

# PROSPECTS FOR THE USE OF ALTERNATIVE FUELS AND ENERGY BY ROAD TRANSPORT IN RUSSIA

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## ABSTRACT

Road transport is one of the main consumers of petroleum products and sources of air pollution. In the conditions of Russia's fast-growing vehicle fleet, it is necessary to develop and implement effective measures to reduce the consumption of scarce oil fuels and stimulate the use of alternative eco-friendly fuels. The aim of this work is to assess the prospects for the use of alternative fuels and energy by cars in Russia. This paper outlines the main ways of reducing the gasoline and diesel fuel consumption by road transport, including the use of the motor fuel alternative types. As the most promising direction of alternative energy development in the road transport sector regarding Russia's conditions, a transition to gas-cylinder fuel is proposed. This study presents the main problems of road transport gasification and the ways to solve them. The effective actions in the selected fields will reduce the consumption of scarce fuel and energy resources and enable improvement of the environmental situation in megalopolises.

*Keywords: alternative fuels and energy, motor transport, liquefied petroleum gas, compressed natural gas, liquefied natural gas, traditional motor fuel, transport gasification.*

## 1 INTRODUCTION

At the present stage of society development, in the conditions of industrial production volumes and the world's vehicle-amount growth, the depletion of fossil fuels is proceeding at high rates. The burning of traditional motor fuel by cars causes significant damage to the environment [1]–[3]. The reduction of consumption of scarce fuels of petroleum origin by road transport is one of the priority problems of society's sustainable development.

Considerable attention is paid to research on the possibility of improving environmental sustainability and the energy efficiency of vehicles [4]–[8].

Liquefied petroleum gas (LPG) [9]–[12], compressed natural gas (CNG) [4], [6]–[10], [13]–[17] and liquefied natural gas (LNG) [2], [11], [12] are environmentally friendly alternatives to traditional liquid motor fuels, and it is advisable to expand their use.

Meanwhile, there is currently no systematic approach to reducing the consumption of traditional motor fuels by expanding the use of alternative fuels by the fleet. This leads to the irrational over-consumption of petroleum origin fuels, inhibits the development of the alternative motor fuel market, and worsens the environmental situation.

Thus, it is necessary to develop and implement mechanisms for the optimal use of oil origin fuels, to stimulate the development of alternative motor fuels in order to create sustainable, ecologically balanced economic development that takes into account the interests of the future generations.

## 2 THE THREAT OF THE FUEL AND ENERGY RESOURCES CONSUMPTION GROWTH

The modern level of civilization development is characterized by a rapid growth of the Earth's population (Table 1) and its ever growing need for exhaustible fuel and energy resources. An extensive scenario for the world energy development leads to the aggravation of the socio-economic and environmental problems, which requires the effective actions to shift to rational energy consumption.



Table 1: The Earth's population dynamics, mln. people\*.

Region	1950	1970	1990	2010	2015	2030	2050	2100
<b>World including:</b>	<b>2,525</b>	<b>3,682</b>	<b>5,310</b>	<b>6,930</b>	<b>7,349</b>	<b>8,501</b>	<b>9,725</b>	<b>11,213</b>
Africa	229	366	632	1,044	1,186	1,679	2,478	4,387
Asia	1,394	2,120	3,202	4,170	4,393	4,923	5,267	4,889
Europe	549	657	721	735	738	734	707	646
L. America	169	288	447	600	634	721	784	721
North America	172	231	281	344	358	396	433	500
Australia, etc.	13	20	27	36	39	47	57	71

\*Based on the data from the United Nations [18], [19].

In 2017, the primary energy consumption in the world was 13.5 billion TOE. The main energy resources consumers are China – 3.1 billion TOE (23.2% of total energy consumption), the USA – 2.2 billion TOE (16.5%), and India – 0.75 billion TOE (5.5%). Russia occupies the fourth place, consuming 698.3 million TOE of the primary energy, which is equal to 5.2% of the total global consumption [20], [21].

Over the past 50 years, the primary energy consumption has increased by 3.7 times (Fig. 1). High rates of growth in fuel and energy resources consumption require the adoption of effective solutions in the field of their rational use and alternative energy development.

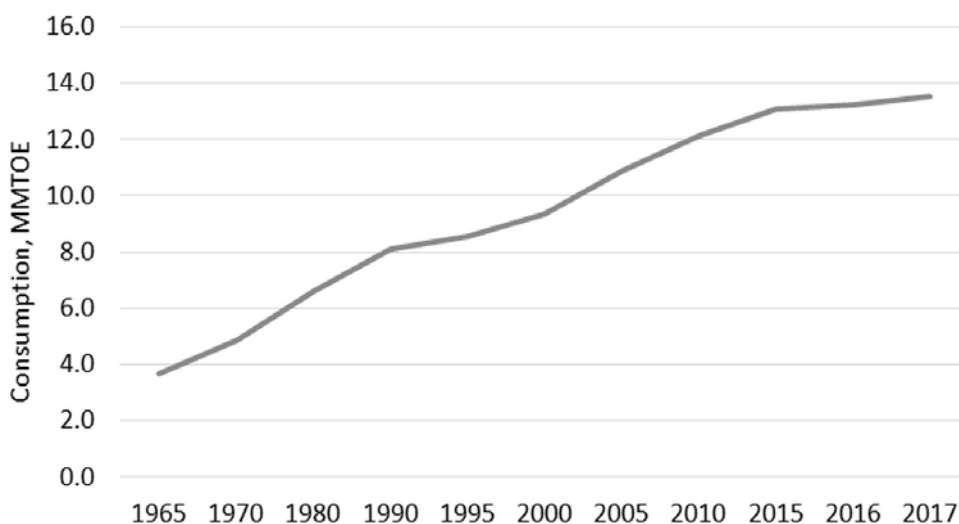


Figure 1: World primary energy consumption dynamics (based on data from BP [20], [21]).

### 3 THE ROLE OF THE ROAD TRANSPORT IN THE REDUCTION OF FUEL AND ENERGY RESOURCES CONSUMPTION

During the last 100 years, oil has been playing a central role in the world balance of energy consumption. In 2017, the share of oil in the total energy consumption was 34.2%, coal – 27.6%, natural gas – 23.4%, while the total contribution of nuclear energy, hydropower and renewable energy sources was only 14.8% (Table 2) [20], [21].

Table 2: Energy resources consumption in 2017, MMTOE.

Region	Energy resources						Total consumption
	Oil	Natural gas	Coal	Nuclear energy	Hydro-power	Renewable energy	
China	608	207	1,893	56	262	107	<b>3,132</b>
USA	913	636	332	192	67	95	<b>2,235</b>
India	222	47	424	8	31	22	<b>754</b>
RF	153	365	92	46	41	0.3	<b>698</b>
<b>World total</b>	<b>4,622</b>	<b>3,156</b>	<b>3,731</b>	<b>596</b>	<b>919</b>	<b>487</b>	<b>13,511</b>

The main consumers of petroleum are transport, industry, energy production, and other sectors. Within that, the priority role is taken by transport (Fig. 2). The main role of transport in oil consumption in the long term is confirmed by the medium- and long-term forecasts made by the BP and the International Energy Agency (IEA).

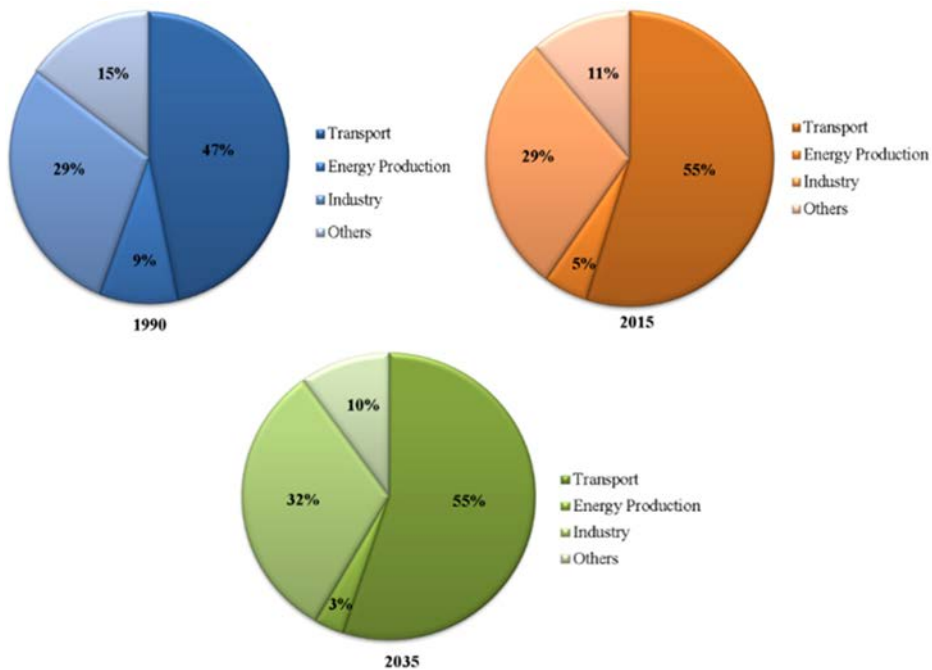


Figure 2: Oil consumption by sectors (based on data from BP [21], [22]).

The fuel combustion by transport causes significant damage to the environment, both from pollution by toxic substances and from CO<sub>2</sub> emissions [6], [7].

Carbon dioxide is the main component of technogenic emissions entering the atmosphere when burning organic fuels, thus being an indicator of the scarce hydrocarbon fuels consumption and the level of civilization development as a whole. The increase of CO<sub>2</sub> emission contributes to global warming and indicates the depletion of fuel and energy resources.

In the structure of CO<sub>2</sub> emission from the transport sector, the main contribution is made by cars, light trucks, and passenger cars weighing up to 3.5 tons (43.3%), as well as by cargo vehicles (22.2%) (Fig. 3).

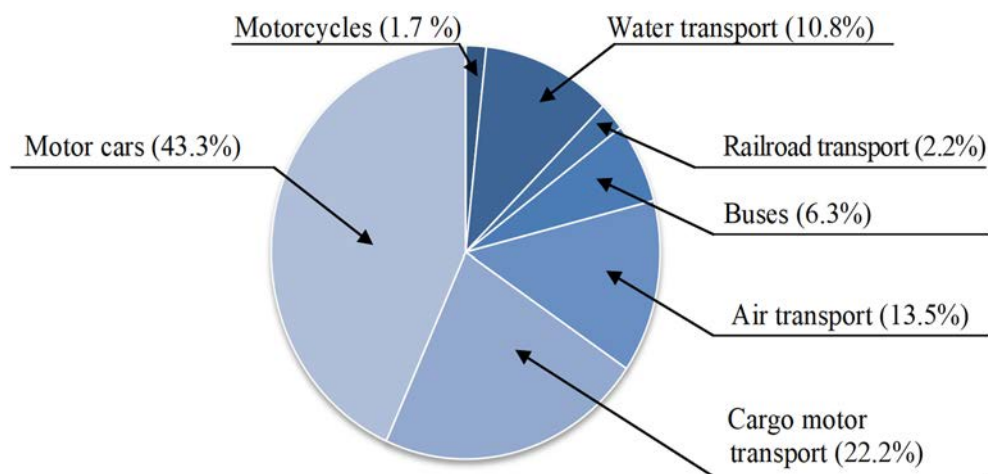


Figure 3: The structure of the world CO<sub>2</sub> emission from the vehicle sector of the economy (based on data from BP [20], [21]).

The data in Table 3 show more than a twofold increase in the number of cars in the country during the period of 2000–2017, which was mainly due to passenger cars. Thus, the search for ways to reduce the traditional motor fuels consumption and, accordingly, CO<sub>2</sub> emission by cars, is a priority task, the solution to which requires urgent action considering the current high rate of the population motorization [7], [23].

Table 3: The dynamics of the amount of cars in Russia [24], [25].

№	Name	Years					
		2000	2005	2010	2012	2015	2017
<b>1</b>	<b>Amount of vehicles, thousands, including:</b>	<b>25,394</b>	<b>31,210</b>	<b>40,662</b>	<b>45,471</b>	<b>51,290</b>	<b>50,600</b>
1.1	Passenger cars	20,353	25,570	34,354	38,792	44,200	46,500
1.2	Trucks	4,401	4,848	5,414	5,751	6,200	3,700
1.3	Buses	640	792	894	928	890	400

#### 4 THE WAYS OF REDUCING THE PETROLEUM FUELS CONSUMPTION BY ROAD TRANSPORT

The conducted research allowed us to offer two main ways to reduce the deficit petroleum-derived fuel consumption by vehicles: 1) the increase of the fuel economy of cars with gasoline and diesel engines and 2) the use of alternative fuel and energy (Fig. 4) [23], [26], [27].



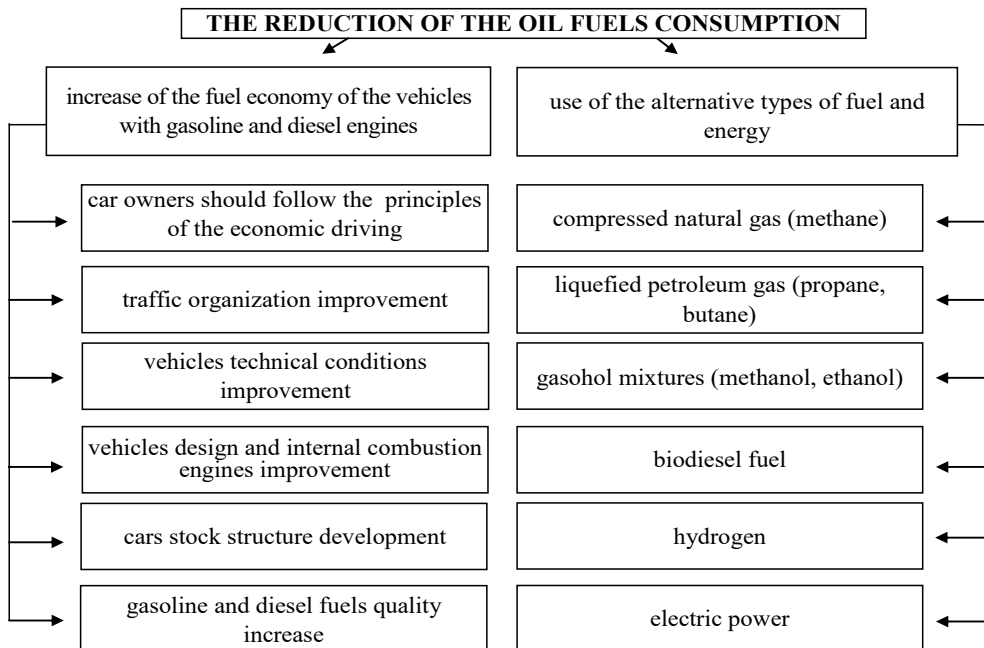


Figure 4: The main ways to reduce petroleum fuels consumption by road transport.

It should be noted that for Russia in the short and medium term, the emphasis should be placed on the quality improvement of traditional motor fuels as one of the most effective ways of increasing vehicle fuel efficiency. One of the possible ways to solve this problem is the effective use of the economic incentive mechanisms of oil products producers, aimed at the improvement of the produced gasoline and diesel fuel environmental characteristics [23], [26]–[29].

The second direction of reducing petroleum fuel consumption by vehicles is the transition to the alternative fuels and energy. It should be underlined that the development of alternative energy in Russia is hampered by a number of objective factors. Russia is rich in traditional fuel and energy resources; as a consequence, the development of alternative energy was not at the forefront.

The raw orientation of the Russian economy extensively exploits traditional energy and hinders the development of alternatives, which requires significant financial resources. The high monopolization of the energy market by the vertically integrated companies is also a serious deterrent to the development of alternative energy in Russia. One cannot ignore the other problems of introducing each type of alternative energy in Russia: financial, geographic (especially climatic), technical, etc.

The change of energy carriers is a painful and long historical period, in which the changes in production technologies are reflected. Meanwhile, the most developed countries at the present stage actively introduce the latest developments in the field of alternative energy. Accordingly, to get the positive results in the matters of alternative energy in the long term, it is necessary to act today.

Despite the obstacles hampering the development of alternative energy in Russia, there are indisputable prerequisites for an increase in the amount of vehicles using gas-cylinder fuel and other alternative types of motor fuel in the country's total automobile fleet.

The main share of the fuel consumption by the Russian vehicle fleet belongs to gasoline, while this country ranks second in the world (after Iran with their reserves of 34 trillion m<sup>3</sup>) in the field of the prospected proven reserves of natural gas (Table 4) [30], that creates a huge potential for the transition to a highly environmentally friendly gas-cylinder fuel.

Table 4: Characteristics of the natural gas proven reserves and production at the beginning of 2017 (based on data from BP [20], [21]).

Region	Gas resources, trillion m <sup>3</sup>	The share in the world resources, %
North America	10.8	5.6
Latin America	8.2	4.2
Europe and Eurasia, including:	62.2	32.1
<b>Russian Federation</b>	<b>35.0</b>	<b>18.1</b>
The Near and Middle East	79.1	40.9
Australia and the rest of Asia	19.3	10.0
Africa	13.8	7.1
<b>World, total</b>	<b>193.5</b>	<b>100.0</b>

As for the electric vehicles and hybrid electric vehicles [31], they are not so relevant for Russia, primarily due to the climatic conditions: the harsh climate in most parts of the country significantly limits their mass use. Also, today, the Russian consumer is not ready to significantly overpay for a car with an environmental performance improvement. The same applies to the vehicles running on biofuel [32]. Under conditions of the large natural gas reserves in Russia, the development of road transport consumption of the other types of alternative energy is only possible in the long term.

## 5 THE MAIN PROBLEMS OF THE ALTERNATIVE TYPES OF MOTOR FUEL MARKET DEVELOPMENT AND THEIR SOLUTION

The main alternative to the petroleum-derived fuels used by Russian transport in the medium term is compressed natural gas (methane) and liquefied petroleum gas (propane-butane mixture) [9], [13]–[17].

Methane is a compressed natural gas supplied to the specialized automobile gas-filling compressor stations (AGSCS) via pipelines. Propane-butane mixture is obtained from oil and condensed petroleum gases. Considering the fact that, firstly, the widespread use of propane-butane as an automotive fuel does not completely abolish dependence on oil; and secondly, our country ranks second in the world in proven prospected reserves of natural gas (Table 4), the use of compressed natural gas is the main alternative to traditional motor fuels.



Despite the fact that Russia ranks second in the world in proven prospected reserves of the natural gas (Table 4), today it is necessary to solve a number of problems for the widespread introduction of the compressed natural gas as a motor fuel. The main ambitions of the Government in the issue of transport large-scale gasification are registered in the Russian Government decree of May 13th, 2013, № 767-r [33], according to which a set of measures should be developed and submitted so that by 2020 in the subjects of the Russian Federation, the level of natural gas use as a motor fuel by public transport and by municipal services transport would reach 50% of the total number of the equipment units (in the cities with a population of more than 1,000,000 people). However, today it is difficult to distinguish the active measures that should be performed by the Government and all the motor fuel market participants to achieve these parameters.

The conducted researches have allowed to reveal the basic problems on a way of the road transport mass gasification in Russia, and also to offer their possible solutions (Figs 5 and 6).

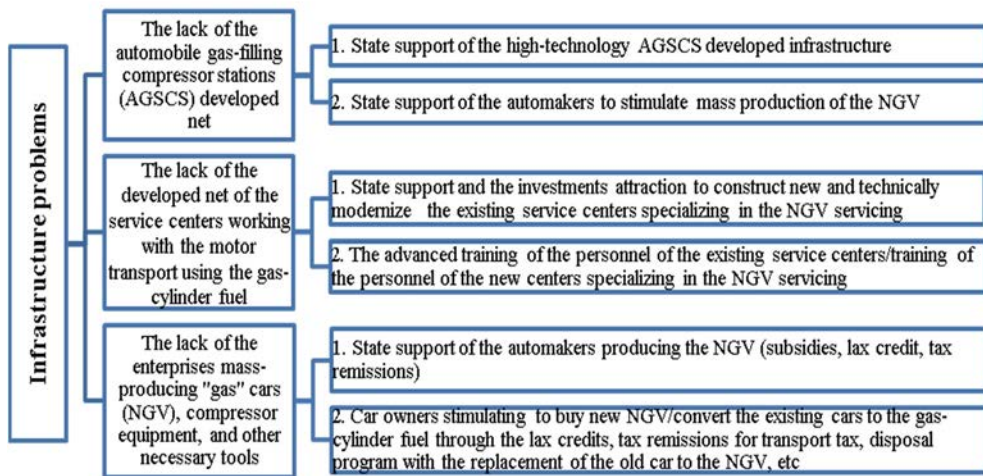


Figure 5: Infrastructure problems of the motor vehicles mass gasification in Russia and ways to solve them.

To date, the infrastructure problems are the major for the mass gasification of transport (Fig. 5). There is not a sufficient number of automobile gas-filling compressor stations (AGSCS) for the large-scale gasification of the car stock. This problem resembles a vicious circle: on the one hand, the development of the gas engine fuel market is hampered by the poorly developed infrastructure, and on the other hand, the infrastructure is absent due to the shortage of natural gas vehicles.

The large-scale gasification of vehicles is a complicated task, requiring a system approach to solve it. In addition to the basic infrastructure problems of this issue, the studies carried out have revealed a number of additional directions for solving the problems of vehicle gasification (Fig. 6).

It is important to note that the transfer of public transport (city buses, fixed-route taxis) to gas, subject to all safety requirements, will lead to a much greater environmental and economic effect than the transfer of the personal vehicles, due to the higher energy efficiency of the trip per passenger.

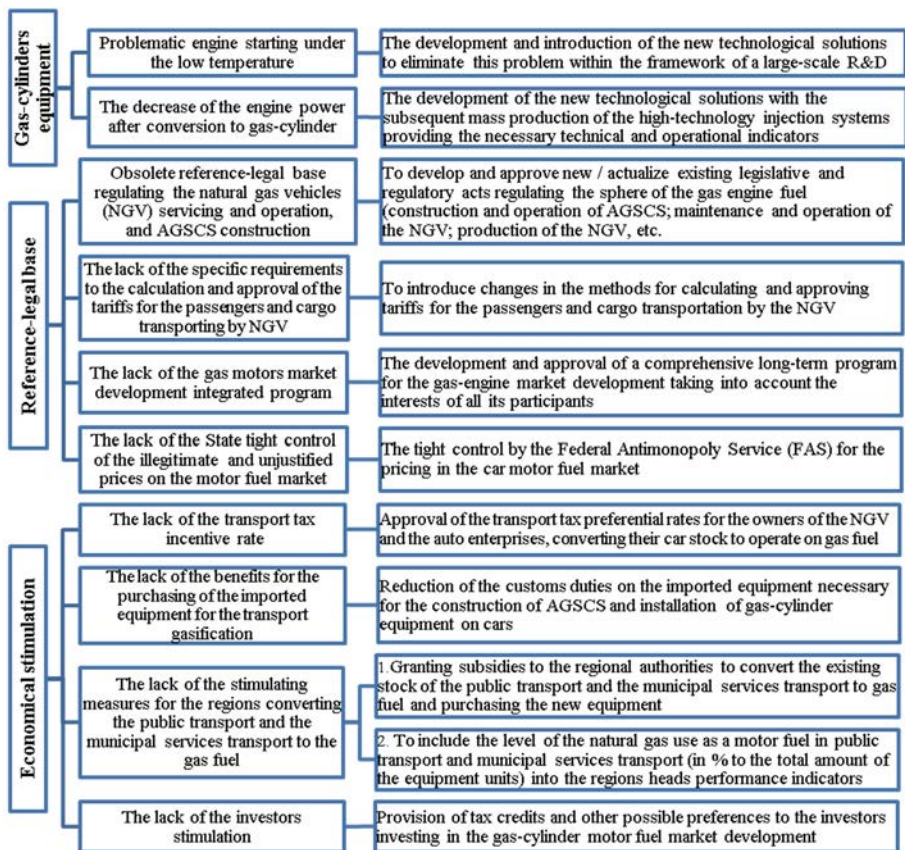


Figure 6: The complex of the additional problems of the vehicles mass gasification in Russia and their solution.

To implement the “modal shift”, it is necessary to stimulate the population to abandon a personal car in favour of public transport. To solve this problem, a well-developed infrastructure of public transport is needed, employing the increase in the traffic frequency and the number of vehicles, the increase in the routes number, the improvement of the transport comfort, and its speed increase.

The consumption of gas fuel, taking into account the significant disposable reserves of the natural gas, the potential of the associated petroleum gas processing, and the complex environmental situation in Russia, should increase. The development of the gas-cylinder fuel market in the country is possible only with substantial state support. The significant dependence of vehicle gasification level on State support is evidenced by the accumulated experience of the countries actively developing in this direction.

Considering the high complexity of solving the problem of the significant share of replacing traditional non-renewable energy resources with new sources of energy in the motor transport sector of Russia, it is necessary to integrate the efforts of all the participants in this matter: the scientists, the government, the society, the automakers, and the fuel producers to resolve it.



## 6 CONCLUSION

In Russia, under the existing conditions of the country's high rate of vehicle-amount growth and the reduction of oil reserves, it is necessary to implement a set of measures to improve the fuel efficiency of vehicles with gasoline and diesel engines, as well as to develop alternative motor fuels. Taking into account the high level of natural gas reserves in the Russian Federation, there is a huge potential for switching to the highly ecological gas-cylinder fuel. An integrated solution of the main problems of vehicle gasification by the selected directions will allow a reduction of scarce fuel and energy resources consumption, reducing air pollution and improving the ecological situation in the country.

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