EXPERT AND ANALYTICAL REPORT

ELECTRIC VEHICLE MARKET AND CHARGING INFRASTRUCTURE DEVELOPMENT PERSPECTIVES IN RUSSIA

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The report is prepared by the group of authors, representing electric vehicle market stakeholder organizations consortium: Fund “Center for Strategic Research “North-West”, Saint-Petersburg Polytechnic University of Peter the Great, KAMAZ, Institute of Research and Expertise VEB.RF, Skolkovo Institute of Science and Technology, in partnership with Innovations and Youth Initiatives Support Foundation of Saint-Petersburg.

The report provides evaluation of the current state of electric vehicle industry in Russia and abroad. EV market volume and dynamics are evaluated, market entering and significant market penetration measures for Russian EV and component production enterprises are provided. The review of Russian companies’ technical capabilities for EV production is provided and key directions for technology development are suggested. Market development factors are highlighted: electric transport influence on decarbonization and energy balance, consumer demand and EV ownership costs, cross-cutting technologies and markets, government policy. Based on the analysis of the Global and Russian experience, authors provide recommendations for policymaking concerning electric vehicles on the federal and regional levels.

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REVIEW

of the expert and analytical report "Electric vehicle market and charging infrastructure development perspectives in Russia", prepared by a team of authors under the editorship of Prof. A. I. Borovkov and Prof. V. N. Knyaginin

The expert and analytical report "Electric vehicle market and charging infrastructure development perspectives in Russia", prepared by a team of authors under the editorship of Prof. A. I. Borovkov and Prof. V. N. Knyaginin, is devoted to the topic of global economy transformation and transition to a new technological and industrial mode, an important feature of which will be an alternative fuel and energy balance.

As a global driver of change in this process, the team of authors has identified and justified the development of technologies for the development and production of electric transport and charging infrastructure, which will entail technological, economic and infrastructural changes in related areas and sectors of the economy.

Based on the authors' analytical research and expert conclusions, the key thesis of the report is is as follows: the "window of opportunity" for achieving leadership positions in the emerging electric transport market, including Russia, is two to three years. The decisions to be made during this period, according to the authors, will form the basis of the most important parameters of the future architecture of the global market – from mandatory educational and production standards to new business models and market regulation.

The content of the report is qualitatively structured and logically built in the form of answers to key questions, necessary to determine the model of regulating the launch and advanced development of the Russian market of electric transport.

Based on their own marketing and industry research, analysis of an extensive list of analytical reports and forecasts of leading expert organizations, as well as their own practical experience in the development and production of electric vehicles, the authors suggest a number of measures that will allow Russia to take advantage of the "window of opportunity" and have time to gain a foothold in the global electric vehicle market before reaching a "breaking point" and market stabilization, and will also help to form domestic demand and supply for electric vehicles in Russia.

I consider that the reviewed work contains important scientific and practical results, and I recommend the expert and analytical report "Electric vehicle market and charging infrastructure development perspectives in Russia" to be published as a scientific publication.

D. in Technical Sciences, Professor, SPbPU,

Honored Scientist of the Russian Federation,

Laureate of the Russian Government Prize in Education ______________________ I. L. Tukkel

REVIEW

of the expert and analytical report "Electric vehicle market and charging infrastructure development perspectives in Russia", prepared by a team of authors under the editorship of Prof. A. I. Borovkov and Prof. V. N. Knyaginin

The paper submitted for review focuses on the topical problem – the development of electric transport and charging infrastructure in Russia. The paper was prepared by a team of authors representing a consortium of organizations interested in the development of the electric vehicle market: the Center for Strategic Research "North-West" Foundation, Peter the Great St. Petersburg Polytechnic University, KAMAZ, Institute of Research and Expertise VEB.RF, Skolkovo Institute of Science and Technology.

The first part of the paper, presented in sections 1–4, gives a general description of the global situation in the field of electric transport. Section 3 also provides estimates of the impact of electric vehicles on the energy balance in Russia.

In sections 4 and 5, the authors examine in detail the prospects for the development of the charging infrastructure market and estimate the cost of owning an electric car in Russia. Of particular importance is the breakdown of the charging infrastructure market market developments according to different scenarios.

In sections 7 and 8, the authors conduct a detailed analysis of Russia's competencies and capabilities in developing the production of electric cars, their components, and the raw material base for such production. Attention is also paid to the development of related markets and end-to-end technologies.

An important part of the text is Section 9, in which the authors formulate proposals and recommendations for public policy in the field of electric vehicles and measures to support the industry of their production.

The work provides the reader with a comprehensive understanding of the prospects for the development of the electric vehicle market and the charging infrastructure in Russia. The analysis is based on a substantial base of Russian and foreign sources and literature – 36 titles. The paper is well structured, informative and concise. The style of presentation and the presence of clear visual materials ensure easy perception of the text.

The work is recommended for review by decision-makers in public authorities and organizations, whose activities are somehow related to the transport industry, transport infrastructure and high-tech production. The work contains useful and applicable practical results and recommendations.

D. in Technical Sciences, Professor, Full member of the
Russian Academy of Natural Sciences, Laureate of the
Prize of the Council of Ministers of the USSR ____________ V. M. Agapkin

CONTENT

INTRODUCTION

The purposeful policy of developed countries to transform the global economy and form a new world order, an important feature of which will be an alternative fuel and energy balance, requires a response from all states, including Russia. Despite its rich hydrocarbon reserves, Russia cannot ignore the fact that the main consumer of energy – transport – has begun to actively gain momentum in the movement to reduce the consumption of fossil fuels. And the most important trigger for change in this process has been the increase in the production of electric vehicles, growing on high expectations of unmet demand.

Competition in the field of electric vehicles gives birth to new technologies, companies, business models – and ultimately forms new markets. In the next two to three years, there will be a window of opportunity to get a head start and achieve a leadership position in the emerging electric vehicle market. In fact, the stage of global market formation is now coming to an end, with total investment in electric vehicle production and infrastructure worldwide growing rapidly. The sequence of decisions that will be made during this period will form the basis for the future architecture of the global market – from educational and manufacturing standards, to the organization of urban infrastructure, to new business models and market regulation conditions. The winners will be the companies which by 2024 will be able to establish production, start sales and gain a foothold in the market, because after passing the "breaking point" in 2025–2026 the structure of the global market will stabilize and new players will have to catch up with the leaders and invest significant amounts to get their market share.

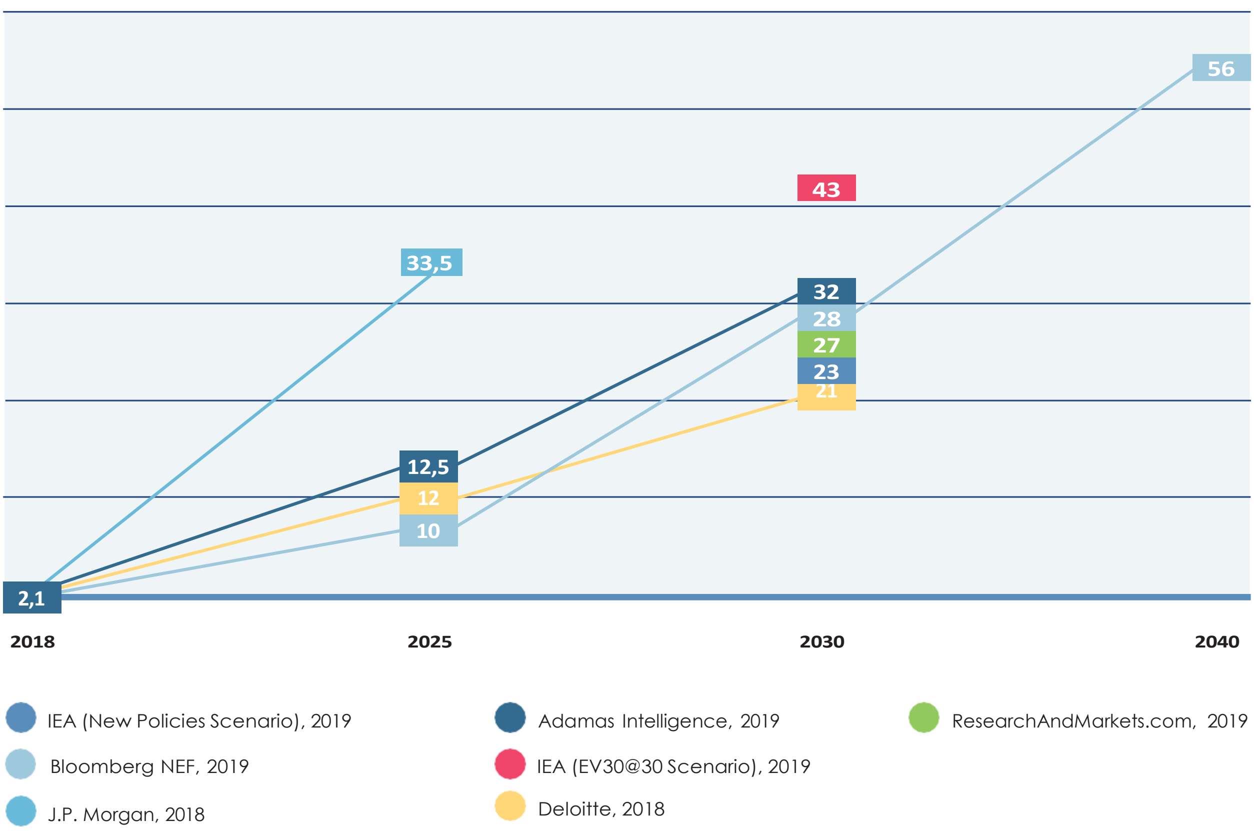

Fig. 1. Global Electric Vehicle Market: Consensus annual sales forecast, million units / Source: STI Center SPbPU, based on open data from expert organizations

Transformation will affect not only the transport industry, but also related segments of related industries. The adoption of carbon neutrality standards, as well as the integration of fundamentally new infrastructure and new modes of transport into everyday life, will require the development of related technologies, deep modernization of existing and the creation of new industries at all stages of the life cycle: extraction of raw materials for batteries, development and production of electric vehicles and components, charging stations and energy infrastructure, information infrastructure and cybersecurity, recycling, etc.

To consolidate its position on the emerging markets for electric transport and, more generally, transport based on new energy sources, Russia needs to define its role on the intensively emerging global market and its internal policy in relation to global automotive concerns and national manufacturers in the electric transport segment. Russia needs to identify zones of protection and zones of prospective cooperation and, in general, to intensify its efforts in this direction. At the moment (March 2021), Russia has every opportunity to integrate into the global automotive industry on a new technological level, becoming an active global market participant.

At the same time, when determining measures to stimulate the transition to electric vehicles, it is necessary to take into account the specifics of the Russian economy. The main line of state policy in the field of electric vehicles market should be careful with regard to prohibitive measures popular in a number of countries to reduce the number of cars with internal combustion engines, as they are related to the basic sector of the Russian economy. To a greater extent, state support measures should be focused on developing the industry for the development and production of globally competitive domestic electric vehicles on their own component base, supporting demand and shaping the market for electric vehicles in Russia.

First and foremost, such support should be aimed at the largest agglomerations – Moscow and St. Petersburg, agglomerations of other large cities (such as Nizhny Novgorod, Kazan and Yekaterinburg), Krasnodar Territory and the Republic of Crimea. In these subjects of the Federation, state investments in the electric car industry will bring the greatest effects due to their geographical, economic and infrastructural features. A full-fledged infrastructure of charging stations should be deployed in these urban systems and major highways, and the purchase and ownership of electric vehicles should be encouraged. This will contribute to strengthening Russia's international image as a technologically advanced and economically developed country.

It is necessary to synchronize the development of production of electric cars, stimulating their purchase and use, as well as opening the domestic market for imports of electric cars (now there are zero import duties), otherwise at the moment of market formation it will be filled with imported products. At the same time, it is important to note that production of domestic electric cars cannot be understood as reproduction of the industrial assembly mechanism. The prospect of positioning Russia as an automobile manufacturing country is associated with mastering key competences in the development and production of electric vehicles, primarily with designing its own platforms and creating energy systems (batteries and, subsequently, fuel cells based on domestic developments). It is this deep "localization" of key electric transport technologies that ensures a high multiplier of the automotive industry, the creation of a large number of innovative enterprises in this segment, and the creation of new jobs in related industries.

The competitiveness of electric cars depends to a great extent on batteries: today they account for up to half of the cost of an electric car and determine its mileage and usability characteristics. In Russia, it is urgent to develop applied technological developments and create production of traction batteries for electric vehicles. The arguments against lithium-ion batteries that exist in the public and expert communities are untenable.

It makes sense to return to defining the way of coordination of the state policy in the sphere of development of electric transport and production of electric cars in the Russian Federation, and, certainly, to update the Strategy of development of automobile industry of the Russian Federation for the period until 2025 and plans for its implementation should be actualized.

The most important mechanism for the development of our own advanced technologies for the development and production of electric transport should be comprehensive "pull-out" projects that concentrate around themselves the scientific, technological, production, organizational resources and provide a breakthrough In key market areas. The project "Russian National Electric Vehicle" / "Smart City Electric Vehicle", as well as related projects to develop the component base (battery technology, IT platforms, microelectronics), to develop the charging infrastructure and components of the "smart city" can become such a driver.

Russia has already created a significant groundwork for the implementation of such initiatives. For example, at the STI Competence Center "New Production Technologies" of the Peter the Great St. Petersburg Polytechnic University, a universal platform for the development of a range of electric vehicles for various consumer needs has been created and is successfully used. On the basis of this digital platform, in the shortest possible time by automotive industry standards, in just two years, in cooperation with industrial partner KAMAZ, a pre-production sample electric vehicle KAMA–1 was developed and manufactured from scratch, without an internal combustion engine precursor, which became the Technology Breakthrough 2020[1]. The presence of an advanced engineering center for the development of electric vehicles forms a solid foundation for the dynamic development of electric transport, and with state support it can reach the world level and become a center of attraction for talents and a source of economic growth throughout the country.

A similar center can be created at the Skolkovo Institute of Science and Technology (Skoltech) to design the key element of electric transport – traction batteries. It should be noted that a number of Russian companies and research centers have a track record in the field of cybersecurity technologies, unmanned and connected transport, etc.

Thus, on the basis of the best Russian developments and with the formation of a scientific-technological and production consortium it is necessary to implement the project "Russian National Electric Vehicle" / "Smart Urban Electric Vehicle", which will become a "pulling" project both for the Russian automotive industry of a full cycle (from development and production of electric vehicles to recycling of batteries by manufacturers and/or fuel and energy companies) and for development of a whole range of end-to-end technologies and productions necessary for Russia's transition to a new level of technological and sustainable development on the way to industrial leadership in global markets.

The proposed measures will allow Russia to take advantage of the "window of opportunity" and gain a foothold in the global electric vehicle market before reaching the "tipping point" (tentatively, 2024) and market stabilization, and will contribute to creating domestic demand and supply for electric vehicles designed and produced in Russia, integrating Russia into the global electric vehicle market, and improving the environmental situation in the country. In addition, the development of electric transport technologies will contribute to progress in related areas, including hydrogen energy and electric transport based on hydrogen fuel cells.

To determine the mechanisms of formation of the electric car market in Russia, it is necessary to answer nine questions:

1. Can the "wave" of electric transport pass Russia?
2. How would electric cars contribute to decarbonization?
3. How would electric cars affect the energy balance in the Russian Federation?
4. How much will the charging infrastructure cost and what is the best way to finance it?
5. Will the ownership of an electric car become attractive compared to the ownership of an internal combustion engine car in the foreseeable future?
6. What is the strategy for advanced development of key elements of the component base for electric vehicles in Russia?
7. When will the electric car market grow larger?
8. Is Russia provided with raw materials for the production of electric cars?
9. What should be the state policy to support the electric car market?

[1] Alexei Borovkov received the "Technological Breakthrough 2020" award for the development of the first Russian electric smart crossover KAMA–1. URL: nticenter.spbstu.ru/news/7593 (accessed 23.03.2021). See also: Andrei Belousov presented commendations to the leaders of the projects of the National Technological Initiative. URL: government.ru/ news/41245 (accessed: 23.03.2021).

Answers to these and many other questions are presented in this report.

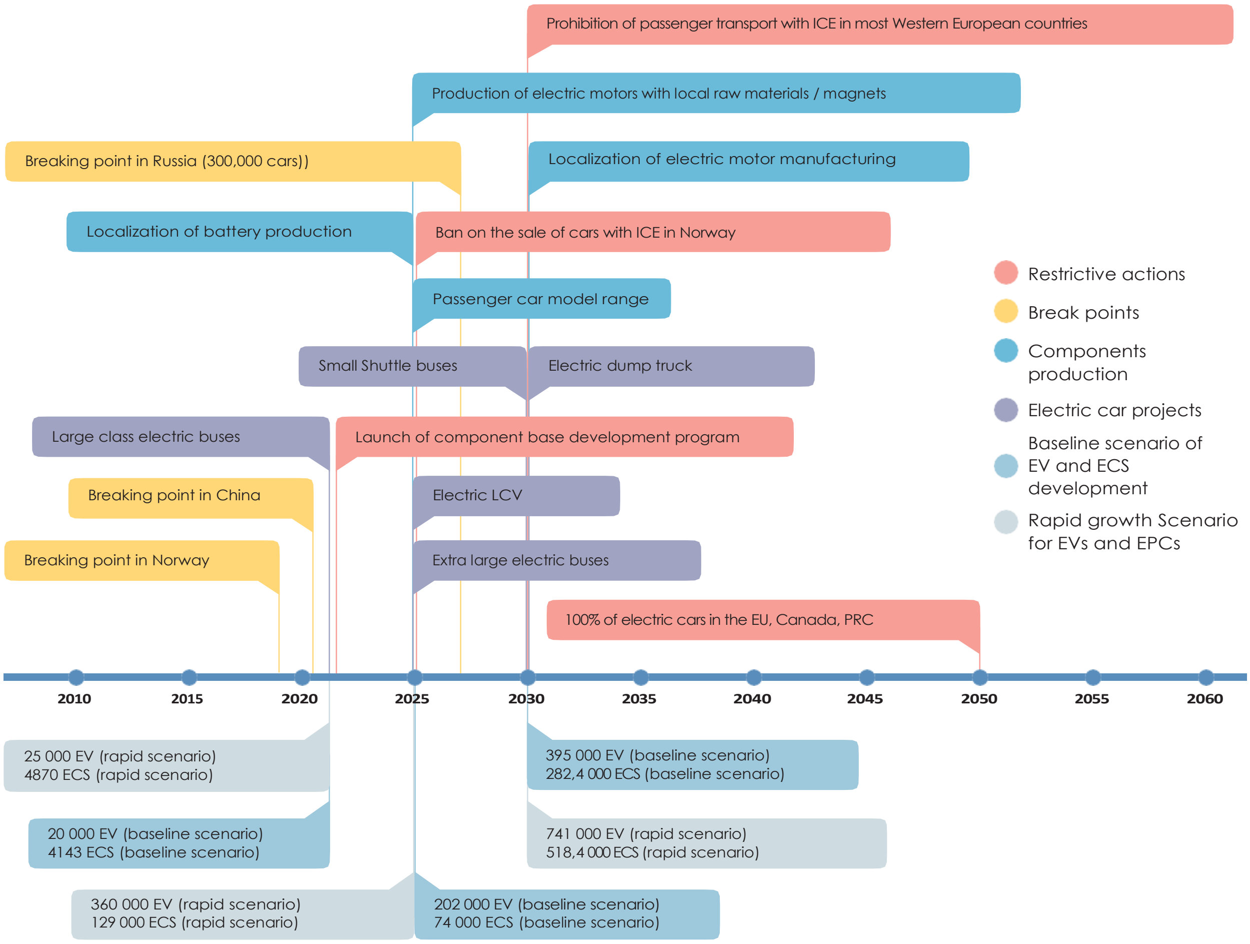

Fig. 2. Scenario for the development of electric transport in Russia [2]

The implementation of the scenario and a comprehensive policy for the development of the electric car market in Russia proposed in this report is aimed at confirming the high scientific and technological level of Russia in the international arena, significantly improving the environment of Russian cities and stimulating the development of a wide range of Russian "smart" digital technologies and productions in the market, the total volume of which is estimated at 7.5 trillion rubles.

[2] EV — electric vehicle. ECS — electrical charging station. LCV — light commercial vehicle.

1. CAN THE "WAVE" OF ELECTRIC TRANSPORT PASS RUSSIA?

The global market for electric cars, even during the pandemic in 2020, showed a 5% growth amid the 18% drop in car sales. Three of the 10 largest automakers by value produce only electric cars. Every week, automobile companies announce new models of electric cars and declare the rejection of internal combustion engines. The process is reminiscent of the "wave" that has been gaining momentum for over 10 years and is now sweeping the world and gradually coming to Russia.

Most major automakers in Europe, Asia, North America have already announced the abandonment of production of vehicles with internal combustion engines, both trucks and cars, within the next 10–15 years.

Sales of electric cars by global brands, number of models in production

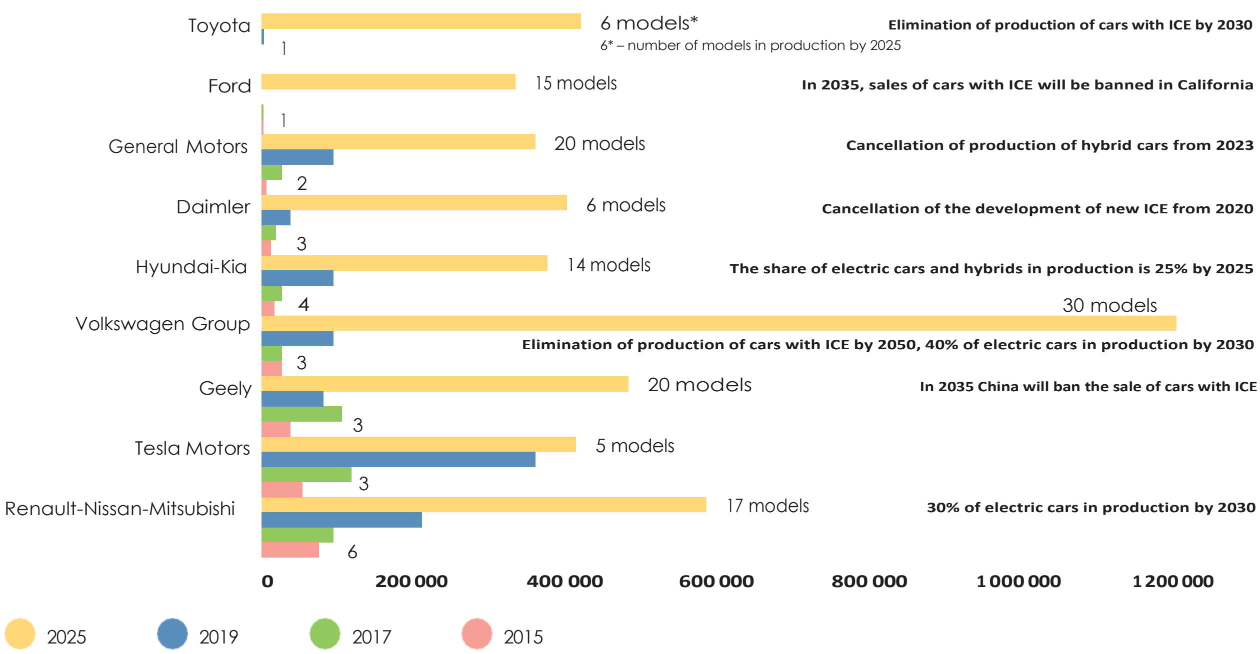

Fig. 3. Major car companies: sales volume and announced plans to produce "clean" electric vehicles (BEV) by 2025 / Sources: SPbPU STI Center (according to corporate websites of car manufacturers), ICCT

At the same time, more than 20 countries, including European countries, China, India, Japan, South Korea and others, have already adopted or are preparing to adopt restrictive measures concerning the production and sale of liquid fuel vehicles. Norway has the most ambitious plans: only electric cars should be sold there from 2025. Other states are planning to completely oust combust internal combustion engine cars from the market by 2030–2040. 3 It is possible that by 2030 the majority of cars imported to Russia will be electric, and for Russian cars with internal combustion engines both foreign markets and roads outside our country (and, probably, CIS countries) will be closed.

Summary 1. Thus, non-participation in the formation of the electric car market and a "wait-and-see" attitude will result in the loss of this market for Russian companies: it will be formed, but based on foreign technologies and products (as it happened, for example, with the cell phone market).

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[3]For a detailed review of vehicle electrification goals and related restrictive measures, see: ICCT Briefing | Update on the Global Transition to Electric Vehicles Through 2019. URL: theicct.org/sites/default/files/publications/ update-global-EV-stats-sept2020-EN.pdf (accessed: 23.03.2021).

2. ELECTRIC VEHICLES PLAY A KEY ROLE IN DECARBONIZATION

Global decarbonization, i.e. the global transition to low-carbon development, is a response to global climate change caused by anthropogenic emissions of greenhouse gases into the atmosphere. The goal of decarbonization is to reduce, and ideally eliminate, these emissions in order to slow down climate change and minimize the damage caused by it. More than 110 countries have stated their goal of achieving carbon neutrality by 2050. The key document in this area is the Paris Agreement, whose signatories are the world's largest economies, including the United States (back in 2021), China, the European Union and Russia. Decarbonization measures are not only internal but also external. This involves restricting imports of "dirty" goods. For example, the EU plans to introduce a border mechanism that involves tracking the "carbon footprint" of imported products. Thus, the decarbonization trend will affect the entire global economy, and ignoring it will lead to the closure of foreign markets for exports of Russian raw materials and goods.

The development of the energy storage (battery) electric vehicle industry, both in terms of consumption and production, will make a significant contribution to decarbonizing the economy and improving the quality of life in large cities. Electric cars based on hydrogen fuel cells will be able to enhance this contribution only in 10–15 years, when cost-effective and environmentally friendly methods of hydrogen extraction are availablede.

The transport sector accounts for 23% of the world's greenhouse gas emissions [4]. Reducing emissions through electrification of transport is a key point of the Paris Agreement, to which Russia is a party. Taking into account average Russian values of mileage and CO_2 emissions from electricity production, electric cars and some hybrids already meet the goals of the Paris Agreement by 2030.

On average, cars with internal combustion engines emit twice as much CO_2 as their electric counterparts. The most significant share of these emissions falls on the period of operation.

With improvements in combustion engine technology, the share of emissions has declined only slightly: from the introduction of the EURO 0 environmental category (1988) to the current EURO 6c (2017), the average CO_2 emission reduction was 9.5 %, i.e. 0.5 % per year [5].

Comparing hydrogen cars with electric cars, it should be noted that since the battery in a hydrogen vehicle can theoretically be absent (in real systems the ratio of fuel (hydrogen) cells to batteries changes), there is a possibility that, if "clean" hydrogen is produced by renewable energy sources (RES), the production cycle of such vehicles will create fewer harmful emissions, due to the relatively high emissions of battery production itself. However, at this point there are four factors that suggest that the contribution of hydrogen vehicles (FCEV) to reducing greenhouse gases will be significantly less than that of electric vehicles (BEV).

The first factor is the low environmental friendliness of hydrogen production using the currently most common method – natural gas reforming [6]. This method releases large amounts of carbon dioxide and carbon monoxide into the atmosphere. The second factor is gas leakage during gas extraction, processing and transportation [7]. In this direction, the prospects for reducing leakage are very limited.

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[4] Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate. URL: www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter8.pdf (accessed: 19.02.2021).

[5] *Weller K., Lipp S., Roeck M., Matzer C., Bittermann A., Hausberger S.* Real World Fuel Consumption and Emissions from LDVs and HDVs. URL: www.frontiersin.org/articles/10.3389/fmech.2019.00045/full (accessed: 19.02.2021). World Fuel Consumption and Emissions from LDVs and HDVs. URL: www.frontiersin.org/articles/10.3389/fmech.2019.00045/full (accessed: 19.02.2021).

[6] America's Zero Carbon Action Plan URL: www.unsdsn.org/zero-carbon-action-plan (accessed: 19.02.2021).

[7] Hydrogen Leaks at the Same Rate as Natural Gas in Typical Low-Pressure Gas Infrastructure. URL: www.sciencedirect.com/science/article/abs/pii/S0360319919347275 (accessed: 19.02.2021).

The third factor is high energy consumption for water electrolysis and its high cost, which does not allow for the foreseeable future to abandon environmentally dirty methane reforming in favor of more environmentally friendly electrolytic methods of hydrogen production [8]. The fourth factor is a significant increase in the environmental friendliness of battery production, whereas the transition to the use of new technologies will be associated with a decrease in "environmental costs" [9].

Thus, electric vehicles can make the greatest contribution to reducing greenhouse gas emissions, especially if the economics of propulsion modes are taken into account.

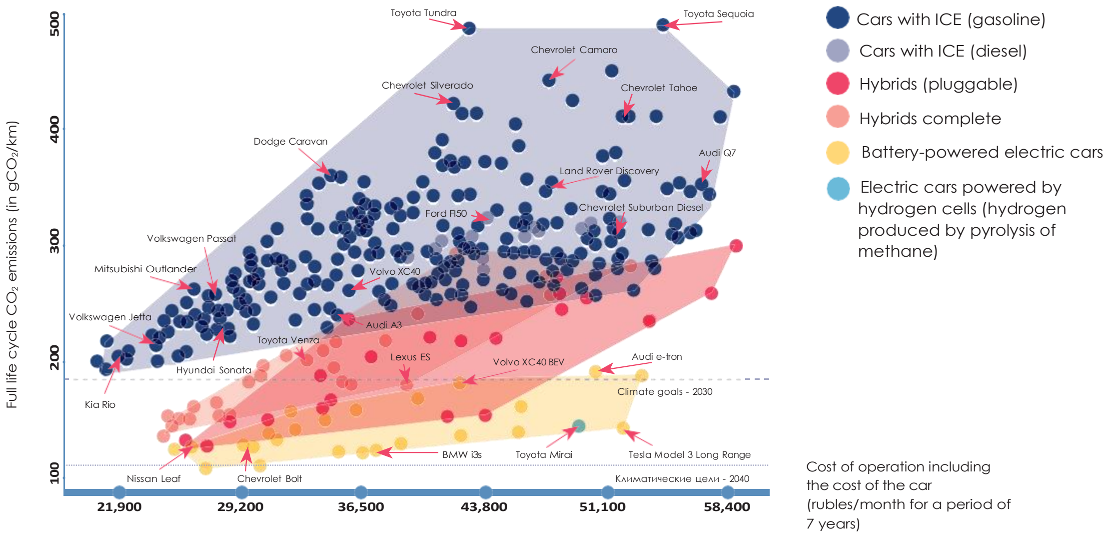

Fig. 3. Comparative table of emissions from different types of cars and their costs / Source: MIT

Consider the structure and prospects for emission reductions using the UK as an example. Three scenarios are possible:

1) Without a significant change in the country's policies (business as usual).
2) Actions aimed at a 50 percent reduction in emissions across all industries by 2050.
3) Actions aimed at an 80 percent reduction in emissions across all industries by 2050.

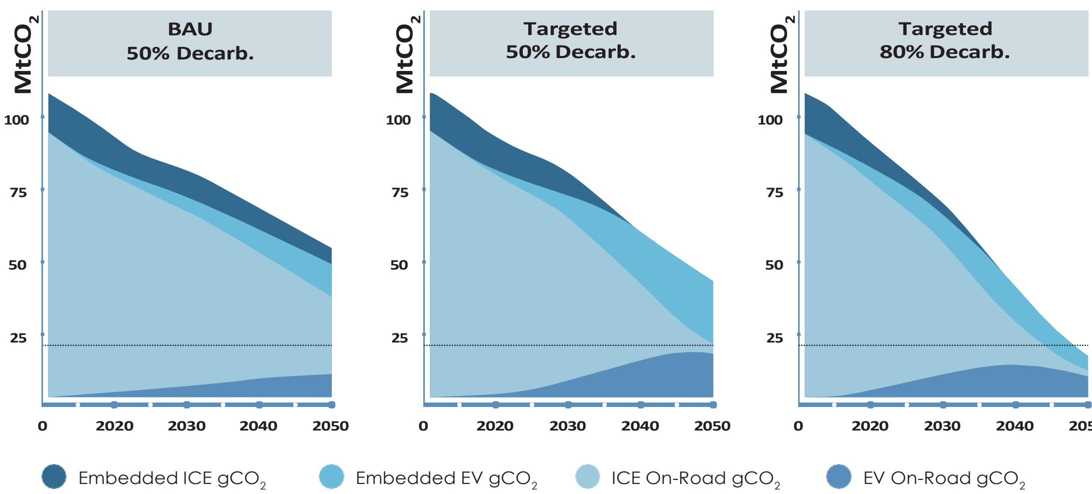

Fig. 4. Scenarios for emission reductions from the entire transport sector in the UK / Source: The Role of Electric Vehicles in Near-term Mitigation Pathways and Achieving the UK's Carbon Budget

[8] America's Zero Carbon Action Plan URL: www.unsdsn.org/zero-carbon-action-plan (accessed: 19.02.2021).

[9] Analysis of the Climate Impact of Lithium-Ion Batteries and how to Measure It. URL: www.transportenvironment.org/sites/te/files/publications/2019_11_Analysis_CO2_footprint_lithium-ion_batteries.pdf (accessed: 19.02.2021).

In this case study, under any scenario, the development of electric vehicles will contribute to a 10% reduction in total transport emissions by 2030. Between 2030 and 2040, the abandonment of internal combustion engine vehicles will become widespread, resulting in a further 35–60% reduction in emissions. And between 2040 and 2050, the difference in scenarios will be most noticeable [10].

With decisive regulatory action by the government to transition to renewables and electric vehicles, the cumulative emissions from the latter will decrease. This will happen even as the number of electric cars on the roads increases significantly. This scenario will allow meeting the goals of the Paris Agreement by 2050 in a complete way.

Under less stringent policies, electric vehicles would still make a significant contribution to emissions reductions, but more of them would cause emissions for electricity generation and production to be higher together, making it more difficult to meet the Paris Agreement's goals.

In a scenario in which the government does not take significant action to develop electric vehicles, emissions from electric cars will remain low due to the fact that the number of electric cars will not grow. However, this assumes that emissions from internal combustion engines will remain high.

Summary 2. The strategic choice to decarbonize the economy and measures to improve the quality of life in large cities leads to the need to encourage the transition to electric transportation.

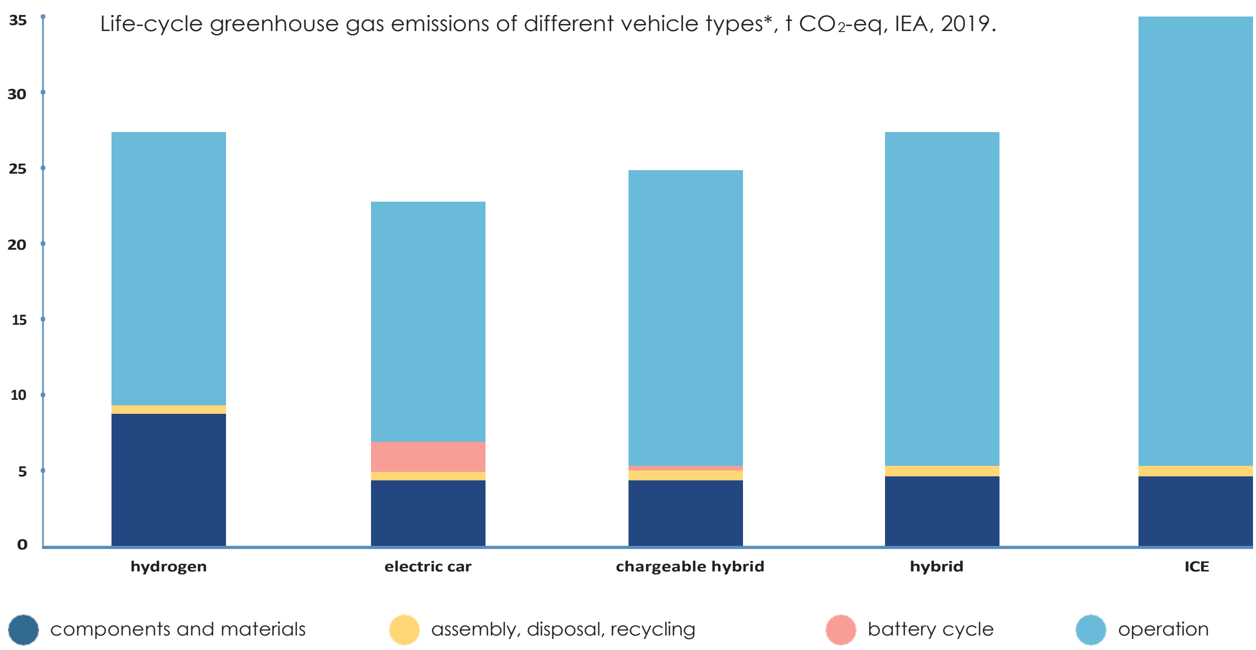

Fig. 5. The electric car with a battery has the lowest lifetime emissions – 35–65% less than those of cars with internal combustion engines or hybrids / Source: CSR "North-West" based on IEA materials

[10] The Role of Electric Vehicles in Near-Term Mitigation Pathways and Achieving the UK's Carbon Budget. URL: www.sciencedirect.com/science/article/pii/S0306261919307834#f0025 (accessed: 19.02.2021).

3. THE GROWTH IN DEMAND FOR ELECTRIC VEHICLES WILL NOT CREATE RISKS FOR THE COUNTRY'S ENERGY BALANCE

The development of electric cars in any of the scenarios will not lead to a shortage of electricity and will not require changing the plans for the development of generating capacity in the Russian Federation

In 2020, power plants of the UES of Russia gene--rated 1,047 billion kWh, while consumption amounted to 1,033 billion kWh. Thus, the positive energy balance is 14 billion kWh [11]. Most of the "surplus" energy is exported, but the planned 2025 disconnection of the Baltic states from the BRELL energy ring could reduce this export by 25 percent [12], i.e. by 3.5 billion kWh.

According to SPbPU experts, the pessimistic and optimistic scenarios of electric transport development will create additional demand for electricity in the amount of 1.8 and 2.7 billion kW·h, respectively [13]. Thus, no additional power generation will be needed under any scenario – and electric cars will help optimize the power balance and increase the volume of the domestic Russian power market, compensating for possible losses in exports.

Analysis of energy consumption in Germany and India demonstrates that the impact of electric transport on the energy balance of the countries is insignificant and will not require major investments in the existing system of energy consumption.

In Germany, electric cars will increase total energy consumption by about 5 GW by 2030, which is about 1% of total energy consumption. By 2050, this figure will increase to 20 GW, which will be 4% of total energy consumption. All these additional capacities are covered by planned commissioning of generating capacities, operating on renewable energy sources, including wind energy and solar energy [14].

With the current development of infrastructure in India, we can expect the market share of electric cars to reach 25–30% by 2030, regardless of the segment. This will require an additional 40 to 60 billion

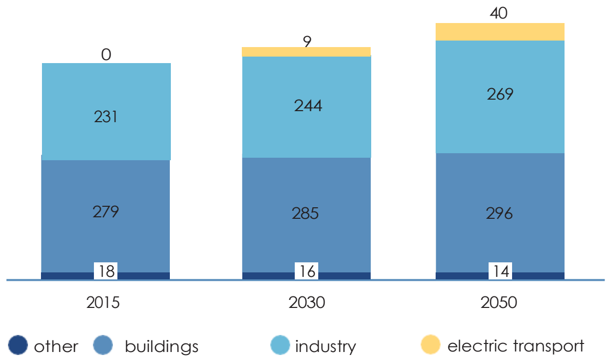

Fig. 6. Electric Vehicle Electricity Demand in Germany in 2015–2050, TWh / Source: elec.ru ("How Electric Vehicles Will Affect Global Electricity Consumption")

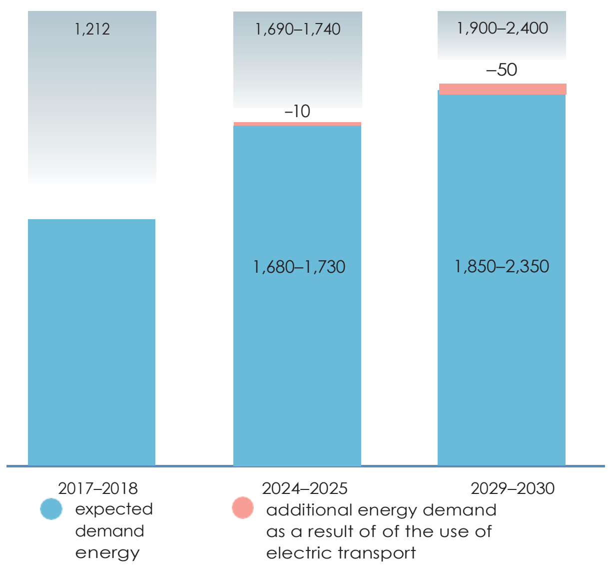

Fig. 7. Forecast of electricity demand in India by 2030, kWh / Sources: Ministry of Electricity of India; A. T. Kearney Consulting

[11] Russia's Unified Energy System. URL: so-ups.ru/functioning/ees/ups2021 (accessed: 18.02.2021).

[12] Current for the homeland. URL: www.kommersant.ru/doc/4692051 (accessed: 18.02.2021).

[13] Reference on the development of transport using alternative energy sources. SPbPU. December 2020.

[14] How electric cars will affect global electricity consumption. URL: www.elec.ru/analytics/kak-elektromobili-povliyayut-na-globalnoe-potreble/ (accessed: 19.02.2021).

(kWh) by 2030, which is 2% to 3% of the expected expected energy demand at that time [15].

The development of electric transport also implies the progress of smart grid technologies, which are being developed by ROSSETI as part of the Digital Transformation 2030 concept. V2G technology (vehicle as part of the grid) allows owners of electric vehicles to become "prosumers" – not only to consume power, but also to give it back, decentralizing and stabilizing the grid. The predominantly night charging mode of the electric vehicle allows the owner to benefit from the difference in daytime and nighttime rates, and the provider to reduce the peak load [16].

Electric cars can also be used as autonomous power sources (V2X technology). For example, in Japan, the Nissan Leaf is used as a power source for recovery work in areas of natural disasters. In 2021, Nissan plans to release a version of the Leaf capable of providing four days of power for the average Japanese household [17].

Summary 3. In addition to making a serious contribution to the decarbonization of consumption, the development of the national electric transport industry can significantly increase the sustainability and efficiency of energy storage systems, their integration into the energy system of Russia, ensuring an increase in its environmental friendliness and reduction of CO_2 emissions.

4. THE ELECTRIC CAR MARKET AT A "TIPPING POINT"

The market for electric cars, including the Russian market, is characterized today by a large unsatisfied demand. Incentive programs could unlock this demand, ensuring that the country becomes a leader in the emerging new global market.

The "tipping point" is the state of the market when the share of a new product reaches 3–5%: it is from this level that the market begins to grow not so much through the efforts of the seller as through the actions of the buyer. At the level of 15% a mass rapid transition to the new product begins; when 40% is reached the market "breaks down" and moves to the new normal.

In terms of sales volume, the electric car market has come closest to a "tipping point". In 2020, global sales of electric vehicles will be 4.2% [18] of the total volume of the global passenger car market – 3.1 million cars [19]. Anticipated institutional changes and technological breakthroughs in the global market will cause the industry to move from a market growth stage to the mass rapid transition stage in the coming years.

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[15] Electric Mobility 2.0: Tracking the Next Wave in India. URL: www.kearney.in/article/?/a/electric-mobility-2-0-tracking-the-next-wave-in-india (accessed: 19.02.2021).

[16] The head of ROSSETI noted the growing role of the consumer in the digital energy transition. URL: tass.ru/ekonomika/9668035 (accessed: 19.02.2021).

[17] *Schmidt B.* Electric Car Uptake Reaches Tipping Point in China and Europe. URL: thedriven.io/2021/01/20/europe-and-china-reach-tipping-point-for-adoption-of-electric-cars (accessed: 05.02.2021).

[18] Global Sales of Electric Cars Accelerate Fast in 2020 Despite Pandemic. URL: www.theguardian.com/environment/2021/jan/19/global-sales-of-electric-cars-accelerate-fast-in-2020-despite-covid-pandemic (accessed: 10.02.2021).

[19] *Singal N.* Electric Vehicles' Global Sales Jump 39% in 2020, 3.1 Million Units Sold. URL: www.businesstoday.in/sectors/auto/electric-vehicles-global-sales-jump-39-percent-in-2020-3-million-units-sold/story/430707.html (accessed: 10.02.2021).

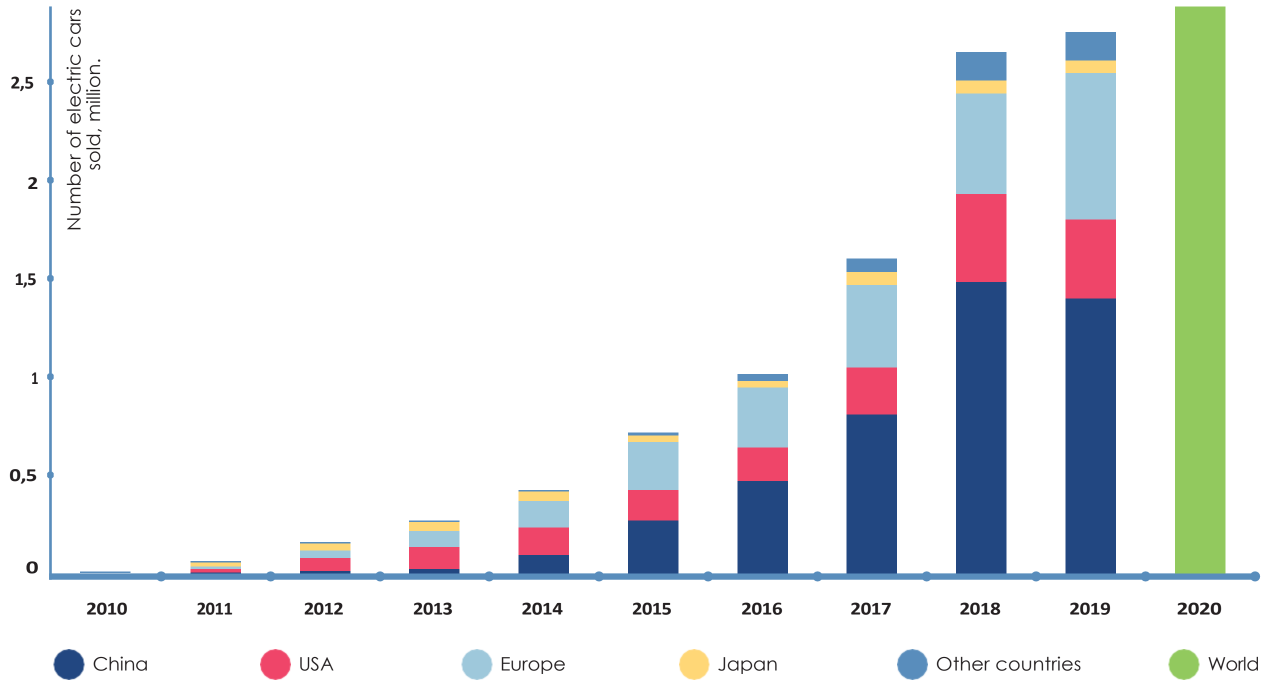

Fig. 8. Number of electric cars sold in 2010–2020, million units / Source: IEA

There are two main scenarios for the development of the electric car market: the baseline scenario and the accelerated development scenario. The latter scenario assumes intensification of the emission control policy (including regulatory restrictions), large-scale investments in the creation of infrastructure at a fast pace, as well as encouragement of the acquisition of electric vehicles.

The electric car market in the baseline scenario will reach 14 million cars in 2025 and 25 million cars in 2030, which corresponds to 10% and 16% of the total car market, respectively. The accelerated scenario assumes that global sales will reach 45 million cars in 2030, accounting for 30% of the total market.

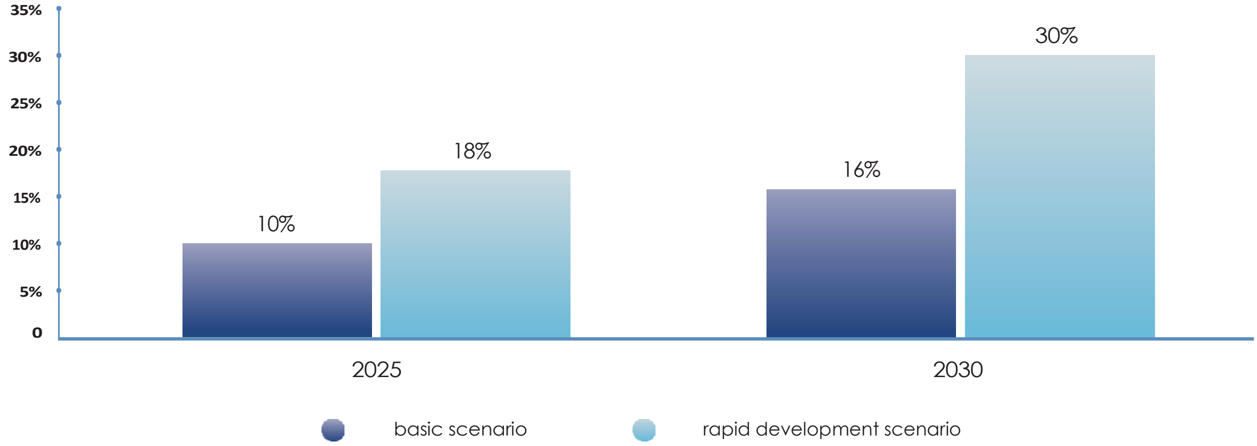

Fig. 9. Target share of electric cars in the Russian market, % / Source: VEB.RF

The “tipping point” of the market has already begun in certain regions of the world, including Western Europe and China [20], where sales of electric cars reached 2.6 million cars in 2020 [21]. It is these countries that set the trends in the development of the global electric vehicle market and are focused on changing the automotive industry towards a growing share of electric vehicles.

- Western Europe as a whole: 2020 – The share of electric cars is 12%. According to this indicator, the European market is the leader, the closest to the stage of rapid mass transition to electric vehicles [22].
- Norway is the world leader in the number of electric cars per total number of vehicles sold in 2019 (55%). The country has already gone through a “tipping point”, and electric cars are the new reality in Norway. By 2025, the parliament plans to completely stop selling cars that run on hydrocarbons.
- In 2020, almost 50% of global sales of electric vehicles were in China, making it the largest market in the world [23]. The series of initiatives launched in 2009 to subsidize the development of electric vehicles was an important factor in the development of China's electric vehicle market [24]. The accumulated effect helped “warm up” the market and bring it to a level of sustainable growth, ensuring a share of up to 5.4% of electric car sales of the total car market in 2020 [25]. Market developments have led to the Chinese government announcing a phased reduction of subsidies for the purchase of electric cars [26].

At the same time, the Russian market lags far behind. As of 2020, the fleet consists of up to 11,000 cars. A significant portion of sales are accounted for by used electric vehicles (in 2020, there were 5,273 sales of used electric vehicles and 687 sales of new electric vehicles), since the supply of new models is limited (the Nissan Leaf accounts for 83% of electric vehicle sales) [27].

It should be noted that the minimum scenario for the development of electric cars in Russia has already been stipulated in the Strategy for the Development of the Automotive Industry of the Russian Federation for the Period up to 2025. According to this document, the share of electric cars in the market should reach 5% by 2025 (129,000 units) [28] with the implementation of an appropriate government support program.

The baseline scenario for the electric vehicle market assumes that their share will be 10% in 2025 (202 thousand cars) and 16% in 2030 (395 thousand cars). The fleet of electric vehicles is expected to be 3% of the total volume of vehicles (2 million electric vehicles).

In the rapid development scenario, the target parameter for the share of electric cars by 2025 is 18% (360,000 units) – 18% (360 thousand cars), and by 2030 – 30% (741 thousand cars). The electric vehicle fleet by 2030 is expected to be 5.5% of the total volume of vehicles (3.6 million electric vehicles).

The implementation of these scenarios is possible if Russia develops and produces its own electric cars and if the support measures mentioned in paragraph 9 of this report begin to be implemented to a greater or lesser degree.

Note that the results of market research by the STI Center of SPbPU demonstrate that Russian car users have a potential demand for electric cars, which will be able to meet the above-

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[20] Global EV Outlook 2020. URL: www.iea.org/reports/global-ev-outlook-2020 (accessed: 20.01.2021).

[21] *Schmidt B.* Electric Car Uptake Reaches Tipping Point in China and Europe. URL: thedriven. io/2021/01/20/europe-and-china-reach-tipping-point-for-adoption-of-electric-cars (accessed: 05.02.2021).

[22] Ibid.

[23] *Barrett E.* China Is Rolling Back the Subsidies that Fueled Its Electric-Vehicle Boom. URL: fortune.com/2021/01/05/china-electric-vehicle-subsidies-sales-tesla/ (дата обращения: 09.03.2021). (accessed: 09.02.2021).

[24] China's Quest to Adopt Electric Vehicles. URL: www.hbs.edu/ris/Publication%20Files/Electric%20Vehicles_89176bc1-1aee-4c6e-829f-bd426beaf5d3.pdf (accessed: 09.02.2021).

[25] *Schmidt B.* Electric Car Uptake Reaches Tipping Point in China and Europe. URL: thedriven. io/2021/01/20/europe-and-china-reach-tipping-point-for-adoption-of-electric-cars (accessed: 05.02.2021).

[26] Ibid.

[27] The number of electric cars in Russia has exceeded 10 thousand units. URL: www.autostat.ru/news/47243 (accessed: 09.02.2021).

[28] Strategy for the Development of the Automotive Industry of the Russian Federation until 2025. URL: http://www. consultant.ru/document/cons_doc_LAW_297129/f8f8138d4327a3b4e9a33b8e9d4f9de6489f71e6/ (accessed: 19.02.2021).

mentioned indicators. Currently, sociologists at Ipsos [29] are already recording a shift from the perception of the electric car as "a toy for the rich" to "a possible car for my next purchase /a second car in the family. Conditions for the transition from potential demand to real – achieving price parity with similar cars with internal combustion engines and the appropriate level of technology and consumer properties.

Summary 4. Thus, the launch of an electric car that meets consumer expectations (price parity with internal combustion engine vehicles, comfort and user-friendly technology) in the Russian market will be ensured by the necessary level of mass demand. Depending on the effectiveness of measures to stimulate the market and the ability of Russian manufacturers to create a demanded product, the volume of the electric car market in Russia will range from 129,000 to 360,000 units (from 5 to 18% of car sales).

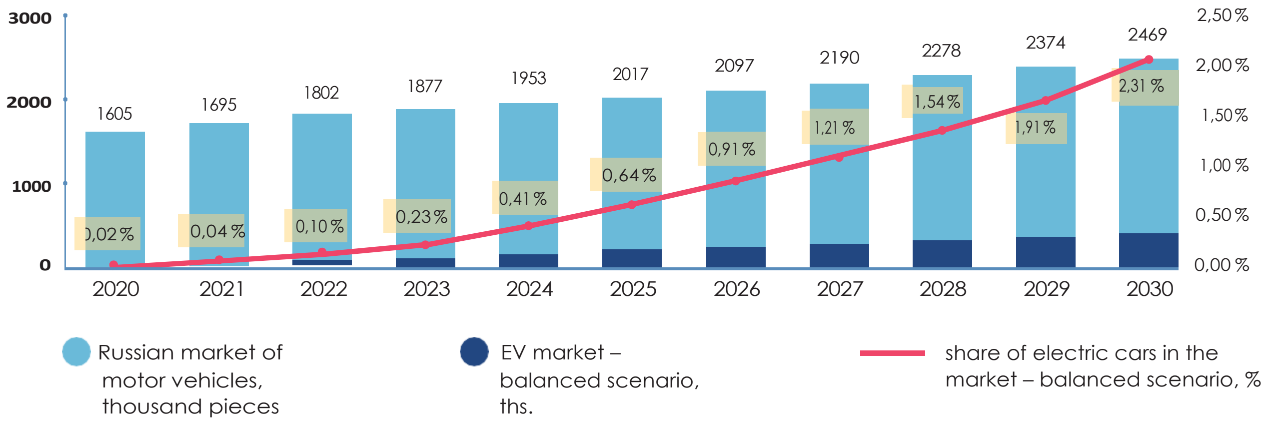

Fig. 10. Automotive market in Russia, balanced scenario / Source: VEB.RF

5. THERE ARE THREE SCENARIOS FOR THE DEVELOPMENT OF EVSE INFRASTRUCTURE: BALANCED, BASIC AND RADICAL

It should be borne in mind that the introduction of electric transport does not mean a radical rejection of internal combustion engines. According to Bloomberg calculations, by 2040, more than 60% of the world's kilometers will still be covered by vehicles with internal combustion engines. Therefore it is not a question of radical technology substitution, but the simultaneous creation and development of new markets, new infrastructure and, finally, new technologies. Thus, in the context of the global economic crisis, this initiative becomes one of the key instruments for ensuring economic growth, both globally and for the countries actively participating in this process.

The development of the electric car market by 2030 will require total financial resources from 267 billion rubles (in the balanced scenario – a market of 147–309 thousand electric cars) to 1,065.4 billion rubles (in the accelerated development scenario – a market of 360–741 thousand electric cars) to create a network of electric cars. It should be noted that a significant share of them may be financed by private business.

[29] Perception of electric cars. A study in the syndicated community Ipsos in Russia. June, 2020. URL: https://www.ipsos.com/sites/default/files/ct/news/documents/2020-06/electricvehicles.pdf (accessed: 19.02.2021).

The types of charging stations taken into account in the calculations are as follows [30]:

- slow charging capacity of about 20 kW, which roughly corresponds to obtaining the energy needed to cover a distance of 6 to 90 km in an hour;
- charging stations with fast charging capability (DCFC) that range in capacity from 20 to 100 kW and above, which in most cases allow for a full charge in less than 20 minutes.

Analysis of the global charging infrastructure shows the share of fast chargers in the total volume of 31%. At the same time, we should note the growing trend of increasing the share of fast charging stations. Further development of the infrastructure is expected mainly due to fast charging stations, in this regard, it is reasonable to initially focus on the parity ratio. Thus, for further evaluation, the target share of fast charging stations in the total volume is assumed to be 50%.

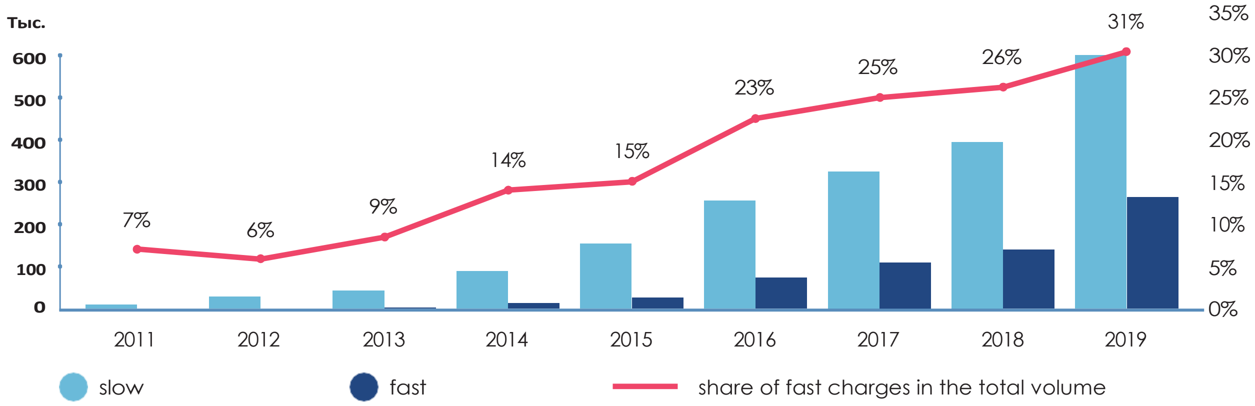

Fig. 11. Development of global charging infrastructure / Source: IEA Global EV Outlook 2020

According to preliminary estimates, the amount of capital costs for the creation of a slow EVSE will be 0.3–0.6 million rubles, a fast EVSE – 2.5–4.8 million rubles [31]. Up to 50% of the cost of the charging station falls on the preparation of the terrain and network infrastructure (upgrading and conducting power supply, installation of transformers, meters and other related electrical equipment) [32].

Further operating costs are 80–120 thousand rubles for a slow EVSE and 150–300 thousand rubles for a fast EVSE per year [33].

The payback period of a charging station (USA, India) is estimated at 7–10 years, with the parameter being highly dependent on the electric car fleet in the country.

In Russia, a similar project is commercially effective only in the future. In this regard, the participation of all interested organizations (car manufacturers, network companies, etc.) with the active state support (up to 50% of costs) is important in the implementation of the infrastructure development program.

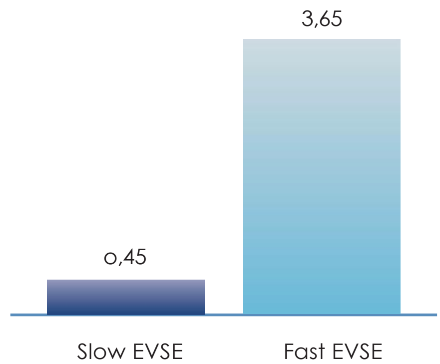

Fig. 12. Average cost of cost of creating an EVSE point, million rubles / Source: VEB.RF

[30] Sources: data for St. Petersburg; Costs Associated with Non-Residential Electric Vehicle Supply Equipment. URL: afdc.energy.gov/files/u/publication/evse_cost_report_2015.pdf (accessed: 09.03.2021).

[31] According to Zevs.

[32] Costs Associated with Non-Residential Electric Vehicle Supply Equipment.

[33] According to Zevs.

In the process of planning the charging infrastructure, special attention should be paid to the specifics of the territorial distribution of charging stations in Russia, given its vast territory.

The main share of electric cars does not allow counting on long intercity travel and has a range on a full charge of about 200 km. This limitation, according to technological trends, will decrease, but at the moment this factor must be overcome with the help of infrastructure solutions, balancing the network along the key communication routes (federal highways). We believe it is reasonable to assume an average vehicle with 200 km on a full charge and a 30% battery depreciation rate. In such a case, under ideal conditions, a difficult situation occurs when the distance to the nearest filling station is about 140 km. In addition, a number of additional factors have to be taken into account, including increased energy consumption during the cold season, as well as behavioral aspects: for example, an EVSE may be missed by the driver when the charge level is high, but not sufficient to cover the distance to the next filling station. Let's take the estimated level of these parameters to be 30%. Thus, in order to guarantee uninterrupted driving across the country the maximum distance between the two nearest charging stations should not exceed 100 km.

Long-term forecasts for Europe and the world as a whole assume 10–15 electric vehicles per filling station. At the same time, as the electric vehicle market and infrastructure develop, the balance in station distribution becomes more important. Taking into account the fact that the number of charging stations should grow somewhat faster than the needs for smooth development of the Russian electric vehicle market, the value of 10 will be included in the assessment as a target parameter for the long term. In the absence of the limiting influence of this parameter, market dynamics will be determined by the general demand for vehicles and the relative preference for electric cars.

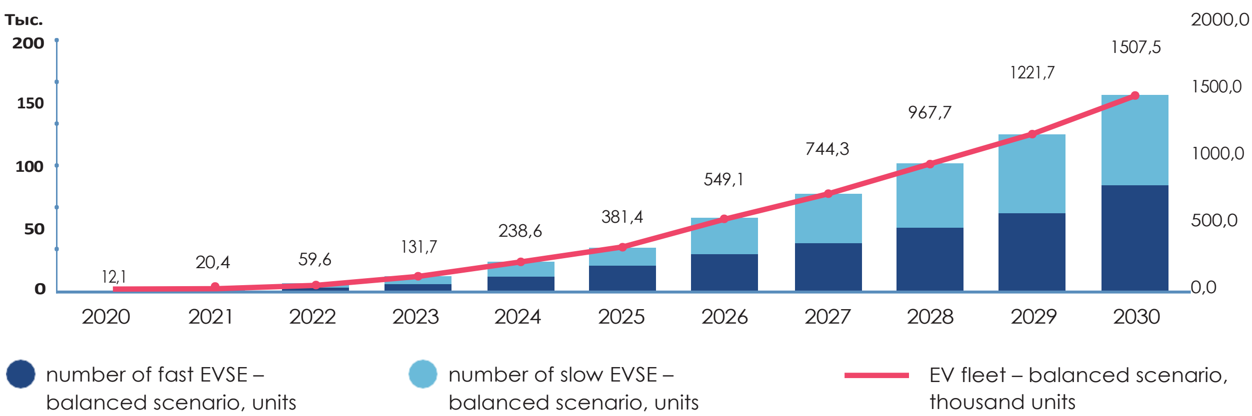

Fig. 13. Development of charging infrastructure in Russia, a balanced scenario / Source: VEB.RF

- The balanced scenario of EVSE infrastructure development by 2030 will require 152,000 charging stations. The total financing will amount to 267 billion rubles (1.5 million electric cars by 2030, 10 electric cars per EVSE, 60% – slow EVSE).
- The basic scenario for EVSE development would require 199,000 charging stations by 2030. The total financing will amount to 411 billion rubles (2 million electric cars by 2030, 10 electric cars per EVSE, 50% – slow EVSE).
- The radical scenario of EVSE development will require 518,000 charging stations by 2030. The total financing will amount to 1,065 billion rubles (3.6 million electric cars by 2030, seven electric cars per EVSE, 50% – slow EVSE).

It should be noted that global experience shows that it is possible to finance a significant share of charging infrastructure by private companies: car manufacturers, private networks of charging stations, fast-food restaurant chains, development companies.

For example, the fast-food chain McDonalds provides charging services for electric cars at its points on major UK highways and in drive-thru restaurants [34].

Volkswagen, Volvo, BMW, as well as Siemens, ABB, and Brazilian energy companies are developing the country's charging network on behalf of the Brazilian government. Private actors have invested about 17 million euros in the project [35].

Summary 5. Thus, in order to develop the market for electric vehicles in the country simultaneously with the support of production it is necessary to implement a vigorous and flexible state policy of regulating the charging infrastructure, including, in addition to direct funding of projects to create charging stations, a number of incentives for private business.

6. THE COST OF OWNING AN ELECTRIC CAR IS ALREADY CLOSE TO THE COST OF OWNING A CAR WITH A COMBUSTION ENGINE

The cost of buying an electric car is still higher than buying a car with an internal combustion engine. But in the next 10 years, its price will fall to an attractive level, which will be due to advances in energy storage technology. In addition, in terms of life cycle, the owners of electric cars, even at present, can significantly outperform the owners of internal combustion engine vehicles. Thus, state support aimed at making the purchase price of an electric car profitable already now will open up the market in terms of the development of mass sales.

The cost of the battery is currently an average of 50% of the cost of an electric car. So, today the difference between the cost of an average electric car and its gasoline counterpart is about 750 thousand rubles [36]. BloombergNEF calculates that the cost of batteries falls by 18% for every doubling of total capacity produced. This ratio is expected to continue for at least the next 10 years. This will bring the price of battery packs down to $93 per kilowatt-hour by 2024 and to $61 by 2030 (today the average cost is estimated at $156, and 10 years ago it was $1,183 per kilowatt-hour). The cost reduction is ensured by the introduction of new designs of cells and units, cathodes with higher energy densities, and increased production efficiency [37]. It is expected that when the cost of the battery crosses the notional $100/kilowatt-hour limit in 2024, the cost of electric cars will become equal to that of internal combustion vehicles and the final transition to the mass market will take place.

However, an electric car can already be more profitable than an internal combustion engine car if the electric car is driven at least 45,000 km annually for at least five years. Savings from fuel consumption and maintenance will compensate for the difference in purchase price, which

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[34] Do You Provide Electric Charging Points at Any of Your Restaurants? URL: www.mcdonalds.com/gb/en-gb/help/faq/18639-do-you-provide-electric-charging-points-at-any-of-your-restaurants.html (accessed: 19.02.2021).

[35] EV Charging Infrastructure Roll-out in Brazil. URL: www.electrive.com/2020/01/21/ev-infrastructure-roll-out-in-brazil/ (accessed: 19.02.2021).

[36] Energy Storage in Russia: An Injection of Sustainable Development. URL: vygon.consulting/upload/iblock/e44/vygon_consulting_storage.pdf (accessed: 19.02.2021).

[37] New Energy Outlook 2020. URL: about.bnef.com/new-energy-outlook/ (accessed: 19.02.2021).

makes it profitable to use electric cars at least in city cabs and carsharing (the comparison was made for the Nissan Leaf and Škoda Octavia).

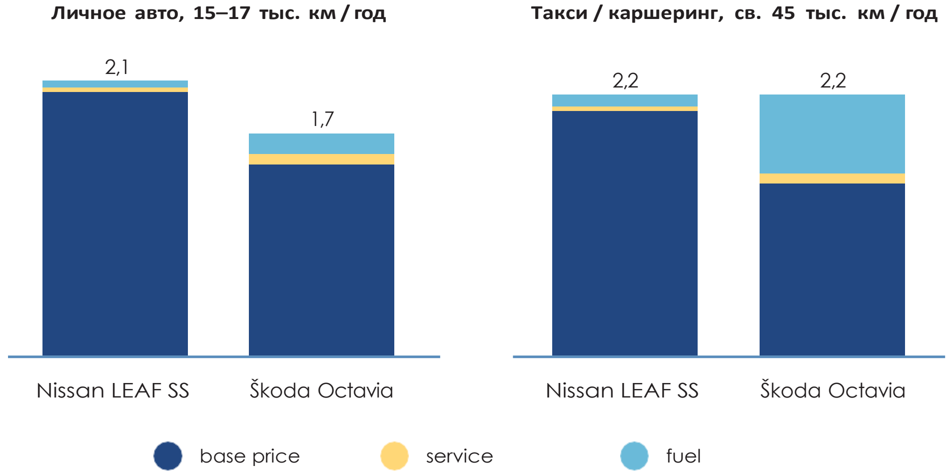

Fig. 14. Difference in the cost of ownership between an electric car and a vehicle with an internal combustion engine in Moscow over five years, million rubles / Source: VYGON-Consulting

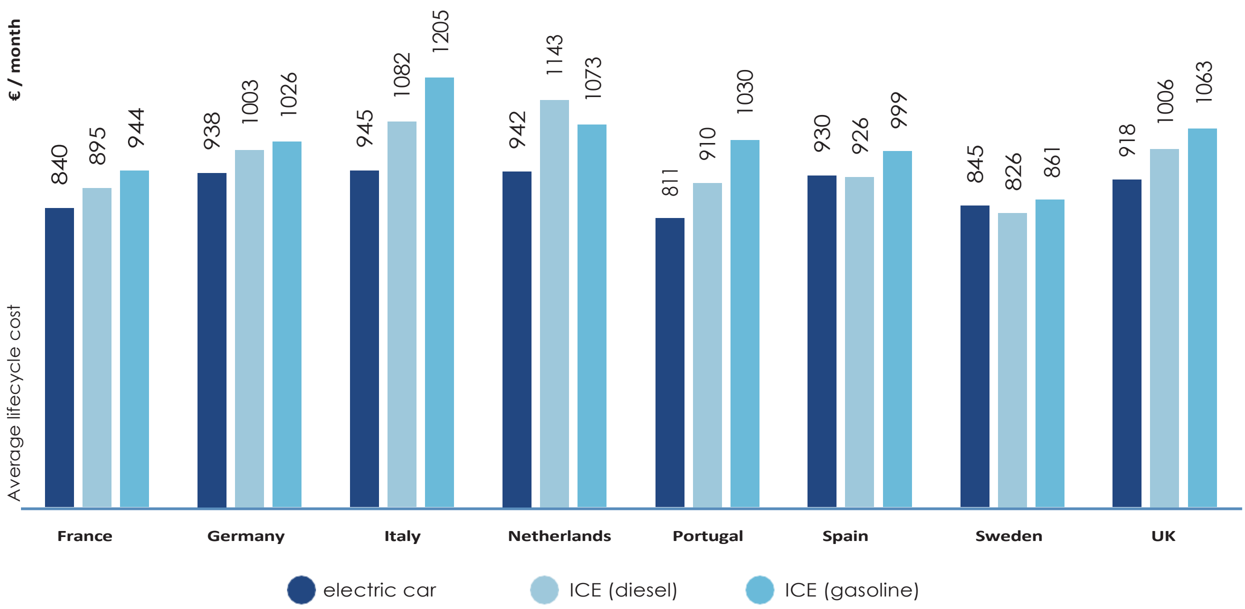

Fig. 15. Cost of vehicle ownership in the medium price segment in Western Europe, euro per month / Source: Car Cost Index 2020

In most Western European countries, the life cycle cost of an electric car in the medium price segment is lower than that of a similar car with a gasoline or diesel engine [38]. For example, in Italy, the life cycle cost of an electric car is 21.5% less than the life cycle cost of a gasoline-powered car.

Regardless of the class of electric vehicle, the lifetime operating savings are in the thousands of dollars – compared to the best-selling cars with internal combustion engines [39].

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[38] Car Cost Index 2020. URL: www.leaseplan.com/-/media/leaseplan-digital/int/blog/2020/car-cost-index/cci-2020-report.pdf?la=en (accessed: 19.02.2021).

[39] *Harto C.* Electric Vehicle Ownership Costs. URL: advocacy.consumerreports.org/wp-content/uploads/2020/10/EV-Ownership-Cost-Final-Report-1.pdf (accessed: 19.02.2021).

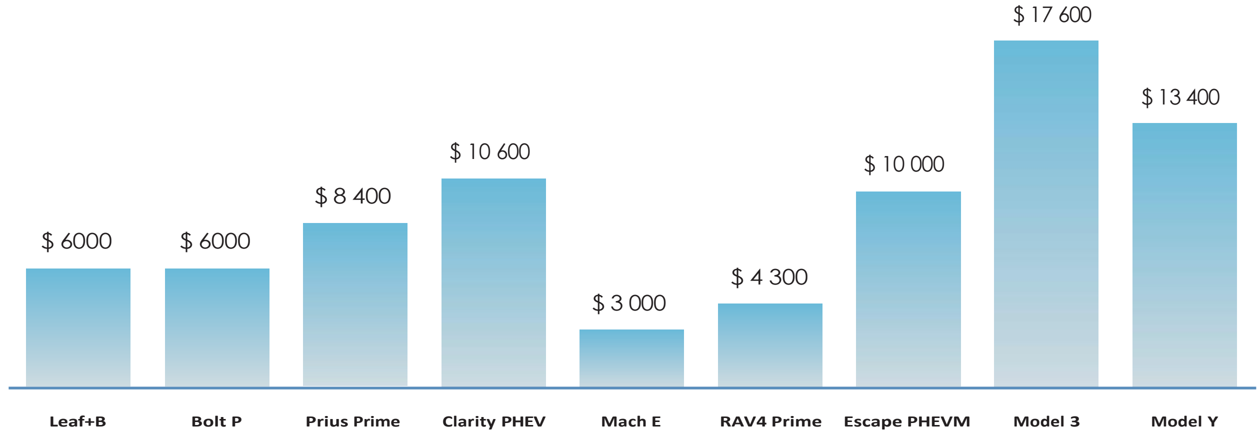

Fig. 16. Lifetime savings in electric vehicle operation compared to best-selling internal combustion engine models / Source: Electric Vehicle Ownership Costs

It should be noted that the Russian component base (primarily batteries) can significantly reduce the cost of ownership of an electric car for the consumer and provide a competitive advantage for Russian electric cars. This is why it is so important promote development the development and production of the entire set of technologies.

Summary 6. Thus, the cost of owning an electric car is among the key factors in making a purchasing decision: measures to reduce the purchase price for the consumer are among the most effective for stimulating the market today. The development of energy storage technologies allows us to expect that by 2024–2025 the price of electric cars will equal the price of cars with internal combustion engines; this will lead to the final formation of mass demand for electric vehicles. Energy modules determine the most important competitive advantage of electric cars, which is why it is so important for Russia to have its own technologies and component base in this area.

7. PRODUCTION OF ELECTRIC CARS IN RUSSIA IS PROMISING ONLY IF WE COMBINE PROPRIETARY PLATFORMS AND OUR OWN PRODUCTION OF ENERGY MODULES (BATTERIES AND FUEL CELLS)

At the moment, production of electric vehicles in Russia is mainly represented by public transport. However, the projects of the leading companies show that the market has entered the zone of experiments and will soon be ready to deploy full-scale production programs for the entire range of vehicles, including passenger cars. The projects implemented in Russia show that a competitive electric vehicle industry can be created in the country if there is appropriate government support.

7.1. Russia has already formed a sector for the development and production of electric transport

At present, several projects in the field of development and production of electric cars are being implemented in the Russian Federation. All of them are at different stages of development and focus on different market segments.

In particular, in the segment of electric buses in Russia today there are mainly three companies: KAMAZ, GAZ and Volgabus. All of them have already launched mass production, and electric buses are operated on the streets of Russian cities, primarily, in Moscow. The annual production volume of Russian electric buses exceeds 300 units per year. One of such projects is the creation of a site for the assembly of electric buses in Moscow on the basis of Sokolnichesky Car Repair and Construction Plant (a branch of GUP Mosgortrans). Assembly production of electric buses and electric components for them will be launched here in 2021 in partnership with KAMAZ. The design production capacity will be at least 500 electric buses per year [40].

Production projects in the field of electric transport are also implemented in other regions. For example, two new technoparks will soon appear in the Nizhny Novgorod region. Their creation has already been approved at the level of the Ministry of Economic Development of Russia. The first resident of one of the technoparks in the Nizhny Novgorod region will be a plant for the production of innovative electric transport GAZ and its components. One more technopark will appear on the territory of the Drobmash. Drobmash residents will be companies engaged in the production of equipment that is in demand in various sectors of the economy of the country [41].

On December 17, 2019, Sinara Transport Machines, a machine-building holding, and Škoda Transportation signed an agreement to establish a joint venture in St. Petersburg to produce urban electric vehicles. The cost of the new vehicles will range from 20 to 40 million rubles, depending on the characteristics of the model. The company is focused on the production of electric buses, trolleybuses, streetcars and metro cars.

The situation is different in the electric vehicle production segment. This sector is represented by models of different readiness levels. The most striking project is KAMA–1 of Peter the Great St. Petersburg Polytechnic University, implemented within the framework of the Federal Target Program "Research and Development in Priority Areas of Development of the Scientific and Technological Complex of Russia in 2014–2020". Industrial partner of the project – KAMAZ.

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[40] Electric cars and unmanned vehicles. URL: apr.moscow/%20content/data/6/02%20Электромобили%20и%20беспилотный%20транспорт.pdf (accessed: 19.02.2021).

[41] Ibid.

Engineers of the STI Center "New Production Technologies" of SPbPU under the guidance of Professor A. I. Borovkov developed a digital twin of the electric car in the shortest time possible – in just two years by automotive standards – and manufactured an experimental prototype of the small-size city electric car KAMA–1. It was presented on December 10–11, 2020 at the VUZPROMMEXPO exhibition. This is the first prototype as a part of the electric transport development platform being created at SPbPU: from a compact city car to urban 18-meter electric buses meeting international certification requirements. KAMA–1 is a unique for the Russian high-tech industry result of the comprehensive cooperation between SPbPU and KAMAZ, which demonstrates the effectiveness of the programs of the Russian Ministry of Education and Science for the formation of a competitive applied research sector and support of specific developments and products in the technological areas of priority for the Russian economy.

Electric car KAMA–1 has a range of up to 250 km, a maximum speed of 150 km/h and a charge time of 20 minutes provided the use of fast EVSE.

There are also other projects for the production of electric cars. Serial production is organized at Zetta LLC in Togliatti under the Zetta brand. The main mass production line is the compact electric car City Modul 1. Three options are available: front-wheel drive with a range of 180 km (from 550 thousand rubles), front-wheel drive with increased battery capacity and a range of about 500 km (from 750 thousand rubles) and all-wheel drive with a range of about 500 km (from 950 thousand rubles) [42]. By mid-October 2020, the certification of the electric car was at the final stage. The first standard equipment electric cars were manufactured, serial equipment technologies were developed practiced [43].

In 2020. GAZ PJSC presented pilot models of electric GAZelle e-NN. The design of the new model is based on a single unified electric platform, the architecture of which allows to produce a full line of light commercial vehicles: flatbed trucks, vans, vans and various versions of special vehicles [44]. In 2021 it is planned to increase production in three modifications: a cargo-passenger van-combi; a minibus; a minibus shuttle. At the moment, the company plans to purchase the main components for production of electric cars – motors and batteries – from Chinese manufacturers. GAZ PJSC plans to launch development of its own component base.

In some cases, projects are launched by companies from production sectors related to transport. Such is the project of the battery company Rigel, which announced the construction of a $50 million electric car plant in St. Petersburg. The feasibility study of the project is in progress. It is assumed that at the initial stage the plant will produce 1 thousand cars per year.

There are also other projects. For example, the NAMI State Research and Production Center of the Russian Federation has developed an electric motorcycle. It is part of the unified modular platform, which also includes cars under the AURUS brand. The purpose of the AURUS brand is to replace the governmental transport and escort vehicles of foreign production with domestic models. Also this model of motorcycles suitable for the Interior Ministry and Emergencies Ministry. NAMI believes that the electric motorcycle they have developed has high consumer qualities, which opens up wide opportunities for creating competitive models on the applied aggregate basis and for free sale [46].

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[42] Russian electric car Zetta: a new model is planned. URL: rg.ru/2020/08/21/rossijskij-elektrokar-zetta-planiruetsia- novaia-model.html (accessed: 19.02.2021).

[43] Zetta (electric car). URL: www.tadviser.ru/index.php/Продукт:Zetta_(электромобиль) (accessed: 19.02.2021).

[44] GAZ presented samples of the first electric commercial vehicles GAZelle e-NN. URL: rg.ru/2020/09/23/gaz-predstavil-obrazcy-pervyh-kommercheskih-elektromobilej-gazelle-e-nn.html (accessed: 20.01.2021).

[45] Russia has created the first-ever domestic commercial electric vehicle. URL: www.cnews.ru/news/ top/2020-09-23_rossiyane_sobrali_pervyj (accessed: 20.01.2021).

[46] State Research Center of the Russian Federation "NAMI" showed the first prototype of an electric motorcycle. URL: nami.ru/news/1342 (accessed: 19.02.2021).

7.2. Russia can compete on the global market in the production of batteries

The Russian Federation has sufficient competences to design traction batteries for electric transport, but at the same time there is no production of lithium-ion battery cells with the necessary specific energy and in sufficient volume. Priority state support should be focused on the development of this segment in view of the fact that battery systems account for up to 50% of the cost of an electric vehicle. The battery is a critical component of an electric vehicle, and sustainable production of electric vehicles is impossible without an in-house production chain, from raw materials to the final product. This is exactly the way the world's leading car manufacturers: BMW, Volkswagen and Tesla have chosen [47]. At the same time, priority should be given to the development and production of batteries based on the most advanced cathode materials (NMC and LFP) with differentiation depending on specific applications.

One of the largest suppliers of batteries based on LFP cathode material, including for KAMAZ, GAZ and Volgabus, is Liotech, a member of Rosnano structures. About a quarter of its 600 million rubles in revenues comes from supplies of batteries for urban passenger transport. The company's management expects this market to grow and new players to appear on it [48]. Its deployed production volume is ~0.1 GWh per year.

The fuel division of TVEL State Corporation Rosatom has created the integrator RENERA, which will develop and promote energy storage units for electric vehicles. RENERA has its own R&D center, provides service support for its products and offers them for lease, leasing and trade-in [49]. In early March 2021, RENERA bought a 49% stake in Enertech International, a South Korean manufacturer of lithium-ion batteries, with a commitment to establish production of lithium-ion cells and rechargeable batteries in Russia [50]. The first stage of the plant should start operating in 2025, and by 2030 its capacity will be at least 2 GWh per year.

Rostec State Corporation conducts a wide range of developments in the field of electric transport. Rostec developments are used in electric buses of KAMAZ and electric motorcycles of Kalashnikov Concern [51].

Priority materials for creating a battery used in electric transport are and will be in the near future NMC materials with increased nickel content; it is this segment that the state support in the development of battery systems should be focused on. In the Russian Federation the development of scalable technologies of cathode materials production is carried out on the basis of Skoltech and Lomonosov Moscow State University. Production of advanced cathode materials NMC622 and NMC811 in Russia is organized only in small amounts (less than 1 ton per year) at one of Skoltech startups (Rustor), it covers part of limited demand of small Russian producers. Skoltech and MIPT have deployed pilot assembly lines for lithium-ion battery cells, and have the competencies needed to deploy larger-scale production on an industrial scale. The resource base required for the production of NMC cathode materials is presented in Table 1. Most of the raw materials required for the production of cathode materials, except for manganese sulfate, are produced in Russia and are available in a price range comparable with the average prices in the Chinese market. Production of 0.5 GWh per year of NMC-based lithium-ion battery cells would require cathode material production of about 850 tons per year.

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[47] The Material Cycle of a Battery Cell. URL: www.bmw.com/en/innovation/life-cycle-of-a-battery-cell.html (accessed: 18.02.2021); Battery Cell Assembly: Pilot Line Started. URL: https://www.volkswagen-newsroom.com/en/stories/battery-cell-assembly-pilot-line-started-5383 (accessed: 18.02.2021); Tesla Gigafactory. URL: www.tesla.com/gigafactory (accessed: 18.02.2021); Ford Is Considering In-House Production of Lithium-Ion Batteries. URL: insideevs.com/news/454390/ ford-considering-in-house-production-batteries/ (accessed: 18.02.2021).

[48] Liotech increased its revenue 1.5 times. More than half of the revenue came from supplies of products for the power industry. URL: www.rusnano.com/about/press-centre/media/20200130-infopro54-liotech-uvelichil-vyruchku (accessed: 19.02.2021).

[49] Rosatom will develop work in the energy storage markets under the Renera brand. URL: tass.ru/ekonomika/9666545 (accessed: 19.02.2021).

[50] Ford Is Considering In-House Production of Lithium-Ion Batteries.

[51] Rostec and Titan Power Solution will create new types of Li-Ion batteries. URL: https://rostec.ru/news/rostekh-i-titan-power- solution-sozdadut-novye-vidy-li-ion-batarey/ (accessed: 19.02.2021).

Table 1. Resource base for the production of cathode materials

Component	USD/ton in China *	USD/ton in Russia **	Supplier in Russia	Supplier status
LiOH * H2O	9 000	10 950	Halmek, Tula	manufacturer
CoSO4 * 7H2O	8 116	9 091	Ural Chemical Industry Factory, Verkhnyaya Pyshma	manufacturer
NiSO4 * 7H2O	4 770	4 112	Kyshtym Copper Electrolyte Factory, Kyshtym	manufacturer
MnSO4 * H2O	864	671	LLC November, Moscow	not manufactured in Russia
FeSO4 * 7H2O	90	195	Vetluzhsky Chemical Factory, Nizhny Novgorod	manufacturer
NaOH (98,5%)	350	400	Mineral Powder Factory Basis, Verkhny Ufaley	manufacturer
Na2CO3 * 10H2O H2 SO4 (95,6%) NH4OH (25%)	300-150	>150	PJSC Khimprom, Novocherkassk	manufacturer

* As of November 1, 2020, according to Bloomberg and SMM. ** As of 01.11.2020 without cost of delivery and VAT / Source: Сколтех

Thus, a comprehensive program of battery production should be formed and implemented in Russia as an integral element of the electric transport development strategy itself.

As far as production of electric transport with fuel (hydrogen) cells is concerned, InEnergy deployed pilot production of such cells in Moscow, and pilot modules for heavy buses were created and exported. The developments of InEnergy and IPCP RAS in the part of fuel cells are supported at the world level. InEnergy presented projects of fuel cell production for heavy transport.

It should also be noted that a possible alternative to lithium-ion batteries is sodium-based electrochemical systems. Prototypes of prismatic sodium-ion battery cells with a capacity of 0.5–3 Ah have been created at Skoltech and Lomonosov Moscow State University, and the foundations have been laid for scalable technologies for the production of cathode and anode materials. Technology of sodium-ion batteries promises to reduce the cost of stored energy by 30%, and does not depend on the state of prices of lithium, nickel, and cobalt in the world, or on their availability. Sodium-ion batteries are based on vanadium compounds, which can be sourced from EVRAZ with annual production of 7,500 tons of vanadium pentoxide in Tula.

7.3. Arguments for the development of lithium-ion battery technologies

In public space and expert discussions, the following arguments are often put forward against the development and adoption of lithium-ion battery (LIB) technologies in Russia, which also partially apply to criticism of battery electric vehicles (BEVs) in general:

- LIB do not (and will not) work in cold climates (for example, in regions where the average temperature in the winter months is below –20°C);
- electric cars do not provide environmental benefits;
- the prospects for improving the batteries of the NMC family are limited;
- LIB production technologies are highly dependent on economies of scale, and domestic car manufacturers will always be able to import batteries at affordable prices if necessary.

The competitiveness of electric cars depends to a great extent on batteries: today they account for up to half of the cost of an electric car and determine its mileage and usability characteristics. In Russia, there is an urgent need to expand applied technological developments and create production of traction batteries for electric vehicles for at least the following reasons.

Firstly, even in the current generation of NMC622 and NMC811 type batteries, there is considerable room for improvement of their characteristics. And the next generations (including post-lithium ones) cannot be mastered without the deployment of a pilot industrial base (pilot conversion lines for the production of materials and cells from 0.1 to 0.5 GWh) – such such are the specifics of electrochemical technologies.

Second, the world is actively working on low-temperature LIAs (capable of functioning at –30°C and below). The most critical component of the LIB, which is sensitive to low temperatures, is the electrolyte, and the battery degradation mainly occurs during low-temperature charging. Therefore, in the electric vehicle complex the problem is solved not only by electrochemical methods, but also on the engineering level, with existing technologies: battery thermostat systems ("thermos"), passive heating, active heating (heat pumps or constant/variable current) when the vehicle is parked. Moreover, about 70% of Russia's population lives in climatic zones where current technologies allow the operation of electric vehicles. Adapting electric vehicles to the specifics of the country is a separate topical technological challenge at the intersection of electrochemistry and modern engineering.

Third, according to the updated estimates of the International Energy Agency (2020) [52], under comparable conditions, the CO_2 equivalent emissions per 10-year life cycle for a battery electric vehicle are 26.2 t, for a vehicle using hydrogen fuel cells – 27.5 t, for a vehicle using internal combustion engines – 34.3 t. These results speak in favor of electric cars, and are consistent with other authoritative studies and our own calculations. We should also note that Russia has a structure of generation sources that is normal by world standards, even taking into account the lag in new RES (a significant share of natural gas, nuclear power, and hydro power plants). Therefore, under Russian conditions, parity in emissions between an electric car and a car with an internal combustion engine occurs as early as the fourth year of operation.

Fourth, the effect of economies of scale is significant at production volumes up to 4–6 GWh of cell capacity per year, and then it is leveled out. Assuming a strategic approach to industry development, this capacity corresponds to about 80–120 thousand domestic electric cars per year, which is a realistic target for the Russian market on the horizon of 2030 (the level of domestic sales during 2010–2020 averaged about 2 million cars per year, including about 1.6 million passenger cars).

Finally, it should be taken into account that in the process of designing a modern electric vehicle, optimization is carried out at all levels: from materials for battery cells to the organization of the assembly space. And with the high global demand for battery systems, domestic manufacturers with low order volumes will be provided with LIB on the residual principle.

7.4. Electric transportation: stimulation of the growth of related markets and end-to-end technologies

Promotion of the development of the domestic electric vehicle industry of the full cycle – from development of electric vehicles to recycling of battery systems and ensuring cybersecurity of the car and IT infrastructure – also means stimulation the development of a whole block of related end-to-end technologies. The example of China shows that the improvement of transport using new energy sources (especially electric transport) stimulates the creation of new projects and productions: thus, by the end of 2020 in China there were more than 180 thousand such companies, 16% of them – in the sectors of research and technical services, and 30% of them were created directly in 2020. Based on this experience, we can assume that by 2030 in Russia

[52] Comparative Life-Cycle Greenhouse Gas Emissions over Ten Year Lifetime of an Average Mid-Size Car by Powertrain, 2018. URL: www.iea.org/data-and-statistics/charts/comparative-life-cycle-greenhouse-gas-emissions-over-ten-year-lifetime-of-an-average-mid-size-car-by-powertrain-2018 (accessed: 19.02.2021).

there will be up to 30 thousand new enterprises related to new energy vehicles, and the total market for electric transport and electric mobility will be more than 7.5 trillion rubles.

Here is a list of end-to-end technologies and corresponding technological solutions based on them, which are being improved in the process of development and production of electric transport and have the most significant impact on the development of related high-tech markets:

- New production technologies: digital engineering, digital platforms (platform IT solutions), digital twins, which ensure the creation and release to the market of competitive products in the shortest possible time, a significant reduction in the cost and timing of development, dynamic updating of the model range and the formation of scientific and technological and product reserves, guaranteed reserved development.
- New and portable energy sources: battery technology, battery materials.
- New materials and substances, additive technologies: composite materials, metamaterials, plastics, production of frames, body panels, components.
- Sensorics and robotics components: modernization of production systems of enterprises, organization of flexible distributed productions.
- Neurotechnology and Artificial Intelligence: Advanced driver-assistance system (ADAS), unmanned vehicle systems.
- Components for a smart car: smart systems for condition monitoring, diagnostics, and control of vehicle components; driver-vehicle interaction systems (HMI systems); integration of electric vehicle with user devices.
- Quantum Technologies and Cybersecurity of Car and IT Infrastructure.
- Big Data and Wireless Technologies, Industrial Internet: Connected Transport Technologies, Smart Transportation.
- Navigation, satellite communication.
- Electrics and electronics, new generations of microelectronics, new component base.

Related markets that will be impacted include: raw materials market (lithium, nickel, rare earth metals, aluminum); component production (batteries, power plant, housing, electrics and electronics, media systems, other components); new production technologies, digital engineering, scientific and technical developments in the field, cross-industry technology transfer; wholesale and retail sales of electric/"hydrogen cars" and components; charging stations; transportation services and freight; development and implementation of relevant software and custom applications, IT infrastructure development and cyber security systems; services; leasing, banking and insurance services, business services.

7.5. Electric vehicle - a step on the road to hydrogen vehicles

Each of the energy sources – electricity, natural gas, hydrogen – has its own advantages and disadvantages, and each technology can occupy its own niche in the field of transport. Therefore, it would be a mistake to bet on only one of the technologies to the detriment of the others: it is necessary to develop all three areas in parallel. Moreover, mastering electric mobility technologies in Russia today is a necessary stage in the development and implementation of hydrogen energy technologies.

According to STI Center at SPbPU experts, all three technologies are quite similar in terms of car design, its layout (compared to the specifics of the layout of a car with an internal combustion engine): it would be much easier to redesign an electric vehicle into hydrogen-powered vehicle than to redesign an internal combustion car into an electric vehicle. Therefore, the development and mastering of the production of electric cars is a necessary stage in the development and mastering of hydrogen vehicles. Electric vehicle technologies are capable of becoming the driver of the process under discussion due to their focus on the mass segment and the relatively lower costs of development and creation of infrastructure.

Summary 7. Thus, provision of support to production of electric vehicles through the implementation of "pull-out" projects is not only about decarbonization and improvement of the quality of life, but above all about the struggle for future technological and economic leadership in new markets with a relatively low entry threshold so far. Such projects as the Russian National Electric Vehicle / Smart City Electric Vehicle, as well as related projects for component base development (battery technologies, IT platforms, microelectronics), charging infrastructure and smart city elements concentrate scientific, technological, production and organizational resources around themselves and provide a breakthrough in key market areas. Thus, electric cars may become the basis for the revival of the Russian car industry of the whole cycle: from development to production of components and creation of infrastructure.

8. THE DEVELOPED RAW MATERIAL BASE WILL ALLOW RUSSIA TO HAVE ITS OWN COMPETITIVE INDUSTRY

Russia's developed raw material base, if supported by the development of its own platforms and energy systems (batteries and, later, fuel cells) will make it possible to build modern, competitive production of electric cars.

The growth of the electric car market increases the demand for raw materials for their key component – batteries. Electric cars mainly use lithium-ion batteries, which are made from compounds of metals such as lithium, nickel, manganese, cobalt, copper, aluminum, etc. Currently, two-thirds of the world's lithium-ion batteries come from China [53].

Russia has substantial raw material reserves of lithium-ion battery components for electric cars and other energy storage devices [54]. Approximately 10% of global nickel, most of which is cathode grade 1, and 3% of cobalt is produced by Nornickel [55].

According to experts from VYGON.Consulting, Russia and Russian companies in the global chain of lithium-ion battery production are assigned the role of a supplier of raw materials (nickel, cobalt, copper, aluminum) with low added value, within 5% of the price of the finished battery [56].

Demand from electric car battery manufacturers for nickel as a cathode material is growing. In 2018. Nornickel and the German company BASF signed an agreement to build a plant for the production of cathode materials for the production of electric cars. Nornickel will supply nickel and

[53] *Goyal N.* Tesla Warns of Shortage of Minerals Required in the Making of Rechargeable Batteries. URL: www.industrytap.com/tesla-warns-of-shortage-of-minerals-required-in-the-making-of-rechargeable-batteries/50438 (accessed: 09.03.2021).

[54] Bulletin of the Accounts Chamber of the Russian Federation. URL: ach.gov.ru/upload/iblock/3ef/3efad1d974fb096eff58368ba6a9fca1.pdf (accessed: 19.02.2021).

[55] Energy Storage in Russia: An Injection of Sustainable Development. URL: www.tadviser.ru/images/d/d9/Vygon_consulting_storage.pdf (accessed: 19.02.2021).

[56] Ibid.

cobalt raw materials to the facility located in Harjavalta (Finland) on a long-term basis [57].

However, Russian nickel production and exports are growing slower than the global market.

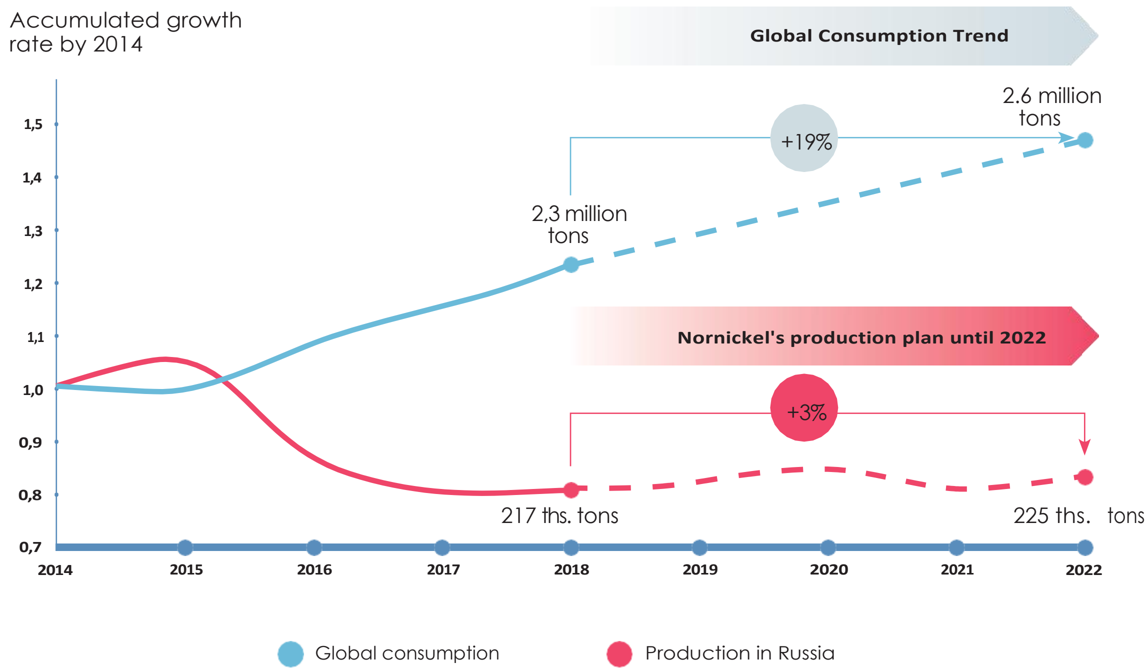

Fig. 17. Nickel market from Nornickel's presentation "Expanding Sustainable Growth Horizons" / Source: VYGON Consulting, November 2019

The RF Audit Chamber Bulletin "Subsoil Use" [58] notes that Russia has significant raw material reserves of lithium-ion battery components for electric vehicles and other energy storage devices. However, the country imports most of this raw material because there is no geological exploration, in particular for lithium mining, there is no complete processing chain, and the resources are located in areas that are difficult to access.

The availability of substantial reserves of certain solid minerals at low quality, remoteness from infrastructure and main consumers, as well as the lack of extraction technologies lead to their import. For example, Russia has a fairly large raw material base of rare-earth metals (25% of global reserves), required for the production of high-tech and innovative products in various industries (including electronics). However, due to the lack of a complete production chain for deep processing of raw materials, the demand for these metals is satisfied by imports. More than a third of strategic minerals are also imported: manganese, chromium, lithium, beryllium and rhenium – 100%, zirconium – 98%, titanium – 95%, tin – 70%, bauxites – 64%, uranium – 65%, molybdenum – 45% [59].

According to current estimates, the raw materials reserves of the Arctic contain about 98% of nickel and 66% of rare-earth metals, but their extraction, given the "fragility" of the Arctic ecosystems, can disturb the ecological balance of the territory..

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[57] BASF and Nornickel join forces to supply battery materials. URL: www.nornickel.ru/news-and- media/press-releases-and-news/basf-i-nornikel-obedinyayut-usiliya-dlya-postavki-akkumulyatornykh-materialov (accessed: 19.02.2021).

[58] Bulletin of the Accounts Chamber of the Russian Federation.

[59] Ibid.

The need to develop and disseminate breakthrough technologies in the energy sector, including energy storage, is outlined in the Doctrine of Energy Security of the Russian Federation. At the same time, there is no lithium mining in Russia, and there is no geological exploration or specialized work on lithium.

Experts note [60] that the Russian resource base of lithium is one of the largest in the world, the metal is found in 16 deposits. Russia's lithium resources are estimated at 1–1.5 million tons, the country ranks 10th in the world. However, no lithium is mined for the Russian domestic market. Instead, up to 1,500 tons of the metal is imported.

In addition to mining, there are prospects in Russia for lithium production as a by-product from oil and gas fields. Gazprom and IST Exploration are preparing a lithium production project at the Kovykta gas field [61].

It should be borne in mind that the pace of development and use of "post-lithium" generation batteries based on sodium is accelerating, since sodium reserves in the world are practically inexhaustible [62]. In 2020, the first industrial samples of Natron Energy's US development were delivered to the Chevron energy company.

Summary 8. Thus, Russia's most important competitive advantage is the developed raw material base necessary for development and production of its own energy systems (accumulator batteries and, subsequently, fuel cells) and, thus, to build a modern electric car industry. Efforts should be made to stimulate the domestic market for lithium and other raw materials for energy storage devices and to form a complete processing chain for these raw materials.

9. PUBLIC POLICY

In connection with the specifics of the economy of the Russian Federation, the main line of state policy in the field of electric vehicles market should be cautious in relation to the popular in some countries prohibitive measures to reduce the number of cars with internal combustion engines and focus on creating the electric vehicle production industry, demand support and formation of electric transport market in Russia.

The most important mechanism for the development of our own advanced technologies for the development and production of electric transport should be comprehensive "pulling" projects that concentrate around themselves the scientific, technological, manufacturing, organizational resources and provide a breakthrough in key areas of the market. Such a driver could be the Russian National Electric Vehicle / Smart City Electric Vehicle and related projects to develop the component base (battery technology, IT platforms, microelectronics), charging infrastructure and elements of the smart city.

9.1. Synchronization of existing electric vehicle support programs in Russia

The first step in the formation of state policy should be the synchronization of existing state programs aimed at creating a new knowledge-intensive manufacturing industry and stimulating consumption.

It is necessary to define a state policy regarding the development of the market of transport services (mobility) in general and electric transport in particular. This policy must be linked to the

[60] Berezina E. Batteries discharged. How political tensions in Bolivia will affect the lithium market. URL: rg.ru/2019/11/12/kak-na-rynke-litiia-otrazitsia-politicheskaia-napriazhennost-v-bolivii.html (accessed: 09.03.2021).

[61] Gazprom will share the brine. URL: www.kommersant.ru/doc/4154770 (accessed: 19.02.2021).

[62] Russian scientists have found a cheap and reliable replacement for lithium batteries. URL: www.cnews.ru/news/top/2020-07-14_rossiyane_pridumali_deshevye (accessed: 19.02.2021).

country's climate agenda and conceptualized in framework documents at both the federal and regional levels.

In the case of the regions, it is especially important to develop concepts for the agglomerations of Moscow and St. Petersburg. In these subjects of the Federation, state investment in the electric vehicle industry will bring the greatest effects due to their climatic, economic, and infrastructural features. Such concepts should be based not only on the experience and best practices of world leaders, but also on the realities and capabilities of Russia, as well as the interests of key industry stakeholders.

It is necessary to coordinate the state policy in the sphere of development of electric transport and production of electric cars in the Russian Federation. At present, many countries around the world are adopting and implementing extensive programs in this area. It is also necessary to update the Strategy of development of the automotive industry of the Russian Federation for the period up to 2025 and develop a state program for the development of infrastructure of the EVSE.

9.2. Stimulating demand for electric cars

The electric car market will grow by leaps and bounds when its share reaches 3–5% of the country's vehicle market (currently 0.16%). And the "scale effect" will be achieved by domestic manufacturers at the level of production of 45,000 electric cars per year. Until then, the most important market development drivers will become:

- Tax regulation: waiving a portion of taxes on electric vehicles. Extension of measures adopted in more than 20 regions of Russia to the federal level.
- Subsidies for individuals to buy electric cars. Remove until 2027 the price restriction under the program for a 25% discount on the purchase of a Russian-made electric car.
- Implementation of a mechanism to subsidize the difference in the cost of an electric car and a car with an internal combustion engine.
- Measures aimed at increasing the share of electric transport in public procurement.
- Encouraging the purchase of electric cars by corporate consumers: transport and carshare companies, taxi fleets, etc..
- Implementation of pilot projects for the use of electric transport in cities, subsidizing part of the cost of purchasing electric buses in pilot regions.

9.3. Support for the development of Russian electric car production

The key measure is investment and regulation of R&D aimed at the development of technologies that ensure the competitiveness of Russian design and production of electric vehicles and component base.

Projects such as the "Russian National Electric Vehicle" should have an aggregate "pulling" effect, i.e. concentrate scientific, technological, production, organizational resources around themselves and ensure victory in the technological race. Therefore, to implement them, it is necessary to organize a single focal point (on the basis of an engineering or research and production center) and work in the cluster / consortium format and provide for them support measures in the form of competitive subsidies or direct state order.

At the moment there is such a de facto center – the Engineering Center, which is part of the STI Center of Competence "New Production Technologies" of SPbPU; it has significant potential, resources and experience in the development of electric vehicles of all classes: from compact urban electric vehicles to 18-meter electric buses. In 2023-2024 KAMAZ plans to launch commercial production of the KAMA–1 electric car created at the STI Competence Center "New Production Technologies" at SPbPU [63].

[63] KAMAZ intends to create a light commercial electric vehicle based on the KAMA–1. URL: tass.ru/ekonomika/10308081 (accessed: 20.01.2021).

In addition, the location of the engineering center in St. Petersburg will provide a number of competitive advantages for the pilot development and production of electric vehicles:

1. The city has the potential to organize the production of the following elements of electric cars: electric motors, frames and body panels, suspension, braking system, and interior components.
2. St. Petersburg has a power source with a low "carbon footprint" – the Leningrad NPP. Using its capacity to supply production and charge electric cars, it is possible to minimize CO_2 emissions at different stages of the life cycle of an electric car. This will not only improve the climatic situation in the city, but also to obtain the necessary certification for the supply of electric cars in the European and global markets.

9.4. Support for component base and material development

The production of batteries and cathode materials should be an integral part of the car production. Options for the creation of such production: within the KAMAZ site; in the Tula industrial cluster (Uzlovaya), near the production of the most important components of cathode materials (both lithium and post-lithium generations). In addition, it is necessary to provide incentives for development in the following areas: microelectronics and electronic component base, IT solutions and cybersecurity technologies, autonomous and connected transport technologies, "smart city" technologies.

Measures to implement this activity should include:

- Localization of production of parts common to vehicles with internal combustion engines.
- Localization of battery production.
- Benefits for manufacturers of electric motors made of Russian raw materials.
- Localization of electric motor production.
- Support for smart digital IT solutions.

Specific steps include refining the list of technologies that will be included in the special investment contract (SPIC) 2.0, taking into account the focus on promising technologies in fuel cells, batteries, microelectronics, and IT solutions.

It is necessary to adjust decree 719 in terms of scoring the localization of electric vehicles in the direction of reducing the requirement for passing scores at the stage of production organization, so that further growth in localization is provided at the expense of domestic technologies and components used in electric motors.

It is also necessary to adjust the rate of utilization fee to encourage automakers to localize their projects.

These measures will support Russian producers and form a new agenda in international cooperation with EU countries and major companies (e.g., in rare metals and batteries, in research and development).

In addition, measures aimed at the development of recycling and recycling of batteries should be provided.

9.5. Infrastructure development

Separately, it is necessary to support the development of charging infrastructure for electric vehicles. The experience of other countries shows that this should be done somewhat ahead of the development of the electric car market. Moreover, variants and standards of this infrastructure may differ significantly. The infrastructure should be somewhat "redundant" – accessible. Russia significantly lags behind in developing a network of charging stations for electric cars, although PJSC Rosseti has adopted a national 30/30 program. The "tipping point" for charging infrastructure is the same as for manufacturers: the share of electric cars is 3–5% of the country's total car fleet. According to Russian Grids estimates, the annual energy consumption in this case will increase by 8–9 billion kW·h and the provision of charging services will become profitable. Particular attention should be paid to the formation of a flexible electricity tariff system for electric transport.

As the experience of Primorye or Irkutsk shows, for example, the existing 220 V outlets at home or in the office may be enough to use an electric car in the "home-work" mode. The main obstacle to the development of electric transport is the inability to travel long distances by electric car. Therefore, it is most important to create charging infrastructure along federal highways, providing connectivity for cities and the ability to travel significant distances by electric vehicle. State support for the development of electric charging infrastructure should begin with the following steps:

1. Include in the regional regulatory documents defining the strategy of socio-economic development items on the development of charging infrastructure in the region with the achievement of the standard: at least five fast charging stations in the center of each city with a population over 500 thousand people by 2024 and at least 30 by 2030.
2. Ensure that at least one charging station for every 300 km of track by 2024 and at least one charging station for every 100 km of track by 2030 on federal highways of "M" and "P" categories.
3. Encourage the emergence and improvement of private networks of fast charging stations as part of the activities of development institutions.
4. Provide financing, development and localization of technologies for creating charging stations, charging infrastructure, as well as the improvement of related technologies through development institutions.
5. Implement measures to encourage entrepreneurs to place charging infrastructure at their facilities. For example, in St. Petersburg there is already a regulation in place that obliges development companies to install charging stations in all residential and office buildings under construction. In general, such companies may include:

а) development companies;
б) vehicle fleets, taxi fleets;
в) carsharing companies;
г) fast-food restaurants, shopping malls;
д) automakers;
е) networks of car service stations, gas station networks.

Perhaps the rule requiring gas stations to be equipped with charging stations should be tightened: now it is a recommendation..

It is also proposed to implement three pilot projects:

1. Pilot line for electric and hydrogen tractors.
2. Pilot city to implement zero-emission delivery vehicles by 2030.
3. Pilot regions for electrification of bus fleets (except Moscow and St. Petersburg).

9.6. "Russian National Electric Vehicle". Creation of a consortium for the development of electric transport

Given the extremely tight timeframe of the window of opportunity for entering the electric car market, it seems appropriate to recommend adopting a comprehensive program "Russian National Electric Vehicle", focusing the efforts of participants on the rapid development and market launch of mass electric vehicles in the lower and medium price segments, not inferior to foreign analogues.

This project will properly continue a number of Russia's latest technological victories, such as the construction of the Crimean bridge, the creation of the Sputnik V vaccine, the creation of hypersonic weapons, etc.

In order to implement a comprehensive program for the development of electric transport, consortia should be formed among interested participants in the areas of activity presented in Table 2.

Table 2. Main activities of the consortium and participants

Course of action	Tasks	Participants
Development and production "russian national electric car"	1. Development of the platform and model range of electric vehicles 2. Ensuring the production of electric cars 3. Ensuring the distribution of electric cars 4. Development of the necessary IT components of an electric vehicle	SPbPU PJSC KAMAZ PJSC GAZ PJSC Sberbank Kaspersky Lab Yandex etc. (the list can be expanded)
The formation of a common vision of the timing and stages of development of the market electric transport	1. Coordination of regulatory requirements and project timelines with state regulators and infrastructure companies 2. Networking of consortium participants and industrial partners 3. Support for startups and entrepreneurs, implementing developments in the field of electric transport	SPbPU VEB.RF CSR North-West Foundation Skolkovo Institute of Science and Technology PJSC KAMAZ PJSC GAZ Zetta LLC Yandex.Drive Delimobil Belka ZEVS IT platform, etc. (the list can be extended)
Development of the electric transport engineering market	1. Creation of engineering centers 2. Use of existing research facilities to support localization of production of parts, common to vehicles with ICE, and electric motors	SPbPU Skolkovo Institute of Science and Technology (the list can be extended)
Development of Russian transport infrastructure management technologies, creation of EHS infrastructure	1. Formation of a road map for the development of EVSE infrastructure 2. Implementation of the All-Russian Charging Infrastructure Development Program for electric transport 3. Implementation of measures to support entrepreneurs who place charging infrastructure at their facilities 4. Implementation of a pilot line for electric and hydrogen-powered tractors 5. Implementation of the project to create pilot regions for electrification of bus fleets	PJSC ROSSETI Avtodor SUE Mosgortrans SUE Gorelectrotrans (St. Petersburg) Ministry of Energy of the Russian Federation Ministry of Transport of the Russian Federation ZEVS IT platform (the list can be extended)

Development of Russian electromobility technologies, creation of component base production	1. Creation of a component base with subsequent integration into its own model range and with the launch on the Russian and export markets 2. Creation of facilities for the production of the necessary component base and finished products in various segments of EV technology 3. Participation in the formation of infrastructure	PJSC KAMAZ PJSC Sberbank (infotainment) PJSC Sibur SC Rosatom NLMK Rusal (the list can be extended)
Creation of production, recycling and disposal of battery systems	1. Formation of the R&D and production preparation roadmap 2. Creation of the component base in the Russian Federation for the production of of lithium-ion and other batteries 3. Localization of battery production 4. Implementation of business models for recycling and recycling of batteries	SC Rosatom RANERA LLC Skolkovo Institute of Science and Technology InEnergy Liotech Halmek UPCR KMEZ Himprom Nornickel Polymetal, etc. (the list can be extended)
Formation of state policy in the field of electric transport development, including measures of state support	1. Development of a state program for the development of electric transport in the Russian Federation 2. Update the existing Strategy for the Development of the Automotive Industry of the Russian Federation until 2025	VEB.RF Russian Ministry of Industry and Trade Ministry of Energy of the Russian Federation Fond CSR North-West Fond (the list can be extended)

Source: CSR North-West

10. SUMMARY: THE EXPECTED EFFECTS OF THE IMPLEMENTATION OF THE PROPOSED POLICY

It is expected that the implementation of the comprehensive policy proposed in the report and the formation of a highly developed domestic market for electric transport and related technologies will lead to the following effects:

1. The experience of the STI Center at SPbPU shows that it is fundamentally possible to create a line of electric vehicles and components in the two to three years of the window of opportunity declared in the report, but this requires applying the entire range of "end-to-end" development and production technologies: "digital twins" as an integrator technology, knowledge-intensive platform solutions, etc. The widespread adoption of these technologies by industrial companies involved in creating the electric transportation market will allow them to move to a new level of development on their way to industrial leadership in global markets. This level implies continuous development as the most important feature of the new paradigm of digital design and modeling based on digital twins, and therefore a significant acceleration of development and production of new products, reducing financial and other resource costs, ensuring competitive performance, flexible response to competitors and market conditions [64].

2. A number of countries are currently working on creation of their own "national" electric vehicles: TOGG in Turkey, Izera in Poland, Arrow in Canada, etc. The development of a "national mass electric vehicle" is an important political symbol for the development and strength of science and industry today. At the same time, the market situation "at the tipping point" of the technological system provides an opportunity for new manufacturers to compete or even outpace the former leaders of the automotive industry. This is already happening now: among the 10 most expensive car companies in the world as of November 2020 – three manufacturers of electric cars that have already appeared in the 21st century (Tesla, NIO, Xpeng). The successful participation of Russia in this process will demonstrate the high level of scientific and technological development of the country.

3. The automotive industry, as a high-tech industry, which ranks third in the world in terms of research and development costs, is currently one of the leading drivers of the digital economy. The creation of a line of electric vehicles and component base will "reboot" the Russian full-cycle automotive industry and make a significant contribution to the sustainability and development of the Russian economy.

4. The implementation of the mass production of electric cars contributes to the formation and growth of an ecosystem of new technologies, including those that are absent or underdeveloped at the moment in Russia: energy storage and raw materials (nickel, lithium, cobalt, rare-earth metals), electric motors and components for them, aluminum and composite structures, energy recovery technologies, microelectronics, advanced automotive components, as well as associated electric mobility technologies of unmanned driving and driver assistance (ADAS), connectivity, industrial internet systems, etc.

5. At the system-wide level, the production of electric transport and its application in the urban economy, requiring the introduction of new digital technologies and platform solutions, certainly contributes to the formation of cyber-physical systems of a fundamentally new type ("smart factory", "smart city", etc.), increasing the sustainability of enterprises, cities and other systems, improving management efficiency and safety, reducing financial and time costs, reducing infrastructure maintenance costs, increasing process speed, transparency and observability, increasing energy efficiency and reducing the negative impact on the environment.

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[64] Based on the experience of SPbPU STI Competence Center "New Manufacturing Technologies" and CompMechLab SPbPU Computing Engineering Center.

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Expertise and analysis report

Edited **A. I. Borovkov, V. N. Knyaginin**

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