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Problems and prospects of decarbonization of road transport in the Russian Federation*

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ABSTRACT On the way of decarbonization of certain sectors of the economy, new types of climate risks arise, and associated losses as a result of actions by the public and private sectors aimed at containing these changes, and not at adapting industries to climate change. Measures for decarbonization of motor transport are considered. The most effective of them in the medium term are measures to diversify the use of natural gas, traction electric drive and hydrogen fuel cells as energy sources. The key organizational, technological and economic problems that hinder the widespread use of these alternative energy sources in road transport are highlighted. The requirements for achieving the competitiveness of cars with traction electric drive and hydrogen fuel cells in comparison with oil-fueled cars are formulated.

It has been established that the total gross GHG emissions of the Russian vehicle fleet in 2050, the expected number of which will decrease from 59.8 to 51.7 million units compared to 2021, may amount to 126.8 million tons of CO_2 equivalent, which is 28.5 % less than in 2021. Compared to previous projections, the value of total GHG emissions from the vehicle fleet in 2050 will lag behind by about 5 years. At the same time, the vehicle fleet in 2050 will be dominated by automatic telephone exchanges with internal combustion engines on hydrocarbon fuels (liquid, gaseous). Only after 2045, the share of sales of electric vehicles of all types can exceed the share of sales of these types of automatic telephone exchanges with internal combustion engines [1].

KEYWORDS: automobiles; decarbonization; greenhouse gas emissions; natural gas; traction electric drive; hydrogen fuel cells; events

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Научная статья

Проблемы и перспективы декарбонизации автомобильного транспорта в Российской Федерации*

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АННОТАЦИЯ На пути декарбонизации отдельных отраслей экономики возникают новые виды климатических рисков и связанные с ними потери в результате действий государственного и частного секторов, направленных на сдерживание этих изменений, а не на адаптацию отраслей к изменению климата. Рассмотрены мероприятия по декарбонизации автомобильного транспорта. Наиболее эффективными из них в среднесрочной перспективе являются меры по диверсификации использования в качестве источников энергии природного газа, тягового электропривода и водо-

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родных топливных элементов. Выделены ключевые организационно-технологические и экономические проблемы, которые сдерживают широкое использование данных альтернативных источников энергии. Сформулированы основные требования, выполнение которых позволит обеспечить конкурентоспособность электромобилей с тяговыми аккумуляторными батареями и водородными топливными элементами по сравнению с автомобилями на нефтяном топливе.

Результаты прогноза выбросов парниковых газов (ПГ) автомобильным транспортом на период до 2050 г. с учетом реализации рассмотренных мероприятий показали, что суммарные валовые выбросы ПГ автомобильным парком России в 2050 г., ожидаемая численность которого сократится по сравнению с 2021 г. с 59,8 до 51,7 млн ед., могут составить 126,8 млн т $CO_{2\text{-экв.}}$, что на 28,5 % меньше, чем в 2021 г. По сравнению с ранее составленными прогнозами значение суммарных выбросов ПГ автомобильным парком в 2050 г. будет отставать примерно на 5 лет. При этом в автомобильном парке в 2050 г. будут преобладать автотранспортные средства (АТС) с двигателями внутреннего сгорания (ДВС) на углеводородном топливе (жидком, газообразном). Только после 2045 г. доля продаж электромобилей всех типов может превысить долю продаж этих типов АТС с ДВС [1].

КЛЮЧЕВЫЕ СЛОВА: автотранспортные средства; декарбонизация; выбросы парниковых газов; природный газ; тяговый электропривод; водородные топливные элементы; мероприятия

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INTRODUCTION

The climate agenda became popular after 198 states signed the Paris Climate Agreement[1], which provides for a set of measures at the national, supranational, regional and corporate levels to decarbonise the economy, including the transport sector, including the following:

- Adopting long-term low-carbon development strategies;
- Establishing a regulatory system to incentivise low greenhouse gas (GHG) emission development, including price regulation and measures to protect national markets;
- Introduction of international and national standardisation of climate action (calculation of direct and indirect GHG emissions by different sectors of the economy and their uptake, validation of calculations);
- Technological development of generating capacities, energy- and carbon-intensive industries with regard to the use of renewable energy sources (RES), increasing the energy efficiency of natural resources consumption;
- Reorientation of investment and financial flows in the direction of technological development with a minimal carbon footprint.

Countries' measures to decarbonise their economies create new types of risks — climate transition risks. The associated losses do not arise from climate change, but from public and private sector actions aimed at curbing these changes (introduction of cross-border carbon tax (CBT), introduction of new technologies, changes in energy consumption patterns, etc.).

1. As noted in the report of the Bank of Russia[2], in countries with a significant share of carbon-intensive exports in GDP, such as Russia, despite changes related to sanctions restrictions in 2022, climate risks continue to pose a significant threat to the Russian economy in the medium and long term due to the following factors:

- expected decline in global demand for key Russian export goods from the second half of the 2020s;
- incomplete reorientation of exports from unfriendly to friendly countries, as well as to domestic markets;
- stricter requirements for reporting on the carbon footprint of products in trading partner countries, inconsistency of Russian regulation with foreign regulation;
- introduction of cross-border carbon regulation in China and other Asian countries in the late 2020s and early 2030s; transfer of EU CBT costs through supply chains with friendly countries;
- accumulation of technological lag (including against the background of restrictions on imports of high-tech equipment), which may lead to increased costs of energy efficiency and carbon footprint reduction projects.

These circumstances directly affect the issues of transport decarbonisation, i.e. improvement of re-

[1] The Paris Agreement under the UN Framework Convention on Climate Change, regulating measures to reduce carbon dioxide in the atmosphere from 2020. URL: https://unfccc.int/files/meetings/paris_nov_2015/application/pdf/paris_agreement_russian_.pdf
[2] Climate risks in changing economic conditions: report for public consultation // Bank of Russia. 2022. 51 p. URL: https://cbr.ru/press/event/?id=14418

source and energy efficiency of the transport complex in the course of transportation by different types of transport, production, use, restoration of serviceability, recycling of vehicles, road construction equipment, operational, structural, construction materials, equipment and technologies. According to the National Report on the inventory of anthropogenic emissions by sources and absorption by sinks of greenhouse gases not regulated by the Montreal Protocol[3], which is being developed in accordance with the obligations of the Russian Federation under the UN Framework Convention on Climate Change and the Kyoto Protocol to the UN Framework Convention on Climate Change, in 2018 the volume of GHGs from combustion of motor fuel (direct emissions) by all types of transport (except pipeline transport) in the Russian Federation was 176.2 million tonnes of CO_2 equivalent, including 153.8 million tonnes by road transport, 12.6 million tonnes by civil aviation, 7.05 million tonnes by railway transport and 2.29 million tonnes by water transport.

If we also take into account indirect GHG emissions by all types of transport, taking into account mobile and stationary sources [2], the share of road and urban electric transport in the total gross GHG emissions by transport in 2018 was 79.2 %. Forecast estimates [3, 4] showed that the situation will not change in the medium term as well. Thus, road transport is the main source of GHG emissions in the transport sector in the Russian Federation with an unfavourable trend of change in gross emissions over the last 20 years and in the mid-term perspective.

MEASURES FOR DECARBONISATION OF ROAD TRANSPORT

As a result of analysis and generalisation of domestic and foreign experience [5, 6] it has been established that GHG emissions reduction by road transport is possible due to the implementation of measures united in three groups:

Group I — improving the energy efficiency of motor vehicles (GHG emission reduction) and transport technologies using traditional types of motor fuels;

Group II — diversification of the use of different energy sources in vehicles with lower GHG emissions;

Group III — mobility management — reduction of excessive, irrational, unjustified movement of goods and passengers, curbing hypermobility of the population through the development of information systems for data collection, intelligent processing, analysis and exchange, as well as the use of enhanced communication capabilities between humans, motor vehicles and road infrastructure.

Table 1

Effectiveness of measures to reduce GHG emissions from road transport, % [10]

Groups of measures	2020	2030	2040	2050
A – improving the energy efficiency of vehicles and transport technologies using conventional motor fuels	97	80	40	3
B – mobility management	2	5	10	20
C – diversification of the use of different energy sources with lower GHG emissions for vehicles	1	15	50	77
Total	100	100	100	100

Group A activities provide for:

- rationing of specific CO_2 emissions from new motor vehicles;
- maintenance of the technical condition of vehicles and transport infrastructure facilities in a standardised state[4].
- formation of an optimal structure (stimulation of renewal) of the rolling stock fleet by managing the processes of its replenishment and retirement.

As follows from Table 1, for the period up to 2030, the share in the total effect on reduction of GHG emissions by road transport from the implementation of measures of group A will be determinant.

Group B activities include:

- management of demand for transport services;
- formation of a rational structure of transport networks in cities and agglomerations;
- low-carbon organisation of the transport process with mutual complementation (but not competition) of different modes of transport (digital transport and logistics technologies, intelligent transport systems, etc.);
- formation of a "smart" system of road toll collection (based on distance travelled, weight of vehicles, level of their energy and environmental efficiency), etc.

Group C measures are related to the substitution of traditional liquid motor fuels (petrol, diesel fuel) for natural gas in compressed (compressed) or liquefied

[3] National inventory report on anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol. Part 1. Moscow: FSBI "IGCE", 2020;480.
[4] A road is considered to be in a normative condition when its parameters and characteristics provide values of the complex indicator of transport-operational condition not lower than normative (EF = EFn) during the whole autumn-spring period. Rosavtodor. Road industrial methodical document (ODM) 218.4.039-2018.

form, as well as for traction electric drive from accumulator batteries or hydrogen fuel cells in vehicles with internal combustion engines.

Mass transition of road transport to alternative fuels in the medium and long term is determined by objective reasons, such as limited world oil reserves, increasing environmental requirements, climatic risks, decarbonisation policy, as well as regional peculiarities. Let us consider the key organisational, technological and economic aspects constraining the process of decarbonisation of road transport.

USE OF NATURAL GAS AS A MOTOR FUEL

The environmental advantages of natural gas as a motor fuel for vehicles with internal combustion engines are well known – an order of magnitude lower emissions of fine particles with exhaust gases compared to diesel-fuelled internal combustion engines and 17 % (at best) lower CO_2 emissions.

At present, the range of commercially produced compressed natural gas (CNG, LNG) vehicles in the Russian Federation includes 227 models, including 127 models of trucks, 43 units of passenger vehicles, 36 units of special vehicles, 19 models of light commercial vehicles and 2 modifications of passenger cars [7].

For several decades the share of CNG (LNG) vehicles in the vehicle fleet remains at the level of less than 0.2 % and as of 01.01.2022, according to Gazprom, PJSC, is about 260 thousand units, including 152.8 thousand units of passenger cars, 51 thousand units of light commercial vehicles, 33.6 thousand units of buses, 20.7 thousand units of trucks of groups 2, 3, as well as 0.8 thousand units of road and municipal equipment. As of 01.01.2023, the increase in the number of the fleet was 30.5 thousand units as compared to 2022. At the same time, the number of automotive gas filling compressor stations (AGFCS) on the territory of the Russian Federation as of 01.01.2022 (64 regions) is extremely small and amounts to 419 units, the maximum capacity of which does not exceed 2 billion m^3 per year. According to Gasprom, PJSC, the volume of natural gas consumption by motor transport in 2022 was 1,720.0 million m^3 (CNG — 1,550.8 million m^3, LNG — 121.7 million tonnes).

Let us highlight the key organisational, technological and economic issues that hinder the widespread use of natural gas as a motor fuel.

1. To maintain the range of vehicles when using CNG it is necessary to install from 1–2 (on passenger cars) to 10–12 cylinders on trucks and buses, which reduces their passenger capacity and load capacity. The cost of vehicles increases by 25–30 %.

2. Filling points (CNG filling stations) are “connected” to the pipeline network of gas pipelines. As a result, the territory of CNG vehicles use is limited, excluding the northern and other regions, which hinders the development of intercity and interregional road transport and the development of the refuelling network.

Insignificant share of CNG (LNG) vehicles in the Russian vehicle fleet (0.5 % as of 01.01.2023) due to lack of demand and, consequently, low production (supply) volumes of both CNG vehicles and CNG equipment kits for retrofitting of CNG vehicles. The draft concept of NGV market development in the Russian Federation for the period until 2035[5] developed by Transport Integration, LLC, provides for a significant increase in the production and retrofitting of natural gas-powered vehicles and provision of the backbone transport network with gas fuelling infrastructure facilities (bringing the number of NGV fleet to 1,373.1 thousand units by 2035). up to 1373.1 thousand units through the production and supply of 616.7 thousand gas-fuelled vehicles to the fleet and conversion of 583.5 thousand vehicles for the use of NGV fuel over the period 2023–2035 and the retirement of 117.6 thousand units of such vehicles over this period).

Due to the need to fulfil the requirements on fire and explosion safety of refuelling points, their location in cities is constrained by the lack of free (uninhabited) areas of the territory.

It is necessary to attract significant financial resources for reconstruction (construction) of production and technical base (PTB) of transport enterprises due to the need to fulfil strict requirements for fire and explosion safety of cylinders and equipment under high pressure. According to MADI (the Moscow State Automobile & Road Technical Unversity) data, the costs of transport enterprises for reconstruction of bus fleets with 200–250 bus units in the Moscow region reach up to 440 million rubles. The costs are associated with the construction of a gas cylinder filling station, CNG release and cylinder degassing station; with the reconstruction of the production building (additional redevelopment; ventilation, additional ventilation works, commissioning works, ventilation dismantling; technological equipment: automation of ventilation systems; communication and alarm system; fire extinguishing pump station, automatic foam fire extinguishing unit; installation of gas alarms; equipment for maintenance and repair of CNG buses).

[5] Development of the concept of the NGV fuel market development in the Russian Federation for the period up to 2035. Transport Integration, LLC, 2023;22. URL: https://www.asroad.org/wp-content/uploads/2023/04/Prezentatsiya-Kontseptsii-GMT-dlya-Gosud.-Dumy-RF_12.04.2023.pdf?ysclid=ln7cjslgp6691572040

The need to attract significant financial resources for the reconstruction (construction) of the production and technical base of transport enterprises restrains the growth of the number of CNG-fuelled vehicles in the fleet.

Calculations have shown that taking into account the above circumstances, *the cost of owning a CNG vehicle, taking into account the full life cycle of a CNG vehicle and refuelling infrastructure, will be higher than the cost of owning a petrol or diesel vehicle, i.e. there is currently no economically justified motivation for economic entities and the population to switch to natural gas*.

The cost of owning a natural gas-powered vehicle can be significantly reduced if it is stored on board in liquefied (LNG) rather than compressed form due to the following:

- dimensions, weight of fuel tanks are reduced (during compression the volume of gas is reduced 200–250 times, during liquefaction at a temperature of –161.5 °C — 600 times);
- the range of vehicles increases 2–3 times (CNG — 300–450 km, LNG — 750–1500 km) [7];
- refuelling time will be reduced (the same as for diesel fuel);
- cryo-fuelling stations[6] can be located in all regions of Russia without being tied to a gas pipe, using cryo-fuelling trucks;
- there is a technological possibility of regasification of LNG into CNG when refuelling vehicles;
- the risks of fire and explosion hazards of vehicles and infrastructure are significantly reduced, as the pressure in cryogenic cylinders and tanks is an order of magnitude lower than in CNG cylinders; the relevant requirements for the location of refuelling stations and PTBs of transport companies are relaxed and the investment attractiveness of the construction of these facilities is increased.

Of course, there are new problems that need to be solved. These include: the lack of serial production of domestic LNG-powered vehicle designs; small number of cryo-fuelling stations (13 units); high cost of cryogenic equipment; lack of benefits and preferences for manufacturers and consumers of cryogenic equipment; lack of state regulation of LNG prices [7].

Meanwhile, the development of domestic designs of vehicles with internal combustion engines on CNG and especially on LNG, refuelling infrastructure allows directing the available technological reserves to the creation of designs of vehicles on hydrogen fuel cells with hydrogen storage on board in compressed or liquefied form, which can ensure high competitiveness of domestic automotive equipment.

ELECTRIC TRACTION DRIVE

It is fundamentally easier to develop, manufacture and maintain a car with traction batteries than a car with an internal combustion engine that meets modern and prospective environmental requirements. For creation and production of electric cars, there is no need for the corresponding technological reserves available at the firms-manufacturers of vehicles with internal combustion engines. In addition, all global car manufacturers are implementing corporate strategies to decarbonise their products, gradually abandoning the production of internal combustion engine vehicles.

As a result, the size of the global fleet of electric vehicles (Battery Electric Vehicle — BEV[7]) and plug-in hybrids (Plug-in Hybrid Electric Vehicle — PHEV[8]) is growing very rapidly. The leader in the production of light electric vehicles and hybrids are automakers from China, which by the end of 2022 should reach 7 million units of such vehicles. These are modern designs of vehicles with battery electric traction drive. According to the Ministry of Industry and Trade of Russia, large-scale assembly of some models is organised in autumn 2022 in Lipetsk Region (Motorinvest plant) and in Moscow. Table 2 shows the technical characteristics of electric passenger cars produced in Lipetsk Region.

Since 2018, competitive electric city buses have been mass-produced in Russia by KAMAZ, PJSC, GAZ, PJSC, and Volgabus, LLC (300 units per year).

At present in Russia the process of electromobilisation of road transport is in the initial phase, as according to the data of the Analytical Agency “Avtostat”, the number of electric vehicles in the fleet is a hundredth of a percent of the total number of vehicles in the fleet (about 20 thousand units).

The key organisational, technological and economic problems that hinder the development of the electric vehicle fleet with traction batteries and refuelling infrastructure are related to:

- absence of a long-term state strategy for the development of the electric vehicle industry and the electric vehicle fleet, as well as a comprehensive state

[6] Cryo-fuelling station — a filling station that runs on NGV fuels, including liquefied natural gas, compressed gas and hydrogen.
[7] Electric vehicle — an all-electric vehicle powered by an electric motor using energy from a battery installed in the vehicle.
[8] Hybrid electric vehicle (internal combustion engine + electric motor) with a high-capacity battery — the main energy source. The internal combustion engine is predominantly used to charge the battery or serves as a backup in case the battery is completely discharged. A key difference between a PHEV and a standard hybrid vehicle is the presence of an additional battery in the initial version of such a vehicle.

Table 2

Technical specifications of Evolute electric passenger cars (manufacturers' data)

Model in the Russian Federation	Model in China	Electric engine power, kW	Battery capacity, kWh	Drive range, km	Acceleration to 100 km/h, sec	Price, mln rubles
Sedan Evolute i-Pro	Dongfeng Aeolus E 70 (Nissan Bluebird Sylphy G11 2005 model year)	110	53	420	9.5	2.99
Crossover Evolute i-Joy	Dongfeng Fengon E 3	129.4	53	405	No data	3.49
Crossover Voyah Free	Dongfeng Voyah Free	179.4 + 179.4	106	600	4.7	7.99

support system for the market of electric vehicles and plug-in hybrids;
- limited range of electric vehicles and hybrids offered on the market, insufficient development of charging infrastructure, and lack of service infrastructure;
- the need to improve the design and serial production of domestic electric cars and hybrids (increasing the range, reliability, energy efficiency, comfort and safety); lack of a testing base for certification and refinement work when designing cars with a low carbon footprint;
- lack of serial production of domestic lithium-ion battery cell designs with the required specific energy and in sufficient volume based on the most advanced cathode materials (NMC and LFP) with differentiation depending on specific applications;
- lack of efficient technologies and infrastructure for utilisation of electric vehicles and their components (batteries);
- imperfect legislation in the sphere of utilisation/sale of accumulated electric power by batteries; lack of infrastructure for secondary use of batteries for accumulation of electric power from RES;
- high cost of electric cars and hybrids, which requires introduction of state support measures for consumers, vehicle manufacturers and fuelling equipment.

It should also be taken into account that the intensive increase in the number of electric vehicles and plug-in hybrids in the car fleet in certain regions may cause a shortage of generating capacity in the energy sector in the medium term.

HYDROGEN TECHNOLOGIES

Electric vehicles using traction batteries are unsuitable for long distances and harsh weather and climate conditions. Electric vehicles using hydrogen fuel cells and the excess heat they generate, which can be used for heating the interior, solve these problems.

Based on the analysis of the current world experience, we can first of all talk about conversion to hydrogen fuel (for use in fuel cells) of heavy intracity transport (buses, intracity freight transport, special transport). This is due to:
- absence of the need to create a wide network of fuelling stations due to the localised nature of the application;
- difficulty of using battery electric transport due to the need to combine high capacity, high power and fast charging of batteries;
- possibility of targeted financial incentives.

The key problems of decarbonisation of transport using hydrogen technologies are related to the lack of a technological backlog of fuel cell electric vehicle designs, as well as stationary and mobile refuelling complexes, infrastructure for maintenance and repair of such vehicles.

Only prototypes of hydrogen fuel cell power units, as well as electrolysers for the production of "green" hydrogen and units for the production of hydrogen from natural gas have been manufactured in Russia. Prototypes of hydrogen vehicles were presented at the Comtrans-2021 exhibition: large class buses — KamAZ-6290, CITYMAX Hydrogen (85 passengers) and small class buses — GAZelle City (22 passengers); Aurus Senat passenger car (NAMI); KAMAZ road train with GVW of 44 tonnes (6 × 2 configuration) powered by hydrogen fuel cells, which develops 570 hp and has a range of 500 km [7].

Meanwhile, the use of hydrogen fuel cells in vehicles reveals a number of relatively new technical challenges related to the safety of on-board storage, refuelling tanks that need to be addressed. The sources of potential risks of fires and explosions on board the vehicle and infrastructure facilities are [8]:
- maximum hydrogen cylinder pressure can reach 87.5 MPa when refuelling in on-board vehicle hydrogen storage systems;
- the diffusion coefficient of hydrogen in air is several times greater than the diffusion coefficient of methane, propane. This means that when hydro-

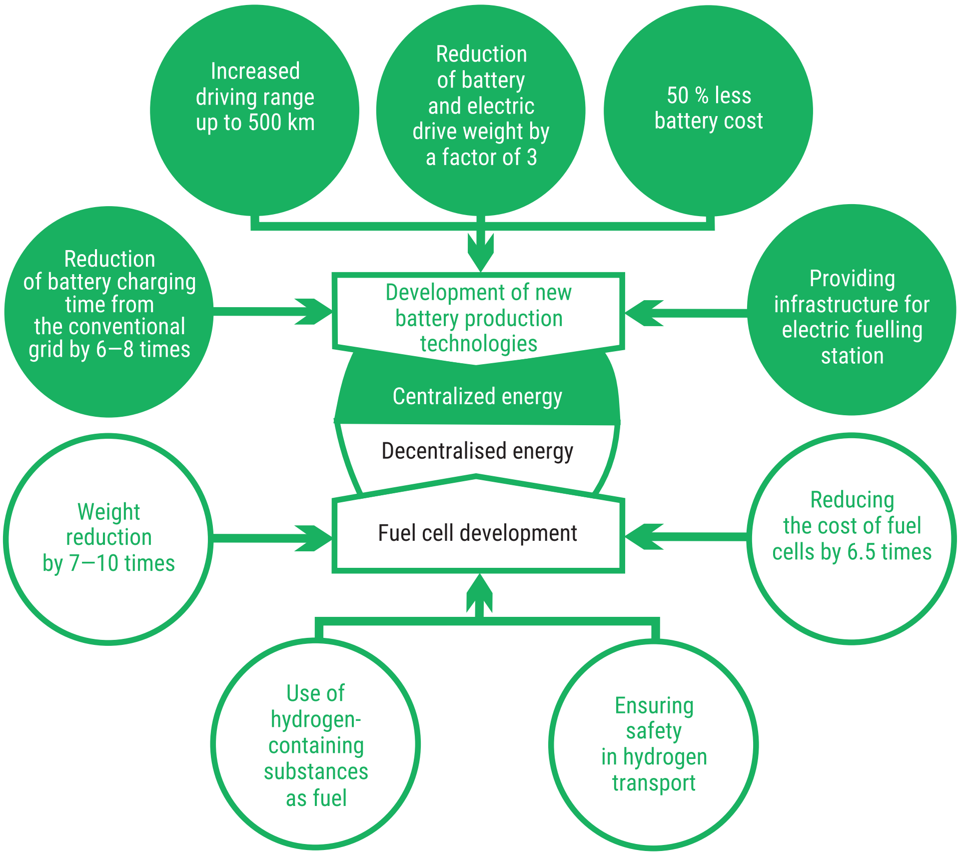

Fig. Requirements for achieving competitiveness of electric vehicles with traction batteries, hydrogen fuel cells compared to petroleum-fuelled vehicles (source "Institute of Petroleum Refining and Petrochemistry" of the Russian Academy of Science, MADI, 2021)

gen leaks into the environment, hydrogen is able to mix and form an explosive mixture with air faster than methane or propane. This is true if hydrogen escapes into an enclosed or top-restricted space such as a garage, tunnel or car park under a domed canopy;

- metals and alloys become more brittle in interaction with hydrogen[9].

Problems of safety, environmental efficiency on the way of decarbonisation may arise not only with storage, transportation, as well as distribution, consumption of hydrogen in electrochemical generators of motor vehicles, but also with the production of "green" hydrogen (from renewable sources). In this case hydrogen becomes a source of renewable electricity storage. And as an energy storage device, hydrogen competes with other types of storage devices, first of all, rechargeable batteries. It is required to solve the complex problem of ensuring the balance of production and consumption of "green" hydrogen in transport, taking into account the seasonal and daily irregularity of electricity production at wind and solar power plants, seasonal irregularity of water resources, as well as to take into account the risks of low-water years. Therefore, the unevenness and low predictability of electricity generation for "green" hydrogen production by water electrolysis at wind and solar power plants will require the creation of a complex system of electricity storage, storage of raw and distilled water, as well as of hydrogen.

A promising direction for obtaining high-purity hydrogen in significant volumes for vehicles is the creation and use of a nuclear energy technology complex — the tandem "high-temperature gas-cooled reactor — methane vapour conversion" [9].

The figure contains a scheme showing the main requirements, fulfilment of which will allow to achieve competitiveness of electric vehicles with traction batteries, hydrogen fuel cells in comparison with petroleum-fuelled vehicles.

[9] As it is known, hydrogen does not form compounds with metals that adversely affect their strength, but at the same time it increases the harmful effect of macro- and microflaws, contributes to a sharp decrease in the plastic properties of the metal and its brittle fracture.

FORECAST OF DECARBONISATION OF MOTOR VEHICLES

Taking into account the implementation of the above measures, the solution of the above problematic issues related to the diversification of energy sources in road transport, new global threats and risks associated with the disruption of established supply chains, insufficient rates of renewal of the fleet of vehicles (moral and physical aging), the need to develop infrastructure for the mass use of electric vehicles, autonomous and connected cars, gas-powered vehicles, which is specified in the Strategy for the Development of the Automotive Industry of the Russian Federation [1].

It has been established that compared to earlier forecast estimates [2, 3, 10], the share of electric cars and hybrids by 2050 will account for 24 % of the number of passenger cars in the car fleet, light commercial vehicles — 12 %, electric trucks and electric buses — 15 % of the total number of these types of vehicles in the car fleet. However, if we assume that in 2045 a political decision will be made to stop access to the Russian market for passenger cars with liquid fuel combustion engines in favour of electric vehicles, then by 2050 the share of electric passenger cars may reach 48.5 % of the total number of passenger car fleet in this year.

As a result, total gross GHG emissions from the Russian car fleet in 2050, the expected number of which will decrease from 59.8 to 51.7 million units compared to 2021, may amount to 126.8 million tonnes of CO_2 equivalent, which is 28.5 % less than in 2021. Compared to earlier forecasts, the value of total GHG emissions from the car fleet in 2050 will lag behind by about 5 years. At the same time, the vehicle fleet in 2050 will be dominated by vehicles with internal combustion engines using hydrocarbon fuels (liquid and gaseous). Only after 2045 the share of sales of electric vehicles of all types may exceed the share of sales of these types of combustion engine vehicles [10].

CONCLUSION

Road transport is the main source of GHG emissions in the transport sector with an unfavourable trend in emissions for the medium term. The most effective in reducing the carbon footprint of motor transport in the medium term is the replacement of traditional motor fuels with natural gas, electric drive on traction batteries and hydrogen fuel cells.

At present, there is no economically justified motivation of economic entities and population to switch to natural gas use, as the cost of owning a CNG vehicle, taking into account the full life cycle of a CNG vehicle and refuelling infrastructure, is higher than the cost of owning a CNG vehicle using petrol or diesel fuel. Motivation may appear when natural gas is stored in liquefied rather than compressed form at the motor vehicles.

The key problems of decarbonisation through the development of the electric vehicle fleet on traction batteries and hydrogen fuel cells are related to the lack of technological backlog of electric vehicle designs, stationary and mobile refuelling complexes, infrastructure for servicing and repair of such vehicles.

The basic requirements are formulated, fulfilment of which will allow to achieve competitiveness of electric vehicles with traction batteries and hydrogen fuel cells in comparison with oil-fuelled vehicles.

It has been established that the total gross GHG emissions by the Russian automobile fleet in 2050, the expected number of which will decrease from 59.8 to 51.7 million units compared to 2021, may amount to 126.8 million tonnes of CO_2 equivalent, which is 28.5 % less than in 2021. Compared to earlier forecasts, the value of total GHG emissions by the automobile fleet in 2050 will lag behind by about 5 years. At the same time, the vehicle fleet in 2050 will be dominated by vehicles with internal combustion engines using hydrocarbon fuels (liquid and gaseous). Only after 2045 the share of sales of electric vehicles of all types may exceed the share of sales of these types of combustion engine vehicles.

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