МОДЕРНИЗАЦИЯ И ИННОВАЦИИ

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The conditional consumer's view on the development of the electric vehicle market: Russian case

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Abstract
Subject/topic. The article presents an original assessment of the electric vehicle market development from the viewpoint of determining the advantages and costs of a potential buyer. ***Goal.*** The study aims to analyze the emerging electric vehicle market in Russia as a fuel-independent country with an environmental agenda for economic development. ***Methodology.*** A comparative analysis of combustion-engine car and electric vehicle according to the characteristics: a) environmental friendliness, b) cost-effectiveness, c) convenience in operation. ***Results.*** The authors present the results of calculations that confirm the environmental friendliness of the electric vehicle, but also the influence of the way of generating energy in the country can increase CO_2 emissions. The price factor, fuel costs for a petrol car, and the cost of charging an electric vehicle with four board options were measured. The calculation of the operating costs of various types of vehicles and the analysis of usability, including access to charging, technical parameters, are presented. ***Conclusion.*** The main target groups of electric vehicle buyers have been identified, as well as the prospects for the development of the electric vehicle market in Russia, taking into account the state support and the need to modernize the energy industry.

Keywords: *electric vehicle market, electric vehicle, combustion-engine car, environmental friendliness, fuel costs, cost of charging, consumer preference.*

Взгляд условного потребителя на развитие рынка электромобилей: российский кейс

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Аннотация
Предмет/тема. В статье представлена оригинальная оценка развития рынка электромобилей с позиции определения преимуществ и затрат потенциального покупателя. ***Цель.*** Исследование имеет целью анализ развивающегося рынка электромобилей в России как топливно-независимой стране с экологической повесткой экономического развития. ***Методология.*** Проведен сравнительный анализ автомобилей с двигателем внутреннего сгорания и электромобилей по характеристикам: а) экологичность, б) экономичность, с) удобство использования. ***Результаты.*** Авторы представляют результаты расчетов, которые подтверждают экологичность электромобиля, но также влияние способа генерации энергии в стране может увеличивать выбросы CO_2. Оценены ценовой фактор, затраты на топливо для бензинового автомобиля и затраты на зарядку электромобиля при четырех вариантах платы. Произведен расчет затрат на эксплуатацию различных типов автомобилей и анализ удобства использования, включая доступ к зарядке, технические параметры. ***Выводы.*** Определены основные целевые группы покупателей электромобилей, а также перспективы развития рынка электромобилей в России с учетом необходимости модернизации энергетической отрасли и развития государственной поддержки.

Ключевые слова: *рынок электромобилей, электромобиль, автомобиль с двигателем внутреннего сгорания, экологичность, стоимость топлива, стоимость зарядки, потребительские предпочтения.*

Introduction

In the world of mechanical engineering today, there is a trend of gradual shift in the interest of leading automobile manufacturers and consumers from vehicles with gasoline and diesel engines to

vehicles using engines on alternative energy sources, in particular, electric vehicles (EVs) (Yoo, Wakamori and Yoshida, 2021). There is an incredible increase in the number of electric vehicles around the world, and industry forecasts suggest that this is just the beginning of the whole journey.

The articles and expert reviews note a possible full transition to EVs in the coming decades (Boulanger et al, 2011) as the best means of mobility for people (Kreydenko and Kovalchuk, 2021), and there are several reasons for the popularity (Daina, Sivakumar and Polak, 2017) and the growing demand for EVs (Cordera, dell'Olio, Ibeas and de Dios Ortúzar, 2019). First, the global reason is the beginning of the transition to «green» energy in different countries, the trend towards «green» technologies and environmental friendliness (Hawkins, Singh, Majeau-Bettez and Strømman, 2012). Now we can talk about the fashion for eco-friendliness, and electric vehicles are the part of modern eco-friendly consumption trend and the attributes of sharing economy (Stepnov, 2020). Even the term «environmental awareness» was introduced to assess people's intentions to purchase an electric vehicle (Austmann and Vigne, 2021).

Many countries are interested in increasing the EV production. The policy of developed countries to «green» the economy, as well as the ambitions of China, contribute to the transition of automobile manufacturers to the EV development, as well as the emergence of new EV companies. Today the Chinese electric vehicles market is the largest and one of the fastest growing (more than half of all electric vehicles are sold in the Chinese market, and this country is the leader in the number of charging stations for vehicles). The Chinese government quickly recognized EVs as a great opportunity to become a world leader in the automotive arena and supports local automobile manufacturers through subsidies and various benefits (Ouyang et al, 2020).

A low-carbon scenario is being discussed in Europe (Colmenar-Santos et al, 2019). By 2050, EU countries are determined to reduce their greenhouse gas emissions to almost zero. Even before the pandemic, documents were developed that set standards for carbon emissions, as well as requirements for zero-emission vehicles. This encourages European automobile manufacturers to actively develop the EV segment.

Clean energy is also a trend for the American economy, so there is an increase in the number of charging stations, and EV manufacturers and startup companies receive the financial support.

Legislative and policy initiatives aimed at promoting the use of electric vehicles are considered in an international context. Norway, Germany, New Zealand, Australia and France are actively working to overcome barriers to faster adoption of electric vehicles, including the payment of bonuses to their buyers.

However, EV introduction to market is currently relatively low, despite the fact that many governments have an active promotion policy (Wang, Tang and Pan, 2019). It is important that today EV is an expensive purchase, not available to the average consumer. Some of the most budget versions cost about $30,000, which, taking into account subsidies, puts the EV on a par with the conventional vehicle’s price. The cheapest version is far from the best, it is inferior in the comfort class due to the low power reserve. Therefore, price support is necessary as long as EVs are more expensive than combustion-engine car (Barton and Schütte, 2017). At the same time, manufacturers are actively expanding the model line of electric vehicles and investing in reducing the cost of the most expensive part of the electric vehicle – the battery (Duarte Castro, Vaccari and Cutaia, 2021), and the government is building additional charging stations (Pagani, Korosec, Chokani and Abhari, 2019).

Researchers and experts note that the EV choice is influenced by a variety of consumer preferences, the age of drivers and the price perception (Cordera, dell'Olio, Ibeas and de Dios Ortúzar, 2019) and the technical characteristics of electric vehicles, such as charging time, driving distance (Junquera, Moreno and Álvarez, 2016).

However, existing studies on this topic (Habich-Sobiegalla, Kostka and Anzinger, 2018) confirm that it is too early to talk about the EV harmlessness, and the ease of use is not comparable to petrol cars – in this regard, the potential market share of electric vehicles in fuel-independent countries may be much less than expected by experts, and a sharp increase in their popularity is still little predicted. Therefore, the very poorly developed market of electric vehicles in Russia and possible directions of its development are of increasing interest at this moment.

Materials and Methods

The study aims to analyze the Russian EV market, which is now insignificant compared to the United States, China or EU countries. In Russia the EV market is only developing and now its share is less than 0,1% of global consumption. Therefore, the authors set the goal of the study as an analysis of the EV market development, taking into account the comparison of electric vehicle and combustion-engine car by environmental and economic characteristics. This is an important confirmation of the prospects for the EV market development, since Russia does not lack fuel for petrol cars, but this country also implements an environmental agenda like other countries in the world.

Methods of comparison, analysis, synthesis, and modeling were used in this study, as well as some results obtained earlier (Kovalchuk, Nepluhina and Kaminsky, 2021). The authors performed calculations of environmental parameters of use and economic parameters of ownership from different types of vehicles. The calculations used the technical characteristics of petrol (or gasoline) cars produced by European and Korean companies and the technical characteristics of the *Nissan Leaf* electric vehicle (this EV model is the most popular among Russians and has a share of about 80% of the total number of electric vehicles registered in Russia).

The study has the following structure of using methods. The authors conduct a comparative analysis of the emissions from the use of different types of vehicles (conventional vehicle vs. electric vehicle). Next, the authors make an assessment of the economy and usability of various types of vehicles from the consumer's viewpoint. Based on the results of calculations and the data obtained, there is a definition of the main target groups for the EVs purchase and a design of the prospects for the development of the electric vehicle market in Russia.

Results

The engineering main difference between electric vehicle and combustion-engine car is an electric type of engine, that is, charged from batteries. In recent years, interest in electric vehicles has increased significantly, largely due to the statements of manufacturers in a high degree of environmental friendliness and economy of this type of vehicle. Consumers' interest is significantly increasing (fig. 1).

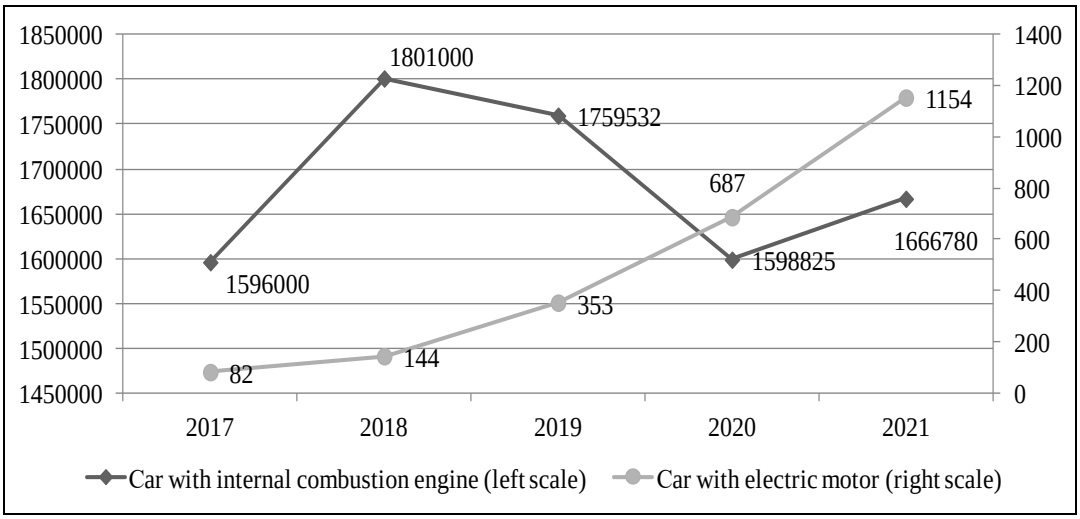

Fig. 1. / Рис. 1. Number of cars purchased from 2017 to 2021 in Russia / Количество автомобилей, приобретенных в России с 2017 по 2021 год

Source / Источник: developed by the authors on the basis of open data from the analytical agency Autostat: Structure and forecast of the passenger car fleet in Russia, available at: https://www.autostat.ru/research/product/397 (Accessed 01.02.2022); The Russian market of new electric vehicles has tripled in 2021, available at: https://www.autostat.ru/news/50525/ (Accessed 01.02.2022) / разработано авторами на основе открытых данных аналитического агентства Autostat: Структура и прогноз парка легковых автомобилей в России, доступно по адресу: https://www.autostat.ru/research/product/397 (Дата обращения 01.02.2022); Российский рынок новых электромобилей в 2021 году вырос втрое, доступно по адресу: https://www.autostat.ru/news/50525/ (Дата обращения 01.02.2022).

The number of electric vehicles sold in Russia is more than doubling every year. Forecasters promise an increase the EV sales in future. The number of combustion-engine car is reduced starting in 2019. In addition, the EV secondary market is also increasing. In 2020, 5,274 used electric vehicles were purchased (this is 60% more than in 2019). However, this is not due to the popularization of electric vehicles, but mainly due to the crisis situation in the country. In absolute numbers, the gap in the purchase of electric vehicles and combustion-engine cars is so large that today it is impossible to talk about any capture of the market by EVs, even with the exponential growth of their popularity.

In order to determine the EVs advantages and potential stakeholders in their acquisition, a comparison was made on next points.

1. Environmental friendliness

The authors used the *Nissan Leaf* with a 50 кWh battery for evaluation as EV, the combustion-engine car data were taken on average in Europe (Philippot, Álvarez, Ayerbe, Van Mierlo and Messagie, 2019). The batteries are manufactured in Asia, which causes a large amount of emissions during production. Calculations show that combustion-engine car produces 2,01 times more CO_2 emissions than an electric vehicle (table 1). However, 128 grams per kilometer is also a significant amount, far from being completely environmentally friendly for EVs.

Table 1 / Таблица 1

Comparison of CO_2 emissions, grams per kilometer / Сравнение выбросов CO_2, грамм на километр

Specifications	Conventional vehicle	Electric vehicle
Battery, кWh	-	50
Fuel cycle (includes oil production, transportation, refining, and electricity generation)	47	40
Manufacture of other vehicle parts	46	38
Exhaust emissions	165	-
In general	258	128

Source / Источник: authors' calculations / расчеты авторов.

A large share in the EV emissions is expected to be taken by battery production, in the second place there is electricity production. So, the environmental friendliness of the vehicle as a comparison indicator varies from country to country. For example, in Russia 70% of all electricity is produced in thermal power plants, accordingly in fact, the electric vehicle is driven by fossil fuel. In other countries, this amount may be different – for example, in Brazil 70% of electricity is provided by hydroelectric power plants, in which case driving an electric vehicle will really be environmentally friendly. For the combustion-engine car, a significant amount of emissions is caused by exhaust gases, which account for more than 50% of the total CO_2 emissions. Therefore, today in Russia, for those interested in the environment, the most rational solution is public transport or natural gas vehicle.

Table 2 shows a comparison of the emissions of electric vehicle and conventional vehicle over their entire service life, based on a total mileage of 150,000 km.

Table 2 / Таблица 2

Dynamics of CO_2 emissions in tons / Динамика выбросов CO_2 в тоннах

Specifications	Conventional vehicle	Electric vehicle
during production	7	10
after 1 year of use	10	10
after 2 year of use	13	11
after 3 year of use	15	11

Specifications	Conventional vehicle	Electric vehicle
after 4 year of use	18	11
after 5 year of use	21	12
after 6 year of use	24	12
after 7 year of use	27	12
after 8 year of use	30	12
after 9 year of use	32	13
after 10 year of use	35	13
after 11 year of use	38	13
after 12 year of use	41	13

Source / Источник: authors' calculations / расчеты авторов.

The authors obtained the result that the battery causes more emissions during the production of the vehicle in «zero year», but this excess carbon debt will be paid off in less than two years of driving. Thus, in terms of ecology, EVs win over combustion-engine cars when used for more than 2 years. After 12 years of use, the amount of emissions produced by combustion-engine cars will exceed the amount of emissions from EVs by more than 3 times. Thus, in the long term, an EV may be of interest to fans of environmental friendliness.

However, speaking about the EVs environmental friendliness, we should not lose sight of the fact that in many countries, most of the electricity generation is provided by thermal power plants. For example, in some cities in China, EVs account for more than 50% of the total number of cars, but the amount of air pollution is almost constant. This is due to the fact that 85% of China's electricity is generated by thermal power plants, which are mainly coal fired. With the transition to electric vehicles, electricity consumption increases, which leads to the need to increase the volume of generation by stations, as a result, air pollution does not decrease, but, on the contrary, increases.

Anyway, an electric vehicle is really much more environmentally friendly than combustion-engine car. It is still too early to talk about complete harmlessness to the environment, given the cost of electricity and lithium in the production of batteries, but investment in this automotive industry is not without meaning, given their growing popularity. Even now, researchers suggest that in the future, the capacity of batteries will be increased (Duarte Castro, Vaccari and Cutaia, 2021), which, in turn, will lead to lower emissions during their production. However, in many countries, the environmental friendliness of an electric vehicle may be lower than the values in the calculations – therefore, in order to reduce CO_2 emissions, not only electric vehicles should be introduced, but also the entire energy industry should be modernized, since the emissions of thermal power plants in the energy production for cars negatively affect the total amount of CO_2 in the atmosphere. The industry's modernization will take a period of much more than a decade, so in Russia, even among the supporters of environmental trends, there are no forecasts for a sharp increase in the EVs purchases.

2. Cost-effectiveness

To identify potential consumer groups, the authors analyzed the economic aspects of using electric vehicles and combustion-engine cars from the same price segment: *Nissan Leaf* (2020 release) at a price of $ 30,000 (2,250,000 rubles at the exchange rate on 01.02.2022) and Kia k5 (2020 release) in one of the best trim levels at a price of 2,299,900 rubles.

Table 3 provides information about comparison results of the cost of driving combustion-engine car and electric vehicle. The average fuel consumption is 8 liters per 100 km for petrol car, and 15 kWh for electric vehicle.

EVs have four options for refueling: 1) daily tariff is the most realistic way (price is 3,4 rubles per 1 kWh); 2) free electric filling station for residents of large metropolitan areas (price is 0 rubles); 3) night tariff especially relevant for residents of cottages, villages (price is 1,7 rubles per 1 kWh); and 4) paid electric filling station for sudden charging in unknown places (price is 17 rubles per 1 kWh).

If the calculations take into account 15,000 km as the vehicle's average mileage per year, the fuel cost is 51,600 rubles for a gasoline engine.

Considering different scenarios of refueling an electric vehicle, we can come to the conclusion that the cost of traveling in combustion-engine car in any case will cost more. The authors identified the scenarios: for combustion-engine car the price difference will be 13,350 rubles in the optimistic scenario, and 51,600 rubles in the worst-case scenario.

Table 3 / Таблица 3

Comparison of the cost of driving a car per year / Сравнение стоимости вождения автомобиля в год

Specifications	Electric vehicle	Petrol car
Energy / fuel consumption per 100 km	15 кWh	8 liters
Petrol price in rubles per 1 liter		43
Daily tariff in rubles per 1 kWh	3,4	
Energy / fuel consumption per 100 km in rubles	51	344
Electric filling station in rubles per 1 kWh	0 (free)	
Energy / fuel consumption per 100 km in rubles (daily tariff)	0	344
Night tariff in rubles per 1 kWh	1,7	
Energy / fuel consumption per 100 km in rubles (night tariff)	25,5	344
Paid electric filling station in rubles per 1 kWh	17	
Cost of car driving of 100 km distance in rubles	255	344
Cost of driving a car of 15,000 km annual distance in rubles		
Daily tariff	7650	51600
Free electric filling station	0	51600
Night tariff	3825	51600
Paid electric filling station	38250	51600

Source / Источник: authors' calculations / расчеты авторов.

According to the data in Table 4, the cost of petrol car's service is 39,500 rubles for 5 years. The cost of electric vehicle service will be 54,600 rubles, which is 15,100 rubles more than its competitor.

Table 4 / Таблица 4

Comparison of car maintenance costs over 5 years in rubles / Сравнение затрат на техническое обслуживание автомобиля за 5 лет в рублях

Specifications	Electric vehicle	Petrol car
Motor oil	-	15000
Air filter	-	1000
Automatic transmission oil	-	16000
Spark plugs	-	2500
Timing belt	-	5000

Specifications	Electric vehicle	Petrol car
Gear oil	2800	-
Battery depreciation	51800	-
In general	54600	39500

Source / Источник: authors' calculations / расчеты авторов.

The final calculations show that average mileage of both types of cars for 5 years (75,000 km) with all possible options and scenarios provides a reduction in EV cost (table 5).

Table 5 / Таблица 5

Comparison of cost for 5 years, including service work, in rubles /
Сравнение стоимости за 5 лет, включая сервисные работы, в рублях

Specifications	Electric vehicle	Petrol car
Overall cost (daily tariff)	92850	297500
Overall cost (free electric filling station)	54600	297500
Overall cost (night tariff)	73725	297500
Overall cost (paid electric filling station)	245850	297500

Source / Источник: authors' calculations / расчеты авторов.

The cost of combustion-engine car will amount to 297,500 rubles, which is: a) 242,900 rubles more than EV free charging at stations, b) 204,650 rubles more than daily tariff charging, c) 223,775 rubles more than night tariff charging, and d) 51,650 rubles more than paid electric filling station charging. Therefore, from the consumer's viewpoint, the EVs operation is more profitable than a combustion-engine cars.

3. Convenience in operation

The economic and environmental factors do not always have a decisive influence when the consumer decides to purchase a car. Ease of use is one of the most important factors from the consumer's viewpoint when choosing a car. This point is currently the main obstacle to the development of electric vehicles in Russia. Despite the many advantages of an electric vehicle, such as environmental friendliness, no taxes, free refueling, easy maintenance and quiet driving, there are a number of significant disadvantages.

First, the lack of the necessary and sufficient number of electric filling station and the long process of charging the battery. There are two types of charging. In the first version, the process is carried out in special places through chargers – here the charging time will be 30-50 minutes. The second version is to charge at home using a 220 V socket (then the charging time of *Nissan Leaf* will be about 13 hours). With the industry's development, it will be possible for consumers to purchase charging stations with a 50 kWh capacity, which will allow them to charge the battery up to 80% in 30-40 minutes. The expected price of such a charging station will be about 1,500,000 rubles. For most of the country's population, this amount is a significant financial investment and, therefore, affects the buyer's preference in favor of a combustion-engine car. It should also be noted that there are a small number of electric filling station for EVs in Russia, which, together with the long charging process, plays a big role in the consumer's choice.

Secondly, the speed and mileage of electric vehicles are currently significantly limited. For example, *Nissan Leaf* is able to go 241 km without recharging, on average, this figure varies from 160-230 km. Obviously, electric vehicles are not provided for long-distance trips, which also repels many potential buyers. The maximum speed reaches 144 km / h, which meets the needs of most consumers (Panchal, Stegen and Lu, 2018).

Third, most often electric vehicles are quite compact cars that are not suitable for large families with children.

Fourth, today the electric vehicle market segment is small and crowded with similar models of the same type.

Thus, the EVs target audience is significantly reduced. Families with children and people who like long trips by car, as well as ordinary users of electric vehicles can have many problems during their operation. Even in the conditions of financial availability of an electric vehicle, a potential buyer will consider the convenience of its use (Stepnov, 2021). The practicality of an electric vehicle at the moment is low, which is likely to tilt the choice of most people in favor of a conventional vehicle.

Discussion

In the course of the research work, in order to determine the EV potential buyers and the prospects for the development of this market, electric vehicles and combustion-engine cars were compared on several points, and the authors received the following conclusions.

1. Environmental friendliness

An electric vehicle in operation is really safer for the environment than a combustion-engine car. But this advantage is very controversial due to the peculiarities of the energy sector in Russia, since electricity is generated by thermal power plants by burning fossil fuels. In addition, the production of batteries is also a significant environmental problem. Buyers who are concerned about the environment can purchase electric vehicles, but these buyers make up a small fraction of all potential car buyers. In the minds of people, the idea of the coincidence of environmental protection and car ownership has not yet been strengthened. Therefore, the relative environmental friendliness of electric vehicles is a weak motivation for the purchase of this type of transport from a typical consumer facing a choice.

2. Cost-effectiveness

A combustion-engine car will cost an average of 180,000 rubles more expensive than an electric vehicle for 5 years of use, taking into account the service cost. But it is worth paying attention to the secondary car market. Conventional vehicles often after their initial operation are successfully sold on the secondary market with a loss in price of 15-50%, depending on the brand, model, configuration and the immediate condition of the car. The EV secondary market is currently developed much worse than the level of conventional vehicles. Accordingly, most of the potential consumers of electric vehicles will consider buying a new car, while buyers of conventional vehicles can consider both options in the public domain. Most electric vihicles are sold from 2,000,000 rubles, while new models of petrol cars can be purchased from 800,000 rubles. This price factor confirms that most people in Russia are likely to consider a combustion-engine car for purchase. And then, their opportunities will increase thanks to the secondary car market. Students, pensioners and people with low wages will also choose conventional vehicles on the secondary market. Definitely, the target audience of electric vehicles is people with a high level of wages, who can afford to buy a new car from 2,000,000 rubles. It is also necessary to take into account the state economic support aimed at supporting the electric vehicle market. In Russia, there is no taxation, there are free parking and charging stations – this is a significant motivation for the EV owners. However, in reality, the state support will not be able to compensate for the large initial cost of an electric vehicle and an undeveloped secondary market. If the state support increases in the future, perhaps the share of electric vehicles will increase, and potential consumers will reconsider their point of view and abandon conventional vehicles.

3. Convenience in operation

Today, the consumer who purchased an electric vehicle in Russia, will not be able to fully enjoy all its amenities, as there are a number of reasons that prevent comfortable operation. For the EV's owner the question of battery charging will be acute, because: a) there are a limited number of charging stations, b) the fully charging battery takes much longer than filling the petrol car. In addition, at the moment, many EVs are not adapted for driving long distances due to the small power reserve, and are also unsuitable for large families due to the small capacity. It is worth noting that every year the number of fast charging stations for EVs increases. This can lead to better infrastructure and then to an increase in demand for electric vehicles, but this process can take a significant amount of time.

Conclusions

Thus, now the electric vehicle market in Russia is at the stage of formation, and its rapid rise in the near future is not expected. The reason for this is that there is a small potential group of buyers – these are mostly well-off people who do not need long trips by car and places for family members, and who are also able to afford an expensive charging station. If we add to them Russians who are concerned about the environment, the total number of buyers who are financially ready to EV purchase will be about 3,34 million people (this is 2,4% of the country's population). This quantity will be significantly lower due to the lack of infrastructure for EVs. Therefore, there is some growth potential in the electric vehicle market, but it is difficult to say whether it will ever exceed the volume of the market for combustion-engines cars.

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