sales due to the COVID-19 pandemic. Analysts believe that strong demand for electric vehicles will continue into 2021, despite economically challenging conditions. For example, the well-known American-British company IHS Markit expects global sales of electric vehicles and rechargeable hybrids to grow by about 70% in 2021 (Garik, 2020).

Electric vehicles accounted for nearly 5% of all new car sales in 2020, and in 2021 EV sales are projected to reach 5 million units, or more than 7% of all new car sales. About 1.3 million electric vehicles were sold in the Chinese and European markets in 2020, which is four times the sales of similar vehicles in the United States.

Canalys analysts believe EV sales will continue to grow throughout the decade, with EVs accounting for 48% of all new cars sold in 2030, assuming governments establish and maintain policies that stimulate the production and sale of EVs. Increasing productivity and expanding the charging station infrastructure will attract even more customers (Figure 4).

Canalys predicts that the number of electric vehicles sold will grow to 30 million units in 2028, and by 2030, electric vehicles will account for almost half of all passenger cars sold in the world (Garik, 2020; Drom, 2021).

According to estimates by the Swedish consulting company EV-volumes, sales of electric vehicles in Europe had more than doubled in 2020. BEV and PHEV sales accounted for 4.2% of the global automotive market in 2020 in comparison with 2.5% in 2019. Global BEV and PHEV sales in 2020 were 3.24 million, in comparison with 2.26 million in 2019. With all the differences in the figures given (3.24 million and 3.1 million), it is obvious that the increase in the number of electric vehicles is significant in any case. In the total number of vehicles sold on electric traction, BEVs in 2020 account for about 69% (Figure 5).

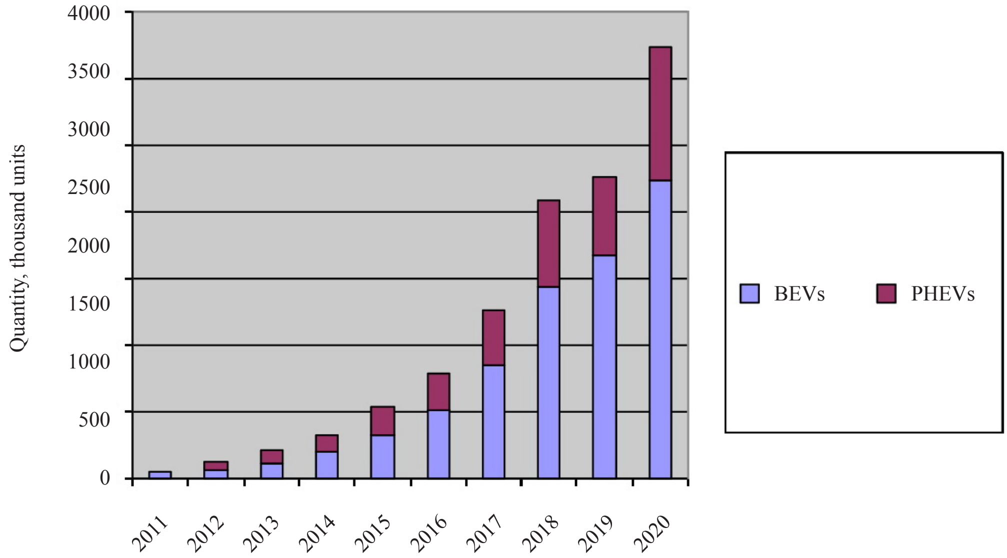


Figure 5. Worldwide sales of light electric vehicles

Source: EV-volumes

EV-volumes data showed that the five highest national EV sales in 2020 were in China (1.3 million), Germany (0.4 million), the United States (0.3 million), France and the United Kingdom (0.2 million). However, in 2020, growth in the United States was only 4% due to the presence of a small number of new models on the market (Figure 6) (HevCars, 2021). For the first time since 2015, sales of BEVs and PHEVs in Europe exceeded sales of new energy vehicles (NEVs, which include electric, plug-in hybrid and hydrogen fuel cell vehicles) in China. In terms of the share of BEV and PHEV vehicles in Europe, taking into account the EFTA countries (Norway, Iceland, Liechtenstein, Switzerland), including the UK, sales increased from 3.3% in 2019 to 10.2% in 2020 (Figure 7).

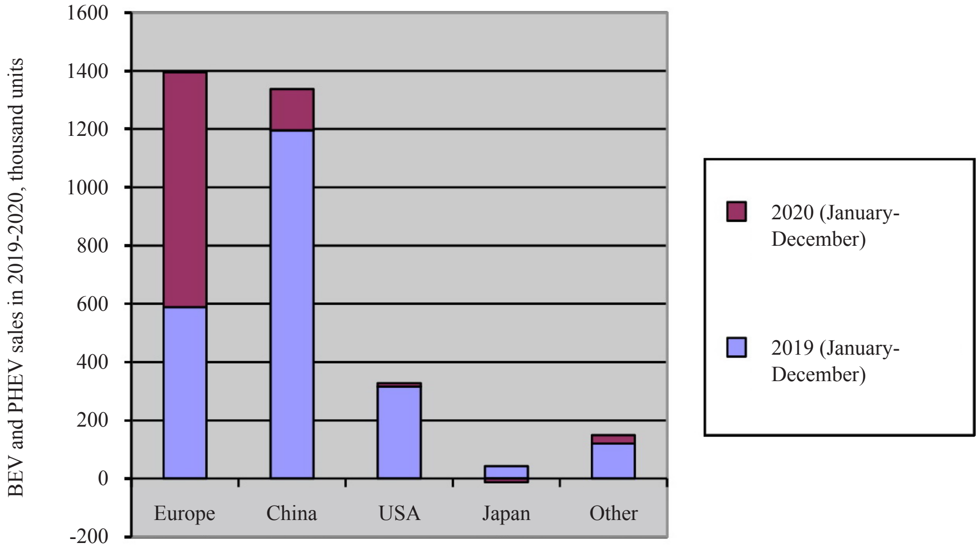


Figure 6. Sales of light electric vehicles by countries in 2019-2020 (HevCars, 2021)

The share of NEV in China in the same period increased from 5.1% to 5.5%. Many European markets had doubled or tripled their EV sales since 2019, and the EU accounted for 43% of EV sales in 2020, up from 26% in 2019. About 150 new BEV and PHEV models are expected to hit the market in 2021 (HevCars.com.ua, 2021).

Tesla is in the lead with 499,535 cars among the leading companies in BEV sales. These sales represent 23% of the total number of purchased electric vehicles. The Chinese company SAIC Motor (243,201 units-11%, the second place) and Volkswagen Group-227,394 vehicles (11%, the third place) have two times lower results. The Renault-Mitsubishi-Nissan alliance ranks fourth with sales of 172,673 electric vehicles (8%). The Chinese company BYD closes the top five with 131,795 electric vehicles (6%).

Electric vehicles made Europe the leader in 2020 (sales growth by 137%-1,395,000 vehicles), surpassing China (sales increase by 12%-1,337,000 units). The USA is in the third position (328,000 electric cars and hybrids sold-an increase of 4%). Germany is the leader among European countries in the purchase of electric vehicles. The total number of BEVs and PHEVs purchased in Germany in 2020 is 398 thousand units (up 254%). This puts Germany in the second place in terms of sales after China (Figure 7).

Considering sales in the context of electric vehicle brands, it is obvious, that the Tesla Model 3 electric car is the leader at the end of 2020, its sales accounted for 12% of the market (more than 365 thousand units, in 2019 it was sold 41% less).

Chinese electric car Wuling Hong Guang Mini EV, which began to be sold only in China in the spring of 2020 (4% of market sales), is in the second place. It is a little known or not sold at all in European countries and the United States, but this car keeps the lead due to its low cost ($ 4,100). Analysts predict that in 2022, it could become a real competitor to the Tesla Model 3.

The third most popular is the Renault Zoe electric car: in 2020, 100,431 electric vehicles of this brand were purchased (sales volume-3%).

The fourth place in the ranking of sales of electric vehicles in 2020 is occupied by the crossover Tesla Model Y (sales volume-3%, 79,734 cars, has been sold for less than a year).

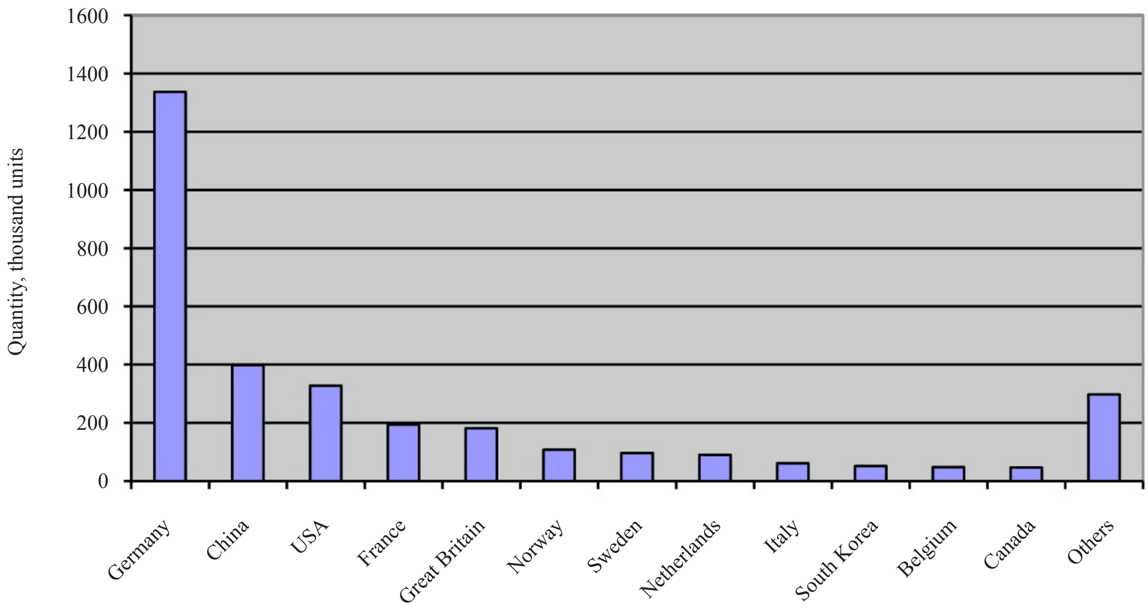
Hyundai Kona EV is in fifth place (sales volume-2%, 65,075 cars have been sold; it was in the 9th place in 2019).

Electric car Volkswagen ID.3 is in sixth place (sales volume-2%, 56,937 units have been sold, started selling in 2020).

Nissan Leaf is in the seventh place (sales volume-2%, 55,724 electric vehicles have been sold, the third place in 2019).

Audi e-tron is in the eighth place (sales volume-2%, 47,928 cars have been sold, the 25th place in 2019).

(a)



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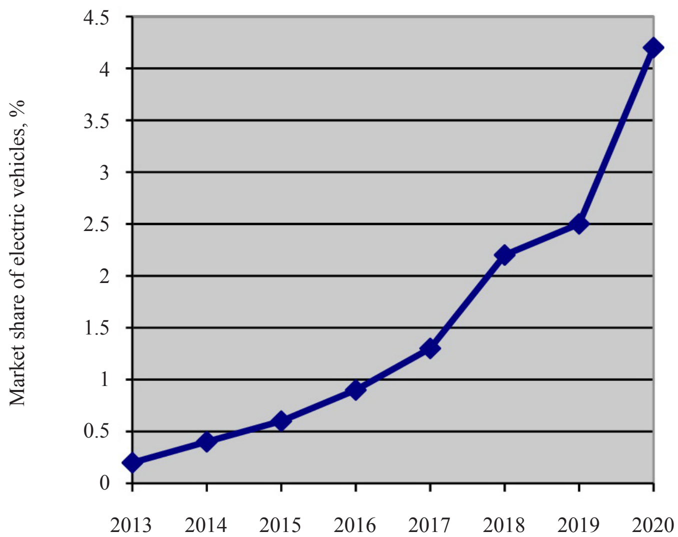

Figure 7. The world's largest passenger car markets BEV and PHEV: (a) sales in 2021; (b) market share of electric vehicles in 2013-2020
Source: EV volumes

The Baojun E-Series electric vehicle is in the ninth place (sales volume-2%, 47,702 electric vehicles have been sold, the fifth place in 2019).

Chinese electric car GW Ora R/1 Black Cat is in the tenth place (sales volume-1%, 46,796 sold cars, the 27th place in 2019) (HevCars.com.ua, 2021).

However, it is usually not taken into account that a car has actually already evolved: Google is experimenting with a small car for the city (its top speed is 25 km/h). Individual transport is rapidly developing in large cities: mono-wheels, segways, gyroscooters.

In addition, according to Bloomberg New Energy Finance, almost half of all buses in the world (47%) will be electric by 2025. The leader in this regard is China, which accounts for 99% of electric buses. One of the first cities where all buses became electric was Chinese Shenzhen (16.3 thousand electric buses).

According to analysts at Bloomberg New Energy Finance (BNEF), the number of electric buses will rise more than triple by 2025 (up to 1.2 million). According to BNEF, electric buses are still more expensive than diesel buses or on natural gas, but operating costs in their case are lower, taking into account the cost of fuel and technical costs. In addition, the decline in the cost of batteries will lead to the fact that by 2026, electric buses will be able to compete with diesel buses.

Electric buses are attracting the attention of city officials not only in China but around the world. For example, the authorities of Paris and Amsterdam have decided to completely switch to buses with zero harmful emissions into the atmosphere in the coming years. Norway is one of the European leaders in the distribution of electric vehicles.

The Los Angeles authorities are planning that by 2030 all buses in the city (about 2,000 units) will be electric (USA. ONE, 2017).

The principles of electromobility are being introduced into aviation with caution. Flying cars are a very likely development option for this technology.

5. Practice of switching to electric vehicles

Currently, only slightly more than 1.3% of cars on the roads of the world are electric (taking into account commercial ones-even less). At the same time, virtually all of humanity has access to electricity. In addition, there is an exponential trend in the number of electric vehicles in the world (Figure 8).

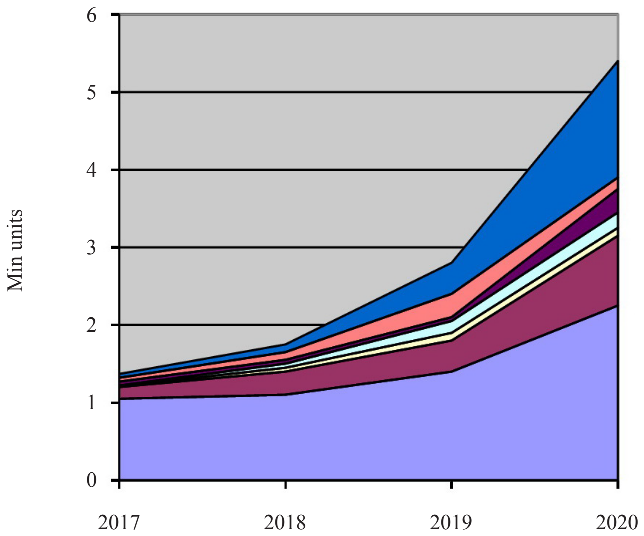

Figure 8. Quantity of electric vehicles in the world by country (million units)

India, Great Britain, France, Norway, China and other countries announced their intention to abandon the use of diesel and gasoline vehicles. For example, India has prepared plans according to which 10 million electric vehicles should be sold in the country by 2030.

The UK and France are also at the forefront of the electromobility. The UK government has pledged to ban the sale of all new diesel and gasoline vehicles by 2040 in an effort to encourage people to use electric vehicles, or at least hybrid vehicles. An independent advisory body to the climate change committee stated, that EVs should make up at least 60% of new cars and vans sold in the UK. France plans to ban the sale of all gasoline and diesel vehicles by 2040.

At the same time, many countries are introducing incentive programs for the purchase of electric vehicles. Nevertheless, buyers not in all EU countries received payments for the purchase of electric vehicles. The corresponding payments exist in: Croatia-11 thousand Euro; Romania-10 thousand Euro; Slovenia-7.5 thousand Euro; France-6 thousand Euro; Sweden-5.5 thousand Euro; Ireland and Luxembourg-5 thousand Euro. Another more 4 countries pay from 2 to 4 thousand Euro: Germany, Austria, Great Britain and Finland.

In the case of direct cash payments absence, the governments of different EU countries establish other benefits. The most common ones are:

1. Exemption from car tax: Germany, Great Britain, Italy, Austria, Sweden, Czech Republic. In almost all other countries, such a tax has not been canceled, but slightly reduced for electric vehicles.

2. Exemption from commercial tax: Sweden.

3. Exemption or reduction of the registration tax rate: Belgium, Greece, Netherlands, Poland, Portugal, Hungary, Cyprus, Denmark.

4. Exemption from property tax: Bulgaria, Romania.

5. Exemption from environmental tax: Malta.

It is clear that taxes may differ in their application and quantity in different countries. Some countries do not provide any benefits to EV owners at all. For example, there is no preferential treatment in the Baltic countries (accordingly, the share of electric vehicles in these countries is small).

In more detail, there were the following benefits when purchasing EVs in different countries in 2020.

Since the summer of 2016, a fixed discount has been in effect in Germany for the purchase of an electric car-2,000 Euro from the state and the same amount from the automaker. Thus, one can get a surcharge of 4,000 Euro, however, the offer is only valid for electric vehicles having the cost of up to 60,000 Euro.

In addition, electric vehicles are exempt from vehicle tax for 10 years after purchase. The reduction of VAT from 19% to 16% also helps to increase the interest of buyers in electric vehicles. There is also an exemption for owners of electric cars from transport tax for 10 years.

At the same time, the main advantage for buyers of electric vehicles, the price of which is less than 40,000 Euro, has been the bonus-9,000 Euro, for buyers of PHEV-6,750 Euro, for electric vehicles over 40,000 Euro-7,500 Euro, for PHEV hybrids-5,625 Euro. Moreover, all these incentives apply not only to electric vehicles and hybrids, but also to hydrogen fuel cell vehicles purchased and registered by the end of 2020.

Car owners in France pay an environmental tax based on the carbon dioxide emissions by their cars, which can reach more than 10,000 Euro per year. Owners of electric vehicles are not only exempted from this obligation, but can also receive 6,000 Euro of an eco-bonus-but no more than 27% of the price of an electric car. In addition, one can get another 2,500 Euro when handing over old gasoline or diesel vehicle for recycling. For the purchase of an electric car worth up to 45,000 Euro, the bonus is 7,000 Euro for individuals and 5,000 Euro for legal entities. If the price of an electric vehicle varies between 45,000 Euro and 60,000 Euro, and for vans more expensive than 60,000 Euro, the bonus is 3,000 Euro, for a PHEV-2,500 Euro.

BEVs are fully exempt from value added tax in the UK. They are also exempt from excise taxes on transport until the end of 2020. In 2021 it will be 1%, in 2022-2%. If the price of the electric vehicle is under £ 3,000, the bonus is £ 3,500. If the price is less than £ 50,000, the bonus is £ 5,000. Bonus is equal to £ 8,000 for vans, £ 7,500-for taxis and £ 20,000-for trucks. PHEV customers are not eligible for this benefit, but they can count on £ 350 bonus on their home charging station. Also, for electric vehicles, it is free to enter certain areas in London, access to which by car with an internal combustion engine will cost £ 11.5-12.5 per day.

When buying an electric car, residents of the Netherlands do not pay a registration fee. Its size is calculated on the basis of the manufacturer's declared carbon dioxide emissions-for example, registering a gasoline car that produces 100 grams of CO_2 per kilometer will cost almost 2,500 Euro. In addition, when calculating the income tax, owners of electric cars take into account only 4% of the price of their car, versus 22% in the case of a car with an internal combustion engine. In addition, BEV and PHEV are exempt from vehicle tax until 2020.

Benefits for the purchase of electric vehicles in Italy appeared in March 2019. One can get a maximum of 6,000 Euro of discount: 2,000 Euro for scrapping a car with an environmental class from Euro 1 to Euro 4, as well as 4,000 Euro when buying an electric car or a car with the carbon dioxide emissions of up to 20 grams per kilometer. Italy completely exempts owners of new electric vehicles from transport tax for 5 years, starting from the 6th year-by 75%.

For the purchase of a BEV worth 50,000 Euro (excluding VAT), the bonus is up to 6,000 Euro; when purchasing PHEV-up to 2,500 Euro.

A bonus of 10,000 Euro for the purchase of an electric vehicle is offered in Romania, to which one can add another 1,500 Euro for scrapping a car over 8 years old (Electric Motors Club, 2019; Stroiteleva, 2021).

The road toll for new electric vehicles has been reduced to SEK 360 in Sweden. When buying an electric car, electric bus or light truck, the buyer can receive a bonus of SEK 60,000, and for the purchase of new PHEVs-SEK 10,000.

Spain has a territorial sampling system. EVs are completely exempt from VAT in the Canary Islands, and in cities such as Madrid, Barcelona, Zaragoza, Valencia-by 75%. In addition, there is an incentive scheme, according to which a bonus is equal to € 4,000-5,000 for a BEV and € 1,900-2,600 for a PHEV for individuals, depending on whether they recycle vehicles over 7 years old, and from 4,400 Euro to 6,000 Euro-for individuals for the disposal of vans and trucks (Yandex Zen, 2020).

Norway is the world leader in terms of market share for electrical machines. More than 30% of electric vehicles are sold in this country per year with a population of about 5.4 million people. Already 20% of all cars in use are electric in Norway (2019-more than one-third of cars sold were electric, in 2020-more than half). Norway introduced governmental subsidies for electric vehicle owners in the 1990s. Owners of electric vehicles in Norway have exemptions on taxes, fees when driving on toll roads, free parking, and access to public transport lanes. All of the above exemptions in Norway apply to full-fledged electric vehicles without internal combustion engines, as well as equivalent plug-in hybrids.

However, it should be noted that subsidies and preferences in Norway also exist for the infrastructure and the business involved in its creation-for example, benefits for companies that develop a charging network. At the same time, these preferences are decreasing over time: the reduced fare on toll roads has already been canceled in 2018, and in 2019 the same thing happened with the free use of ferries (only a 50% discount is offered). The situation is similar with municipal parking lots, which have become paid (with a discount of 50% or more). Only bus lanes remain of the privileges, as well as zero duties for individuals-companies will now have to pay some of the taxes. A revision of all benefits for EVs is possible in 2021 in Norway, however, due to the COVID-19 pandemic, this revision may be postponed.

It is expected that instead of providing exemptions to electric cars in Norway, the tax burden on the owners of gasoline and diesel cars will increase, and the higher the amount of vehicle emissions (more powerful engine), the more taxes will have to be paid. At the same time, opinion polls show that Norwegians are very concerned about trends in the taxation of personal transport, including the abolition of benefits for owners of electric vehicles (Lyakov, 2019). All of these incentive programs are temporary. Depending on the situation in the market and in the economy of a particular country, they may be extended for another period or not. Incentives are used to give impetus to the implementation of electric transport. Charging infrastructure is expected to expand during the incentive period and prices for electric vehicles are expected to decline as technology improves. Thus, the further transition of the EU countries from ICE to clean modes of transport should happen by itself.

Major changes are also taking place in China, which accounts for about as many EV sales as all other countries combined (almost half of EV sales in 2020). China is the largest market in terms of volume in the world, and this country, the world's largest emitter of greenhouse gases, is interested in using alternative fuels for vehicles. The country is seriously engaged in the production of lithium-ion batteries, which are the basis of electric cars' price. The Chinese government supports local carmakers with subsidies and a variety of incentives. There are a number of business strategies in China that lower the purchase price of an electric vehicle. In particular, the rental of removable batteries, allows drivers to buy NIO electric vehicles without batteries. The business model is called Battery as a Service ("BaaS") and requires drivers to pay a monthly rent to use the battery. Since the battery is one of the most expensive components of EVs, this helps keep the starting prices of NIO EVs down.

The owners of electric vehicles are not the subject to various prohibitions on registration and driving on certain days (this practice is common for cars with ICE in large cities). Discounts for the purchase of electric vehicles under government programs were in effect in all previous years in China. So, for the purchase of an electric car with a power reserve of more than 400 km, the discount was 3,300 Euro (7,300 Euro earlier), from 250 to 400 km-2,400 Euro. However, at the end of 2020, the sales incentives for NEV must be expired. But due to the pandemic, the Chinese government has decided to extend the subsidy and 10% tax exemption for another two years. Moreover, this relaxation will apply only to manufacturers of EVs. ICE cars are still subject to full tax.

Subsidies for car owners are still being established-the issue of assigning a compensation payment of 3,500 USD (or about 25 thousand yuan) for drivers who purchase electric cars with a mileage on one charge of at least 400 km. If the mileage traveled by an electric vehicle is up to 250 km on one charge, subsidies are not paid (E-CARS-TECH, 2020).

More than 400 electric vehicle companies are registered in China. These include both traditional domestic car manufacturers such as Geely, Dongfeng and Chery, as well as newly established and fast-growing companies such as NIO, Li Auto, and XPeng.

More and more Chinese tech companies are partnering with overseas companies to produce globally competitive electric vehicles. The latter ones include the partnership between Alibaba and SAIC, as well as between Foxconn and Geely. Moreover, at the end of 2019 Tesla completed the construction of a new plant in Shanghai (the second in a row after the one in California). Chinese electric car companies can create serious competition for their Western counterparts and very quickly capture the market, as Japanese low-cost models did in the 1970-80s. Now the quality of Chinese electric vehicles is not inferior to European and American brands, while their price is significantly lower. In any case, these trends indicate an increase in transnational cooperation in the field of electromobility.

EVs's buyers are eligible for tax breaks in the United States. In addition to the fact that the owners of electric cars do not pay excise taxes included in the price of fuel, the state provides for tax breaks in the amount of 7,500 USD. However, the procedure for obtaining this benefit depends on the manufacturer of a particular electric car model-if more than 200,000 electric vehicles are produced under this brand, the benefits for their purchase disappear. However, the United States also plans to abolish privileges for electric vehicles, in particular, a tax subsidy of $ 7,500. In accordance with the rules, the manufacturer can sell only 200 thousand cars with this "discount" (not a year, but in general), and then it decreases and soon becomes invalid. Especially this approach hit Tesla, which has already reached its limit, and it will be difficult for the company to compete Audi, Jaguar or Mercedes-Benz.

The US market is interesting in that although novice manufacturers of electric vehicles have a production plan only "on paper", a lot of money is already poured into them. Traditional automakers have a hard time competing with the American market leader Tesla, so they use the tactics of investing in startups. For example, the automaker General Motors in September 2020 announced plans to acquire an 11% stake in the infamous Nikola in order to produce electric pickups, but then refused. Another example of the potential entry of traditional American carmakers into the electric vehicle market is Ford's investment in Rivian to start producing electric trucks (Rivian's business is focused on producing these cars).

Taking EV companies to the public market through mergers with the so-called Specialized Acquisition Companies (SPAC) now is trending in the US market. Through SPAC, electric car manufacturers have already managed to enter the public market in 2020, such as Nikola with an estimate of more than $ 3.3 billion, Fisker with an estimate of $ 2.9 billion, Lordstown Motors with an estimate of $ 1.6 billion, Canoo with an estimate of $ 2.4 billion. Arrival also plans to come out with an estimate of $ 5.4 billion. Recently it was reported that electric car maker Lucid Motors is in talks to enter the stock exchange through a merger with another SPAC company, Churchill Capital Corp IV (CCIV). Manufacturers of components and technologies for electric vehicles are following the same path. Battery maker Quantum Scape and self-driving lidar developers Luminar and Velodyne Lider have already entered the stock market through SPAC, even though their products are planned for the future.

6. Charging infrastructure progress

The growth of the electric vehicle market must be supported not only by the development of infrastructure for their recharging, but also by providing it with a sufficient amount of generated electricity.

Today according to various estimates, more than 6 million electric vehicles in the world are in private use only. Charging these electric vehicles (depending on the charger used) will require 21 to 144 GW of grid power. The installed capacity of global generation, according to the CIA World Factbook, is more than 6,300 GW. Considering the fact that only a small share of the electric vehicle fleet is simultaneously charging, there is no need to talk about the problem of a shortage of generating capacities today.

It will be necessary to increase electricity generation by 60% over 30 years to shift all vehicles to electric traction (that is, by 2% per year). Within the framework of world energy, this is not such a difficult task that can be solved by connecting not only conventional power plants to the network, but also solar stations and wind turbines. If the conditions for electricity generation are met, the benefits of electromobility are fully realized.

Over the past five years, the number of charging points has grown significantly, but more is needed for widespread adoption of e-mobility, Bloomberg analysts write. According to their forecasts, even those countries that are now leaders in the promotion of electric vehicles (China, the USA, and part of Europe) (Figure 9), may face a lack of infrastructure for charging in the early 2030s, due to which the growth of sales of electric cars may slow down significantly.

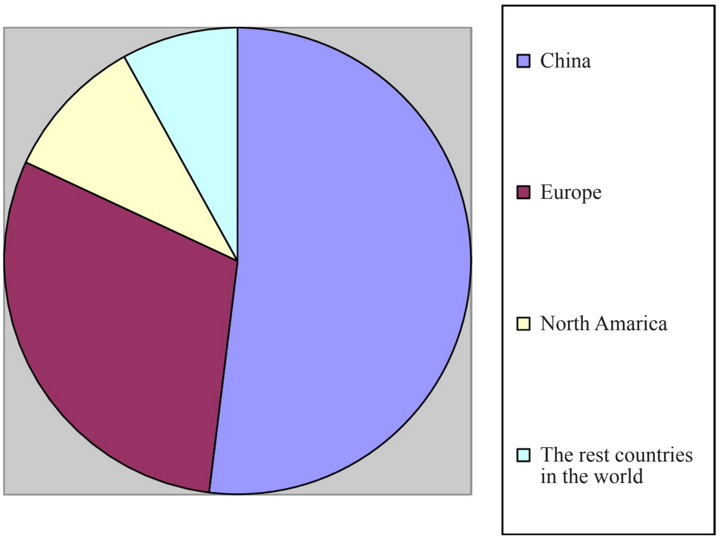

Figure 9. Quantity of charging stations in the world in 2020
Source: IEA, Bloomberg

So the growth in the number of electric vehicles should lead to global infrastructure changes. At the moment, the main reason for refusing to buy electric cars is the insufficient number of charging stations. In addition, drivers are confused by the long charging time of the batteries, because the car needs to be charged for 7-10 hours from a regular electrical net. That is why one of the most promising industries in the economy of the future is the production of so-called fast charging stations, which will allow you to charge batteries with enough energy in a few minutes to travel long distances.

Analysts at McKinsey & Co estimate that about $ 50 billion will be invested in the development of fast charging stations by 2030. Thus, the Volkswagen concern announced its plans to put a network of new charging stations along the main roads of Europe, which will allow quick charging of several cars at once. It is assumed that at least every 120 km of track there will be at least one charging station, and in total the concern will spend 30 billion Euro on the implementation of the electric program by 2023.

Ford, Volkswagen, Tesla and numerous startups (primarily in China and the USA) are engaged in this area. Fundamentally new charging stations are being created in scientific centers around the world. After all, if slow charging stations in one hour charge the batteries with energy for about 30 km, then fast charging can provide a car with 120 km of the path in just half an hour. At the same time, for example, the Ionity company (the shareholders include Volkswagen and Ford) began production of charging stations that provide a mileage of 340 km in 10 minutes.

Tesla having over 12,000 Superchargers in the United States, Europe and Asia is by far the most widely used electric car filling network. At the same time, Tesla announced the creation of a new version of its stations, which was called Supercharger V3 (peak output-250 kW). This makes it possible to charge cars up to twice as fast as before. In addition, the Supercharger V3 does not reduce its power in the event that several cars have arrived for recharging (Gaidukevich, 2019b).

The European Union has passed a law according to which every new home in Europe built after 2019 must-have charging for electric vehicles. More than 90% of German cars are charged in a home or office garage, which uses a regular electricity grid with a separate counter.

According to the report prepared by the Norwegian Electric Vehicle Association nearly all (96%) electric vehicle owners in Norway have personal charging stations. In a number of countries, such as Japan and Denmark, the number of EV charging stations has already exceeded the number of gas stations.

An interesting solution to the problem of recharging batteries was proposed by Highways England. In the UK, where there are about 50,000 electric vehicles, an experimental track will be built to power battery-powered vehicles. Electric and hybrid vehicles with wireless charging will be able to recharge on-the-go from equipment installed below the road surface. In the next five years, the government plans to invest £ 500 million in the development of this technology (Olkhovskaya, 2017).

7. Storage batteries

According to BloombergNEF, in 2020 for the first time the cost of battery packs for electric vehicles (the cheapest batteries that are installed on buses in China) fell below $ 100/kWh. At the same time, the volume-weighted average price for batteries for electric buses in China was 105 USD/kWh. For light electric vehicles, the average cost of a battery is now $ 126 per kilowatt-hour, of which $ 100 is spent on batteries and $ 26 on assembling them into a battery. Thus, the cost of the battery pack in the total vehicle price dropped to 21%.

In 2020 the average cost of all batteries for transportation (including electric cars, rechargeable hybrids, motor vehicles, etc.) was $ 137/kWh. For comparison, in 2010, such a battery cost an average of $ 1,100/kWh (i.e. in 2020, prices for batteries fell by 89%). According to the BloombergNEF forecast, the average price of batteries in the world will fall below the $ 100 mark in 2023. Judging by the statistics, in recent years there has been a certain trend towards a slowdown in the fall: in 2019-2020, prices fell by only 13%. On the other hand, the same slowdown was observed in 2013-2014, followed by a sharp decline in the market by 35%.

Exactly expensive batteries have long been the main reason for the inflated prices of electric vehicles relative to cars with ICE. So, according to estimates in 2020, the cost of a 100 kWh battery, which is enough for an average electric car for about 500 kilometers, is $ 13,700.

According to the BNEF forecast, which looks at light electric vehicles, buses, commercial electric vehicles and stationary storage, by 2023 average battery prices will be $ 101/kWh. It is at this price point that automakers will have the opportunity to produce and sell mass-produced electric vehicles in some markets at the same price as comparable ICE vehicles. This assumes no subsidies, but actual pricing strategies will vary by automaker and geography.

The price decline in 2020 was driven by increased order sizes, increased sales of electric vehicles and the introduction of new battery case designs. New cathode chemistry and falling production costs will drive prices down in the short term. Prices for cathode materials fell from their highs in the spring of 2018 and moved to a more stable level during 2020. Moreover, even if commodity prices return to their 2018 highs, this will delay the achievement of the $ 100/kWh milestone by only two years, but will not destroy the industry. The industry is becoming more resilient to changes in raw material prices, and leading battery manufacturers are investing in the production of cathodes and even in mines, that is, in the extraction of raw materials directly.

According to the BNEF report, leading battery manufacturers currently have gross margins of less than 20% and factories operating at over 85% utilization, the report said. Maintaining high utilization rates is a key to lower cell prices.

Battery manufacturers are striving to mass-produce batteries with higher energy density using some new chemicals such as lithium-nickel-manganese-cobalt-oxide (NMC) and lithium-nickel-manganese-cobalt-aluminum-oxide (NMCA). These alloys are used for the production of cathodes. Such batteries will be mass-produced as early as 2021. However, lithium iron phosphate (LFP) remains a cheap alternative and is used in the cheapest cells at $ 80/kWh.

According to the BNEF forecast, by 2030 the cost of batteries will fall to $ 58/kWh due to new technological advances. Solid-state batteries (with solid electrolyte) are one of the promising technologies.

However, Goldman Sachs analysts have released a report according to which, due to the massive transition to the production of electric vehicles, battery prices, on the contrary, will begin to rise again by an average of 18%. At the same time, prices for the main materials for their production (cobalt, nickel and lithium) have been growing since the beginning of 2021. According to analysts' estimates if prices, for example, for nickel return to their record values of around 50,000 USD per tonne, each electric vehicle will rise in price in production by 1,200-1,500 USD, which could seriously slow down the demand for electric transport among consumers (Cheng, 2021).

Solid-state cells can be made 40% cheaper than current lithium-ion cells due to savings in materials and costs of production, equipment and the introduction of new cathodes with a high energy density. For low prices to be possible, it is necessary to establish a supply chain for key materials that are currently not used at all in lithium-ion batteries.

Lithium-ion batteries are a key technology in the energy sector of the future. They are necessary to smooth out the peaks of energy generated by wind farms and solar panels (Blog of the company Data Center "Miran", 2020; Ivanov, 2020). Analysts believe that the slowdown in the decline in battery costs is due to a shortage of essential raw materials. It is considering that there are enough directly discovered deposits of chemical elements on the planet, but it will take some time to increase their production.

China holds a leading position in lithium production (about 51%, where the US has only 2%), and in cobalt production with 62% of the market. All of these elements are essential for the production of lithium-ion batteries.

8. Prospects for the spread of electromobility, existing risks

Despite the fact that the number of electric vehicles is growing, the global number of electric vehicles in the world is only about 1.3% of the total number of passenger cars in exploitation.

Electric mobility has a long way to go before reaching EVs that can make a significant contribution to meeting greenhouse gas emission reduction targets: to limit the rise in temperature of the Earth's atmosphere, the number of EVs in the world will have to reach 600 million by 2040.

Research and development and improvement in mass production are driving down battery costs and this trend should continue, which should narrow the competitiveness gap between electric vehicles and combustion engines.

According to various experts, the demand for electric vehicles will accelerate. So the world's largest oil company ExxonMobil raised its forecast to 100 million electric vehicles by 2040 compared to previous figures. The International Energy Agency has more than doubled its baseline EV forecast for 2030. OPEC also revised its forecast to 266 million electric vehicles in 2040. Bloomberg New Energy Finance predicts that by 2030, 31% of new car sales and 20% of the global vehicle fleet will be electric. The well-known US-British company IHS Markit expects global sales of electric cars and rechargeable hybrids to grow by about 70% in 2021 (Olkhovskaya, 2017).

Nevertheless, American automakers (Chrysler Group LLC, General Motors, Ford Motor Company), like many German automakers, are moving in this direction rather slowly. Moreover, the largest British automakers have called on the UK government to postpone the ban on the use of gasoline and diesel vehicles due to the risk of falling sales and job losses (according to the plans of the UK government, the ban on the sale of new cars and trucks with gasoline and diesel engines will be introduced by 2030, which is 10 years earlier than originally planned. Hybrid cars will be allowed to sell until 2035). The earlier introduction of the ban was opposed by such companies as BMW, Ford, Honda, Jaguar Land Rover and McLaren (Cheng, 2021).

Consolidated graph-forecast of the spread of electric vehicles until 2030 is presented in Figure 10. It has been developed under the following conditions:

1. Cars with hydrogen engines will not gain popularity;
2. Synthetic fuel for internal combustion engines will not become cheaper;
3. Environmental bans and restrictions in Europe will not be canceled and will continue to increase;
4. Work in the field of development and modernization of electric vehicle technologies will continue to be intensive (they will become cheaper, faster charging, more mileage, more reliable) (NA 88, 2019).

Anyway, for the widespread use of electromobility, it is necessary to solve the following problems.

8.1 *Supply of raw materials for the production of batteries*

Lithium, cobalt, neodymium, etc. are key raw materials in the production of batteries. Scientists at the Natural History Museum in London have considered the issue of depletion of the natural resources in the case of solving the problem set by the UK government-to abandon cars with an internal combustion engine by 2050. At the same time, they found that for the realization of this task the world production of cobalt has to double. Moreover, all the neodymium mined on the planet and three quarters of lithium must be spent on the production of batteries for only Great Britain. In addition, for the full transition to electric vehicles in Great Britain (31.5 million cars) half of all copper mined in the World in a year will be required.

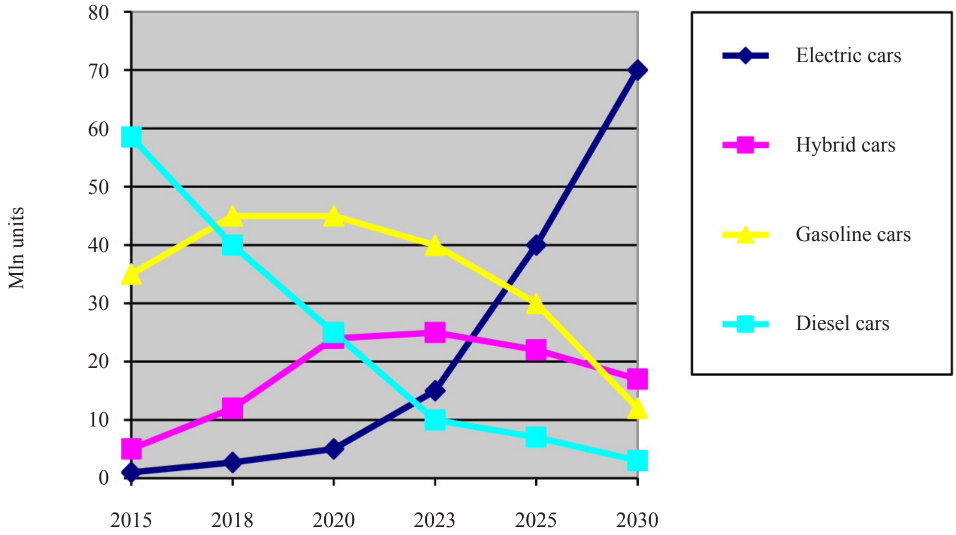

Figure 10. Production of cars by fuel type (consolidated forecast) (NA 88, 2019)

The cost of lithium forms 12% of the price of a whole battery even now, and 14% of all produced lithium goes to electric vehicles. By 2025, this share will grow to 40%. At the same time, the demand for cobalt and rare earth metals has increased significantly.

Therefore, manufacturers of batteries for electric vehicles may simply run out of stocks of metals. Copper, lithium and nickel are under the threat of an imminent shortage. But the worst of all is the situation with cobalt, a rare chemical element that underlies the design of accumulators for electric cars. BMW estimates that one electric vehicle requires an average of 21 kg of cobalt. According to Green Optimistic, the industry may begin to feel a shortage of this metal in the near future-already in the 2020s.

Of course, humanity can invent new ways to extract cobalt. Such developments exist, but at the moment they are unreasonably expensive (Pogorel, 2020).

8.2 *Creation of a business model that provides for profit in the production of electric vehicles*

Vacuum cleaner manufacturer Dyson, which declared its ambition to develop an electric car, was one of the first to admit that the production of electric cars does not pay off. The company hoped to invest $ 2.7 billion in the new direction, for which Dyson acquired several startups and switched 523 employees to develop an electric vehicle. The company even developed a prototype, but eventually closed the project because it did not see how to make it commercially viable.

In 2020, Ford Motor canceled the launch of a Lincoln-branded electric pickup. The company worked on a new electric car in conjunction with the startup Rivian, but decided to write off the $ 500 million investment and forget about the failed project.

If one looks at the financial reports of startups for the production of electric vehicles, then the common feature for all is obvious-colossal losses (for example, Nikola, Rivian, etc.). According to a study by the international company Deloitte, which is engaged in consulting large businesses, many startups producing electric vehicles and components for them will not survive due to the extremely high cost of equipment and production.

If one looks at the financial reports of startups for the production of electric vehicles, then the common feature for all of them is obvious-colossal losses (for example, Nikola, Rivian, etc.). According to the study made by the international company Deloitte (engaged in consulting large businesses), many startups producing electric vehicles and components for them will not survive due to the extremely high cost of equipment and production. GM, Mercedes-Benz and Fiat Chrysler cover the loss of their electrical projects with revenues from the sale of conventional cars with internal combustion engines. But if the world really completely switches to electric traction and abandons gasoline and diesel, the profits from cars with internal combustion engines will also disappear, and automakers may be left with unprofitable projects.

In the early 2010s, a number of countries introduced all sorts of support measures for electric cars in order to artificially stimulate demand for such cars and the transition of companies to the production of electric cars. For example, China directly paid car manufacturers for the production of electric vehicles and installed electric filling stations at the expense of the budget. Germany has funded research aimed at improving electric vehicles.

A number of countries have exempted such cars from taxes. Dozens of cities have made parking for electric cars free. In Norway, electric cars were allowed to travel in dedicated lanes along with passenger buses. In Switzerland, electric cars were exempted from import duties. In Ireland, such cars were allowed to travel free of charge on toll roads. Direct subsidies for the purchase of electric vehicles have become the most popular method. This measure appeared in almost all EU countries, the USA, India and South Korea.

However, now a number of states refuse such incentives. India canceled driver subsidies-and so the sales of electric vehicles plummeted. In the US, the discount is decreasing in proportion to the increase in the number of electric vehicles.

Lack of support could lead not only to a drop in sales of electric vehicles, but also to increase unemployment. Since India ended its electric car subsidy program in 2012, 10,000 people have lost their jobs. They were employed in the electro-mobile industry in various capacities: either directly in manufacturing companies such as Ultra Motors or BSA Motors, or in contractor companies such as Luminous Power Technologies. These companies supply components for electric vehicles, and therefore are highly dependent on the demand for cars (Pogorel, 2020).

However, Tesla posted a profit of $ 104 million in the second quarter of 2020. Tesla may be one of the few car companies in the world that will be profitable during the crisis (Auto Mail.ru, 2020).

Tesla sold 184,800 EVs in the first quarter of 2021 (+13% compared to the fourth quarter of 2020) despite the fact that the company was forced to suspend the assembly line in Fremont to organize the production of refreshed Model S and Model X. The best for Tesla was the fourth quarter of the previous year when the company delivered 180,570 vehicles to customers. The vast majority of electric vehicles sold in the first quarter are the Model 3 sedan and the Model Y crossover. It should be noted that in 2021 Tesla is going to launch two new “Gigafactories”-in Germany and Texas.

8.3 *Electromobility is not actively supported by all countries over the world*

There are states for which such a transition may be economically disadvantageous (for example, Russia). As an exporter of oil and gas, a massive refusal of gasoline is unprofitable for the country. As an environmentally friendly alternative to diesel and gasoline, the state-owned Gazprom corporation began promoting natural gas-methane (EcoGas). Methane has advantages really: for example, natural gas cars are cheaper to maintain due to the lower cost of fuel, and their environmental characteristics are better.

Despite the fact that Saudi Arabia announced a transition to electric vehicles, the International Energy Agency (IEA, 29 member countries) said that large-scale electrification of passenger transport will provoke a decrease in oil demand by 3.3 barrels per day. The IEA made a forecast based on the expected doubling of the number of cars on the planet by 2040. According to the agency’s calculations, in 20 years, 2 billion vehicles will travel on Earth, and a significant part of these vehicles will not need oil.

Even the United States is slowly limiting the spread of electric transport. For example, the state of Indiana has introduced an additional tax of $ 150/year from the owners of electric cars (the reason is that such drivers do not spend money at gas stations and thereby reduce the tax base of the state). According to the calculations of local authorities, this measure can bring up to $ 2 million annually to the budget.

Additional charges for electric vehicle owners apply in other states, such as Michigan, Minnesota and Arkansas.

The issue is gradually acquiring significance at the level of the whole country. Five years ago, it was impossible to imagine a discussion about whether to finance the proliferation of electric vehicles from the budget: the answer was a priori positive. But now the discussion has begun. American ICE drivers are outraged that only they pay for road repairs; the emerging political request stimulates the authorities not only to cut subsidies for electric cars, but also to increase the cost of maintaining an electric car as a whole.

There is also a significant foreign policy factor for the United States and other Western countries, because deposits of 95% of the world's reserves of rare earth metals, which are necessary for the operation of electric vehicles, are concentrated in China. The trade war between the United States and China, combined with the growing opposition to mainland China from the countries of Southeast Asia and individual European states, introduces a geopolitical risk (Table 3). Finally, nearly 60% of the world's cobalt (a critical substance for electric vehicle batteries) comes from the mines of the Democratic Republic of the Congo. Russia, which is the second largest producer, has only 5% of the market.

Table 3. Extraction of minerals used in the production of batteries for electric vehicles

Mineral	Totally produced, thousand of tons	Country	Extraction share
Lithium	43,0	Australia	44%
		Chile	34%
		Argentina	13%
		The rest of the world	9%
Cobalt	110,0	Democratic Republic of the Congo	59%
		Russia	5%
		Australia	5%
		The rest of the world	31%
Nickel	2,100,0	Philippines	11%
		Australia	9%
		The rest of the world	61%
Manganese	16,000,0	South Africa	33%
		China	16%
		Australia	14%
		The rest of the world	37%
Natural graphite	1,200,0	China	67%
		India	13%
		Brazil	8%
		The rest of the world	12%

Source: Gaidukevich (2019a)

However, many investors believe that soon the price of this metal may rise again, because demand for it will only grow in the long term. Cobalt is mined in violation of safety, human rights and child labor. Recently, activists accused Apple, Google, Dell, Microsoft, Tesla, that they knew about the origin and mining conditions of the cobalt used in their products, but still wanted to get a significant financial advantage. However, over the past 20 years, China has become the largest partner of African countries and annually invests huge sums (primarily in mining-China controls 85% of its global production). True, some analysts believe that the proportion of cobalt can be reduced by 5 times in favor of more affordable nickel, which, moreover, is more evenly distributed around the world (Pogorel, 2020; Gagarin, 2019).

A similar situation exists with natural graphite: the production of this mineral is now also controlled by China (extraction of 67% of all graphite). India accounts for 13%, Brazil-8% (Gaidukevich, 2019a).

At the same time, the issue of organizing the purification of used raw materials from impurities is also important: of the eight largest enterprises specializing in the purification of raw materials, seven are located in China. The same goes for the production of cathodes for batteries (China has overtaken Japan and Korea, the former traditional leaders).

Analysts believe that the recycled batteries from which metal can be reused will soon be available. But the situation will depend on the real demand for electric vehicles, because as soon as in some countries cars with internal combustion engines are completely banned, all the losses incurred will fall on the shoulders of buyers, which can reduce sales (Blog of the company Data Center "Miran", 2020; Ivanov, 2020).

8.4 *Refusal from cars with internal combustion engines can provoke an increase in electricity prices*

According to a BloombergNEF study (BloombergNEF, 2021), the ubiquitous proliferation of electric vehicles by 2040 will lead to an increase in electricity consumption worldwide by 6.8%. In addition, experts argue that the electrification of all passenger cars, for example, in the UK, will increase electricity consumption in the country by 20% by 2050 (Natural History Museum, 2019).

However, additional electricity will also be required for the extraction of rare earth metals required for batteries of electric cars (according to preliminary estimates, 22.5 terawatt-hours are needed to extract neodymium, cobalt and other elements for batteries).

Thomson Reuters analysts have built a mathematical model of how electricity consumption will change in the event of a full transition to the production of electric vehicles by 2040 (Thomson Reuters, 2019). It turned out that the world will need 1,350 additional terawatt hours to charge electric cars by 2040.

Therefore, by the time of the final decommissioning of gasoline and diesel vehicles (by about 2050), the consumption of electricity by electric vehicles will reach 3000 terawatt-hours-this is how much the entire European Union now spends on everything that is powered by electricity. All this together will require a large-scale construction of new power plants (including wind, solar, etc.). At the same time, an increase in demand can lead to an increase in prices (electricity tariffs) (Pogorel, 2020).

8.5 *Ecology*

About 38% of the world's electricity comes from coal burning. This process releases sulfur dioxide and nitrogen oxides into the atmosphere, which can cause acid rain. Emissions from coal-fired power plants also include fly ash, arsenic, mercury, and even radioactive thorium with uranium. As long as electricity for electric cars comes from coal-fired power plants, electric cars will only increase the poisoning of nature.

Nuclear power plants create spent nuclear fuel that can poison the environment and kill all living things for tens of thousands of years after use. According to a large Greenpeace study, existing disposal methods for such waste do not guarantee reliable isolation, and all analyzed landfills have leaks (Thomson Reuters, 2019).

The extraction of cadmium, tellurium, gallium, germanium, indium, selenium and, of course, silicon, which no solar panel can do without, provokes toxic pollution of soil, air and water in the most vulnerable natural zones: a significant part of these materials are obtained in regions of Asia, Africa and South America with a fragile ecosystem (Roche et al., 2020).

Even if the method of generating electricity is not taken into account, many questions arise about the batteries themselves (both nickel-cadmium and lithium-ion batteries). Extraction of cadmium and lithium not only pollutes groundwater, but also leads to desertification. A prime example is Atacama in Chile. The area of this desert is growing, and the oases are disappearing due to the extraction of lithium. When extracting this substance, companies pump out gigaliters of water, which dries up the soil and deprives local animals of food. A similar scenario is developing in Bolivia, Tibet, Australia and other lithium-producing regions. People directly involved in this trade are susceptible to the development of pulmonary edema and pleurisy due to inhalation of lithium dust and alkaline lithium compounds.

Electromobility stimulated the growth of lithium production: in ten years, from 2008 to 2018, the world production of lithium increased eightfold (Agusdinata et al., 2018).

The Paris Protocol, signed by many countries, equates a wide variety of environmental pollution with measurable

CO_2, which is considered a key culprit in the greenhouse effect. Although CO_2 itself is not toxic and does not poison wildlife (as opposed to cadmium, mercury, soot and other consequences of the operation of power plants), most scientific works study carbon dioxide as a source of the greenhouse effect.

But even with this approach, electric cars turn out to be dirtier than cars with internal combustion engines. This is the conclusion reached by the authors of a study published by the German scientific journal Ifo Schnelldienst at the University of Munich. In their work, scientists compared the carbon footprint of a gasoline Mercedes-Benz and an electric Tesla (Buchal et al., 2019). Due to the large CO_2 emissions from the production of batteries and the extraction of lithium, manganese and cobalt, Tesla's carbon footprint was 156-181 grams per kilometer. The carbon footprint of a gasoline Mercedes-Benz was 112 grams per kilometer traveled.

The researchers' findings were supported by practitioners from Polestar, a Volvo sub-brand. The Swedish car manufacturer compared the carbon footprint of the electric Polestar 2 and the petrol Volvo XC40. It turned out that the production of a crossover with an internal combustion engine provokes the emission of 14 tons of CO_2, and the production of the Polestar 2 electric car, taking into account the battery, costs the atmosphere 24 tons of CO_2.

It is possible to equalize the performance of these cars only after 50,000 kilometers, but even then the models will be equal only in terms of CO_2 emissions. Vanadium compounds, anhydrides, arsenic and other substances that emit power plants necessary for regular charging of an electric vehicle are not taken into account here (Pogorel, 2020; Sarkhanyants, 2021).

9. Conclusions

1. The global transition to electric vehicles is an important step towards a carbon-free future. Despite the decline in the car market during the COVID-19 pandemic, sales of electric vehicles have increased, indicating a move towards total electrification in the world.

2. The damage caused to the environment is measured not only by the amount of CO_2 emitted directly during the movement of the electric car, but also by the value of the "carbon footprint", which is the aggregate of all harmful emissions and greenhouse gases produced by an object during its life cycle. In the case of a single electric car, the carbon footprint is defined by all environmental pollution during the production of a car and the electricity it consumes.

3. Electric mobility has a long way to go before reaching by EVs a significant contribution to meeting greenhouse gas emission reduction targets. Research and development and improvement in mass production are driving down battery costs and this trend should continue, which should narrow the competitiveness gap between electric vehicles and combustion engines. At the same time, a number of issues remain unresolved demanding a consolidated strategy of all countries committed to electromobility.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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