Energy Consumption of the Russian Road Transportation Sector: Prospects for Inter-Fuel Competition in Terms of Technological Innovation

Dmitriy Grushevenko

Research Fellow [a]; and Leading Expert [b], grushevenkod@gmail.com

Ekaterina Grushevenko

Research Fellow [a]; and Expert [c], e.grushevenko@gmail.com

Vyacheslav Kulagin

Head of Division [a]; and Director [b], vakulagin@hse.ru

[a] Energy Research Institute of the Russian Academy of Sciences (ERI RAS), 31, bldg 2, Nagornaya str., Moscow 117186, Russian Federation

[b] Centre for Energy Studies, Institute of Pricing and Regulation of Natural Monopolies at the National Research University Higher School of Economics (HSE IPCREM), 7 Vavilova str., Moscow, 117312, Russian Federation

[c] Energy Centre, 100, Novaya str., Skolkovo village, Odintsovsky District, Moscow Region, 143025, Russian Federation

Abstract

The development of production and consumption technologies for the road transport has led to large scale introduction of alternative energy in this sector. These alternatives to the conventional petroleum fuels include biofuels, electricity, natural gas and synthetic fuels produced from coal and natural gas. However, it is very important to point out, that inter-fuel competition is determined not only by the development of technologies, but also by such parameters as availability, fuel cost, consumer preferences and government legislations, all of which vary greatly across the globe. In other words, the very same technologies can be capable of radically altering the fuel mix in some countries while having little to none impact in the others. The topic of the inter-fuel competition development in the transportation sector holds much importance for Russia, as the country's fuels mix is almost totally dominated by the petroleum products. The diversification of energy sources for transport may positively influence energy security and domestic fuels market stability; reduce the strain on ecology, especially in major cities; all the while increasing Russian oil and petroleum products export potential.

The article presents results of the research for prospects of the developments in Russian transport sector fuel mix. The research was carried out using the tools of economic and mathematical modeling under various scenario assumptions. The analysis has shown that natural gas and, to a lesser extent, electricity hold the best prospects as petroleum products substitutes in the long-term. Their cumulative share in the total energy consumption of the road transport sector has the potential of reaching as high as 26% by 2040. Yet, the extent of substitution largely depends on the government actions for infrastructure development and tax incentives for alternative vehicle owners.

Keywords: inter-fuel competition; road transportation; technological innovations; alternative fuels; energy consumption; scenario planning

Citation: Grushevenko D., Grushevenko E., Kulagin V. (2018) Energy Consumption of the Russian Road Transportation Sector: Prospects for Inter-Fuel Competition in Terms of Technological Innovation. *Foresight and STI Governance*, vol. 12, no 4, pp. 35–44. DOI: 10.17323/2500-2597.2018.4.35.44

Diversification of the road transport sector's fuel mix is a new global trend. In 1990-2013 the share of petroleum products (which historically dominated in the sector) has decreased, for the whole world, from 99 to 95% [IEA, 2014], despite the significant growth of the total energy consumption in the sector. This is due to growing demand for electricity, natural gas, biofuel, and synthetic motor fuels derived from natural gas and coal. And the sector's interest in new energy types is growing all the time, among consumers and vehicle manufacturers alike.

It should be noted that this diversification is characteristic not just for the developed countries which have traditionally been major oil and petroleum product importers (for them it's mainly prompted by the desire to reduce imports of these energy resources), but also for major oil producers. E.g. in Iran, natural gas accounted for 14% of the total energy consumption in the road transport sector already in 2013, while in Brazil biofuels and natural gas combined share of the sector's total energy consumption amounted to about 19% [IEA, 2014].

To oil exporters, diversification of the fuel mix provides an opportunity to increase exports of petroleum fuels. Also, for all countries it serves as an environmental policy tool – since all alternative transportation modes allow to significantly reduce vehicles' direct emissions (not counting the emissions made during production of energy resources).

So far, in terms of diversification of the road transport sector's fuel mix Russia lags behind most of the other countries: petroleum products amount to 99% of the sector's energy balance, while consumption of gas motor fuel and electricity remains negligible (at 1.4 million tonnes of oil equivalent). At the same time the sector's demand for petroleum products amounts to up to 90% of total domestic consumption [IEA 2014]. Despite the road transport sector's importance to the national economy (along with that of demand for oil as such), the number of studies forecasting the sector's fuel mix prospects remains rather small. Some works [e.g. *Bobylev et al.,* 2006; *Braginskiy,* 2012; *Milovidov et al.,* 2006] do describe certain methodological approaches to forecasting demand, but they cannot be considered as detailed, integrated studies of future energy demand in the road transport sector. The authors of this paper have developed a unique tool for forecasting demand for motor fuel, which helps to study potential demand prospects in the road transport sector. For detailed description of the forecasting tool's theoretical and methodological basis see [*Mitrova et al.,* 2015; *Grushevenko et al.,* 2015].

The current study has the following objectives: identify key incentives for diversifying the fuel mix; assess the current state of interfuel competition in the Russian road transport sector; using the state-of-the-art economic and mathematical modelling tool, determine whether Russia has a potential of large-scale switching to alternative energy resources in the road transport sector; assess the potential for growth of demand for energy in the sector, and the prospects for meeting it.

The structure of energy demand in the transport sector: incentives for diversification

In 2015 energy consumption in the Russian transport sector amounted to about 65 million tonnes of oil equivalent; 99% of that were petroleum fuels (liquefied hydrocarbon gases, gasoline, and diesel); the share of gasoline amounted to 60% [IEA, 2014]. The remaining one percent came in the form of natural gas, in condensed (compressed) form.

At first glance this structure of energy consumption in the road transport sector of one of the world's largest exporters and producers of oil appears quite natural, especially considering that domestic retail prices of petroleum products are practically twice lower than in Europe. However, there are several reasons to believe this structure is not optimal for the country

The first one is that Russia regularly experiences problems with supplying the domestic market with high-quality high-octane petrol (which dominates the energy demand from personal road transport). Particularly acute shortages were experienced in 2011, when the Omsk Refinery and the Angarsk Petrochemical Works had to conduct unplanned repair and maintenance; in 2012, after the accident at the Moscow Refinery; and in 2014, when the accident at the Achinsk Refinery coincided with the delayed completion of maintenance work at the Yaroslavl Refinery.

The reason such crises keep occurring is quite simple: lack of petrol refining capacities. E.g. as of 2016, combined maximum technological capacity of all Russian refineries to produce high-octane Euro-5 standard petrol (and usage of fuel types with lower environmental standards is banned in Russia since July, 2016), with full utilisation of all secondary production processes (i.e. no downtime, no repair or maintenance during the year) amounts to about 40 million tons per year. Meanwhile the demand has already reached 39 million tons (for more about Russian refineries' production capacities, their current state, and development prospects see [*Kapustin, Grushevenko,* 2016; *Kapustin, Grushevenko,* 2018]).

If demand for petrol keeps growing (as it does, even despite the difficult economic situation in the country), extension and modernisation of required production capacities and supporting infrastructure of the oil refinery sector will require significant investments: about $20 billion [*Kapustin, Grushevenko,* 2018] in the next 5-10 years, which is comparable with investments in, e.g., building gas filling infrastructure (investments required to convert Russian petrol stations for use of gas fuel are estimated at $12.6-31.5 billion [Promexpertisa, 2016]). It's also important to keep in mind that Russian refineries are quite strongly dependent on imported equipment and consumables (e.g. between 50-100% of catalysts applied to produce commercial petrol are imported [*Kulagin et al.,* 2015]). The weak rouble makes these costs heavier, especially combined with reduced oil export revenues. High dependence on imported supplies also negatively affects the country's energy security. Launching domestic production of, e.g., the above-mentioned catalysts would require major investments, but more importantly, it wouldn't be possible to fully substitute imports

even by 2020 [*Kapustin, Grushevenko,* 2018]. Accordingly, a valid question arises: should we invest in oil refining, almost exclusively to meet the growing domestic demand for petrol (and the sole source of these investments would be oil companies), or spread the risks between numerous market players and invest in reducing demand for petrol, among other things by diversifying the fuel mix?

The second reason which raises doubts about the structure of the Russian road transport sector's fuel mix is that several Russian cities with over a million dwellers are facing severe environmental problems, while petroleum products dominating the road transport sector are relatively "dirty" energy resources. E.g. on average, CO_2 emissions from gas-powered cars are 20–25% lower than those of petrol cars of the same class, while emissions of the very toxic nitric oxides are 90% lower compared with diesel cars [*Curran et al.,* 2014]. Switching to electric cars can also significantly reduce emissions of hothouse gases, if we don't take into account the emissions made in the course of electricity generation.

Thirdly, oil and petroleum products are key sources of the Russian Federation's currency revenues; according to the Rosstat, these products' share in the exports' value structure even in the crisis-hit 2015 exceeded 45%[1]. More active use of alternative fuel types by the road transport sector would allow exporting more oil and oil products, which would help to step up the country's export potential following Iran's example.

Note also that there's a huge surplus of already installed gas production capacities in the European part of the country, whose output is only limited by the limited markets. Russia has a significant potential to step up gas production, which could be used to generate electricity, or directly in vehicle engines. This industry's development would also allow to increase exports of oil and petroleum products (which are more expensive). This is particularly relevant in a situation when the niche for domestic consumption and export of gas is limited, while the potential for stepping up production is much higher for gas than oil [*Mitrova,* 2016].

All of the above reasons can be seen as incentives for the government to encourage substitution of petroleum products in the road transport sector with alternative energy sources. However, the extent of such shift would largely depend on consumer preferences, namely how much more attractive the available alternatives would look in terms of costs, convenience, and environmental characteristics.

To assess future prospects for emergence of a new energy mix in the road transport sector, we'll need to analyse various aspects of interfuel competition, taking into account consumer preferences and expected government regulatory measures.

Interfuel competition in the Russian road transport sector

Interfuel competition is becoming increasingly active in the present-day transport sector. Conventional oil-based fuels types (such as petrol, diesel fuel, and to a lesser extent, liquefied hydrocarbon gases (LHG)) compete with alternative energy sources which can be divided into direct and indirect substitutes (for more detailed classification see a study previously published in the *Foresight and STI Governance* journal [*Mitrova et al.,* 2015]):

1. Direct substitutes which do not require motorists to radically modify their car engines, such as:
   - biofuel made from plant materials: bioethanol and biodiesel [*Mussatto,* 2016];
   - coal-to-liquids and gas-to-liquids fuels [*Höök, Aleklett,* 2010; *Glebova,* 2013].
2. Indirect substitutes which do require radical modification of vehicles and consumer infrastructure, such as:
   - electricity to power electric or hybrid cars;
   - fuel cells converting hydrogen energy into electricity [*Sorensen,* 2012].
   - gas motor fuel (GMF) made from natural gas or biomethane.

Certainly not all these alternatives are finding wide application in the world. E.g. due to sufficiently high production costs, synthetic GTL and CTL fuels turned out to be globally noncompetitive in price terms. According to [*Höök, Aleklett,* 2010], production costs of coal- and gas-based liquefied fuels are between $48–75 per barrel, not counting raw materials costs and producers' tax burden. Meanwhile the average international production cost of oil-based fuel is between $5–15 per barrel. This ratio of oil- and non-oil-based fuel production costs is expected to remain in place in the long term.

Technologies for large-scale application of fuel cells in transport vehicles are still seen as an issue for the future. E.g. the hydrogen-powered Toyota Mirai car is sold for $55,000, which is comparable with luxury cars' prices. And according to experts, the company makes not a profit but a loss selling these cars, to the tune of up to $100,000 per vehicle [*Voelcker,* 2014]. For Russia, that kind of price, and lack of fuelling stations infrastructure for the time being make forecasting demand for hydrogen-powered cars irrelevant.

For biofuels, the key limitation is the high cost. According to the Russian legislation[2] biofuel is classified not as an energy source but as ethyl alcohol, and is subject to excise duty at 102 roubles ($1.6.) per litre, while retail price of petroleum-based fuel as of 2016 was at around 40 roubles ($0.6.) per litre – which of course makes biofuel noncompetitive, on the government regulation level.

The positions of electricity as an alternative energy source for the Russian road transport sector are also quite shaky – unlike, e.g., in the European market where, as the authors' calculations show, electricity as

[1] Calculated by the authors using data of Bank of Russia. Access mode: http://www.cbr.ru/statistics/?PrtId=svs, last accessed on 23.12.2017.

[2] Federal law № 171-FZ of 22.11.1995 "On government regulation of production and turnover of ethyl alcohol, alcohol- and spirits-containing products, and limiting consumption (drinking) of alcohol products"

a motor fuel can not only pressure conventional petroleum products, but also limit growth of demand for compressed natural gas (CNG) [*Grushevenko et al.,* 2016]. In Russia, large-capacity public transportation vehicles (trolleybuses and trams) account for almost 100% of all electricity consumption in the road transport sector. It should be noted that according to the RF Ministry of Transport, the number of passengers carried by such vehicles was declining since the early 2000s [AC, 2015]. Many large cities already display a trend to gradually dismantle these types of transportation: e.g. in St. Petersburg the fleet of trolleybuses between 2005 and 2014 decreased by 12%, and the fleet of trams – by 30%. The recent years' decision by the Moscow authorities to reduce the trolleybus fleet in favor of diesel buses leads to the expanding consumption of petroleum products in this segment; however, it is worth noting that in parallel there are significant plans to purchase electric buses. If this trend continues, demand for electricity in the large-capacity road transport segment would be bound to decrease in the mid-term perspective; however, there are grounds for its future growth owing to the extensive use of electro buses.

As to increasing the number of electric cars (which would lead to increased demand for electricity in that segment), there are again several limiting factors affecting the Russian market. E.g. up to 90% of new car sales in Russia take place in the budget segment (up to $13,000) [Autostat, 2016], while the available electric cars (6 models altogether), and even hybrid ones (7 models) belong in the medium and premium segments (with prices starting from $16,000)[3] – so they remain simply unaffordable to the average consumer. Another problem is the extremely low level of the service infrastructure. E.g. only official dealers can service electric and hybrid cars available on the market: other service stations simply do not have the equipment and skilled personnel to repair such vehicles.

Also, Russia almost completely lacks charging infrastructure for electric cars – which significantly reduces their consumer appeal compared with petroleum-powered models, even with the lower fuel costs (on average 3–6 times cheaper than petrol). Given the almost total absence of public charging stations (about 60 altogether in the country), the only choice consumers have is charging their cars at home – which is a very awkward task for residents of large city buildings with no parking facilities (as a rule, apartment buildings in Russia do not have sufficiently powerful energy supply). It should be noted that Rosseti, PLC plans to build 1 thousand electric car charging stations by 2018 [*Voronov et al.,* 2016], but these overly optimistic plans raise doubts: in just two years' time the company would have to build 16 times more charging stations than their current total number (60).

Inadequate government policy to promote electric car purchases is also worthy of note. Relevant initiatives include zero customs duties for importing such vehicles into the EAEU countries until September, 2017 [Interfax, 2016]; free parking in paid parking zones in Moscow, and free issue of parking permits for residents of such areas; and free charging until the end of 2016 [Moscow 24, 2016]. There are also plans to equip petrol stations with electric car charging outlets, starting from 1 November, 2016.[4]

But the key factor limiting wide use of electric cars at the current stage is their high prices: on average an electric car costs 25–50% more than a petrol- or diesel-powered one of a similar class (the world over). The same is also true for the lorry segment (with practically no medium-capacity electric vehicles available at all). E.g. according to out estimates, the average annual cost of owning an electric car in 2016 was twice higher than for internal combustion vehicles. As to Russia, the situation is further aggravated by the very limited range of available electric cars: it's either super-compact vehicles relatively unpopular among Russian consumers, or luxury cars unaffordable to the average buyer.

In terms of combined consumer, operational, and environmental properties, gas-powered cars seem to offer the most attractive alternative in all market segments. In addition to significant savings on fuel (according to our calculations, such cars are 2.5 times cheaper to run than petroleum-powered ones, per 100 km), and a moderate price difference (compared with similar class vehicles in various market segments), using natural gas prolongs the service life of the internal combustion engine, significantly increases the mileage between repairs, and reduces explosion and fire hazards compared with petrol and LPG (gas is lighter than air, and in case of leakage it immediately evaporates, which significantly reduces the risk of fire). Also, natural gas has a much higher self-ignition temperature and a lower explosiveness limit than, e.g., petrol which in case of a leak flows under the car and creates a pool of an explosive mixture with air on the ground.

Also, installing a gas bottle and other necessary equipment doesn't imply total rejection of conventional fuel types. Even mass-produced gas-powered cars have fuel tanks, and can operate using gas and petrol/diesel in turn – which significantly increases their mileage and makes them much more convenient to use. Still, as of 2015 the share of gas motor fuel in Russia was just about 0.5% of the road transport's total energy consumption (or less than 0.4 million tonnes of oil equivalent) [IEA, 2014].

A key reason of this low gasification rate in the sector is inadequate infrastructure. About 280 gas filling stations operate in Russia altogether [NGA, 2016], compared with 24 thousand conventional filling stations. Plus, most of the existing gas stations need upgrading because they were built in the late 1980s – early 1990s. The design capacity of the filling stations exceeds 2 billion m^3 of CNG, but their average utilisation rate is just 20% due to the small number of gas-powered vehicles in the country – just 110 thousand altogether, or about 2% of the total motor vehicle fleet. In effect it's a classic infrastructure paradox: "consumers do not buy cars due to lack of filling stations, and companies do not invest in building filling stations due to low consumer demand" [*Mitrova, Galkina,* 2013].

The second reason of the slow growth of the gas-powered vehicles' fleet is problems with supply of such vehicles. As of 2016, practically no factory-made gas-powered cars and commercial minivans were available

[3] The price of Mitsubishi i-MiEV.

[4] RF Government Regulation № 890 of 27.08.2015 "On amendments to certain RF Government acts regarding use of charging outlets for electric vehicles at filling stations".

Table 1. **Recommended use of CNG-powered vehicles for public transportation in cities**

Population (thousand)	Share of CNG-powered vehicles (%)
1,000+	Up to 50
300+	Up to 30
100+	Up to 10

Source: composed by the authors on the basis of the RF Government Regulation of 13.05.2013 № 767-r "On regulating use of gas motor fuel". Available at: http://www.consultant.ru/document/cons_doc_LAW_146288/, accessed 24.10.2018.

on the market, while the supply of such lorries and buses was very limited. To switch to using natural gas, most consumers have to resort to the relatively expensive custom conversion – which in most cases voids the manufacturer's warranty.

The third reason is uncertain future prospects for CNG prices. After changes were made to the Russian legislation,[5] the price of methane is no longer linked to the price of A-76 petrol (due to absence of A-76 on the market, A-80, and then AI-92 prices were used instead). Currently no official documents regulate the upper limit of CNG prices. Accordingly, owners of gas-powered cars have no guaranties that this fuel will remain attractively priced in the future, while producers already have reservations about the economic advisability of selling gas at gas filling stations – again, due to lack of an official price ceiling.

The government pays significant attention to promoting use of gas motor fuel and dealing with the existing adverse situation (the infrastructural paradox). E.g. the Russian Energy Strategy Until 2030 [Ministry of Energy, 2009], and draft Energy Strategy Until 2035 [AC, 2014] mention increased use of natural gas as motor fuel, and increasing the share of gas-powered vehicles to 7% of the total motor vehicle fleet by 2035 as a promising area of developing the country's energy sector.

To promote growth of the CNG market, the RF Government introduced norms regulating use of this fuel type in cities (table 1). A specialised company called Gazprom Gas Motor Fuel, OJSC was established in 2012, whose mission was to promote integrated development of the gas motor fuel market in the Russian Federation. To this end Gazprom, PLC signs cooperation agreements with regional authorities, according to which the company undertakes to build and launch gas filling infrastructure facilities and organise conversion of vehicles. Regional authorities provide subsidies for creating fleets of gas-powered vehicles for public and municipal use, helping organisations to put in place necessary maintenance facilities, and train staff. As of September, 2016 such agreements were signed with 38 regions. Out of them, 10 were selected for priority development: St. Petersburg and the Leningrad Region, Moscow and the Moscow Region, the Krasnodar, Stavropol, Rostov, and Sverdlovsk Regions, and the Republics of Tatarstan and Bashkortostan. Already in 2016 investments were made to build 35 gas filling stations; until the end of 2018 Gazprom plans to extend the federal network of gas filling stations to 488 [Gazprom, 2016].

To promote use of gas-powered vehicles, Gazprom Gas Motor Fuel, OJSC signed cooperation agreements with numerous Russian and international vehicle manufacturers.

These steps are intended to create "guaranteed demand" for gas motor fuel by municipal motor transport organisations, but they do not promote use of gas-powered vehicles in the private sector: for the latter, the critical factor of switching to an alternative fuel type, in addition to infrastructural limitations, is vehicle conversion costs.

A system of subsidies for converting vehicles to run on CNG should be designed and put in place; import duties for components and parts required to build gas-filling stations, and make methane-powered motor vehicles should be reduced or cancelled altogether. Russian public authorities were recommended to reduce transport tax rates for owners of gas-powered vehicles[6].

Still, even these measures to promote use of gas motor fuel won't be enough to attract private consumers, given the uncertainty regarding future prospects for gas prices, first of all compressed methane.

Analysis of gas-powered vehicles' cost recovery shows that passenger cars (which dominate the private sector) are particularly sensitive to changes of CNG prices – due to low purchase prices, and low mileage. Gas price ceiling (if the average price of petrol/diesel fuel remains at about 40 roubles per litre) is estimated at about 19–20 roubles per m^3; after that using a gas-powered car becomes unprofitable for the whole period of its service life (figure 1).

At the same time it's important to keep in mind that there's also a price floor, and selling gas motor fuel below this level becomes unprofitable for filling station owners. This floor is close to 19 roubles per m^3 too (at this level, the cost recovery period for a Russian gas filling station, given the current rate of wholesale gas prices and with full utilisation, would be about 2.5 years, or roughly the same as for petrol stations).

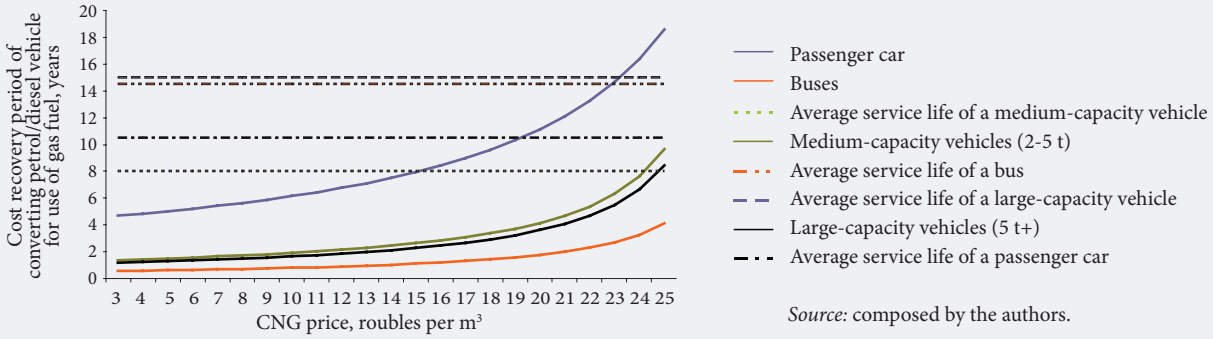
Interestingly, though gas motor fuel prices are not officially linked to prices of petrol products, 19 roubles per litre is just about 50% of the average petrol price. We'll be using this figure as reference in our subsequent calculations, and to outline the prospects for interfuel competition in Russia.

An integrated long-term analysis of interfuel competition also requires taking into account electricity – as another substitute of petroleum products in the road transport sector with good prospects in Russia.

[5] RF Government Regulation of 10.04.2015 № 338 "On invalidation of the RF Government Regulation of 15 January, 1993 №31".

[6] RF Government of 13.05.2013 № 767-r "On regulating use of gas motor fuel".

Figure 1. **Cost recovery period of gas-powered motor vehicles depending on the average CNG price (with the average petrol price of 40 roubles per litre)**



Source: composed by the authors.

The competitiveness estimates, and subsequent calculations are based on the following key characteristics (scenario prerequisites): fuel costs, basic car costs, availability of infrastructure, environmental characteristics. The current values of these parameters for various motor vehicle types are presented in table 2.

Scenario building

Demand for energy in the road transport sector was forecasted using two scenarios: "Basic", and "Promoting alternative fuel types". Both scenarios are based on the same prerequisites and macroeconomic indicators (GDP, population, prices of oil, petroleum products, electricity, and natural gas), but differ in terms of how successful government policies promoting and supporting use of alternative motor fuels in Russia are going to be. The main macro-parameters of the study are presented in table 3.

Both scenarios also share the same vehicle efficiency prerequisites (they assume that efficiency of vehicles powered by liquid and gas fuels would grow by 20-25% in the next 25 years, due to increased efficiency of the internal combustion engine among other things achieved through application of hybrid technologies and use of more advanced body and tyre materials[7]). Efficiency of electric cars during the same period is expected to increase by 5% (only use of better body and tyre materials was taken into account, with the electric motor's efficiency factor remaining unchanged at about 90%).

Also, neither scenario envisages major changes of conditions for interfuel competition between petroleum products, electricity, and natural gas on the one hand, and gas-, coal-, and biomass-based synthetic fuels on the other. In particular, such fuel types are not expected to become competitive with the alternatives in the foreseeable future in terms of production costs. I.e. no large-scale production of such fuel types is expected to be launched, so there will be no supply, and consumers wouldn't have an opportunity to switch to them.

Commercialisation, or large-scale use of fuel cell-powered motor vehicles is not expected either. Individual consumers can certainly buy various concept or prototype cars or luxury vehicles, but this wouldn't significantly affect the transport sector's energy balance during the period until 2040.

Table 2. **Key consumer properties of motor vehicles powered by various alternative fuel types in Russia (2015 data)**

Parameter	Fuel type			
	Petroleum products	Gas motor fuel	Electricity	Biofuels
Fuel costs (*roubles per 100 km*)	300–400	130–160	70–150	800–1000
Price of a motor vehicle powered specific fuel type (*% of the cheapest car in the main consumer class*)	100	120	150–350	100
Availability of infrastructure	24000 petrol stations	250 gas filling stations	40 charging stations*	24000 petrol stations**
CO_2 emissions in the atmosphere (*g/km*)	290–320	200–250	0***	95–114

Notes:
* "Fast charger" public stations, without taking into account opportunities to charge cars at private homes or public parking lots
** Assuming each filling station has additional biofuel storage capacity, or that biofuel is mixed with petroleum products
*** CO_2 emissions of electric cars do not take into account emissions made while electricity is generated
The colour coding (from lighter to darker) indicates which fuel type is better than others in terms of the relevant parameter

Source: composed by the authors.

[7] For more on prerequisites of increasing motor vehicles' fuel efficiency see [*Makarov et al.*, 2014].

The key difference between the scenarios is the prerequisites for changing conditions for interfuel competition between petroleum products and their indirect substitutes – natural gas and electricity.

The basic scenario implies that key government decisions on gasification of the public transport will be carried out. Mass production of large-capacity gas-powered motor vehicles will be launched, but no subsidies will be provided for conversion of passenger cars and medium-capacity vehicles, and no mass production of gas-powered motor vehicles is expected to begin at Russian facilities. Regarding electric transport: no support will be provided for construction of public charging stations; the existing government initiatives such as zero transport tax, permission to drive on dedicated lanes, and zero import duties will retain their current status (i.e. will not become laws). Meanwhile electricity is gradually becoming more available; individual charging stations appear at various parking lots and in public areas, making charging an electric car more convenient than it currently is.

The "Promoting alternative fuel types" scenario implies extending the gas filling stations' network by 2030 (following introduction of the requirement to provide such services at all existing and new petrol stations) to the level when the infrastructure factor stops hindering people's switching to this vehicle type. Also, this scenario implies providing subsidies to convert passenger cars and medium-capacity vehicles for use of CNG (either full compensation of consumers' costs to convert their cars, or launching large-scale mass production of gas-powered motor vehicles at Russian automobile factories), which would allow to fully level the difference in basic prices of petrol/diesel and gas-powered vehicles by 2025.

Regarding development of electric transport after 2025, the "Promoting alternative fuel types" scenario envisages construction of public "quick charging" infrastructure, creating better conditions for charging cars at home (installing charging outlets at underground parking lots and in private buildings). Generally, the charging infrastructure is expected to become comparable with the network of petrol stations by 2040. Electric car prices will be brought down by reducing import duties (from 25% of the car price to 0% after 2025), and by promoting domestic production. Cars powered by alternative fuels will be made more attractive to customers through active promotion and advertising, and by allowing to drive them on dedicated lanes in large cities.

Results of the modelling

Our calculations show that under both scenarios, the total number of cars in Russia is expected to more than double – from 43 to 97 million. However, this will not double the demand for energy, due to increased efficiency which the scenarios take into account. Total energy demand in the road transport sector is estimated to reach 109 million tonnes of oil equivalent by 2040, compared with 64 million tonnes in 2015 (figure 2).

Our calculations show that even if the current situation with promotion of alternative fuel types remains unchanged, interfuel competition in the Russian road transport sector is still going to increase, up to a point. Note that compressed natural gas is the key alternative to petroleum products. E.g. even under the relatively pessimistic "Basic" scenario its share of the total motor fuel consumption is going to reach 11% by 2040, or 11.5 million tonnes of oil equivalent – which is comparable with the amount of petrol consumed in 2014 in the Central and North-Western Federal Districts combined. It should also be noted that about 35% of this amount is expected to be consumed by large-capacity vehicles which make the highest emissions into the atmosphere, so it would lead to a significantly reduced environmental pressure (compared with the situation when this substitution doesn't happen).

If no additional effort is made to promote use of electric vehicles, electricity's potential to substitute petroleum-based fuels seems to be much lower. E.g. under the "Basic" scenario, its share of the total energy consumption in the road transport sector is not going to exceed 1% by 2040, or just over 1 million tonnes of oil equivalent. Still, it would be enough to fully meet demand for petrol in 2014 in the Far-Eastern Federal District, which commonly experiences shortages of petroleum products.

If the regulatory parameters remain unchanged, petroleum products will retain their dominating position. The combined demand for such products by the road transport sector by 2040 will reach 95.8 million tonnes of oil equivalent (figure 3). Note that under the "Basic" scenario, demand for petrol by 2040 is expected to grow almost by 12.3 million tonnes of oil equivalent (compared with the current level), which would require the Russian oil industry to make a significant technological and investment effort – to upgrade, and possibly extend its production capacities.

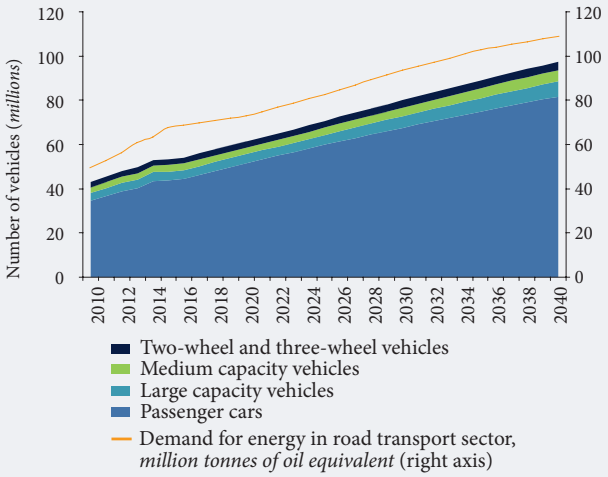
Table 3. **Dynamics of major macro-parameters between 2014-2040**

Parameter	2014 г.	2040 г.
Average growth rate of the Russian GDP	2.4% annual growth	
Russian population	0.4% decrease, in line with the UN forecast [UN 2015].	
Domestic Russian petroleum product prices (*rouble/l*)*	40	60
Prices of natural gas sold at filling stations (*rouble/m3*)	20	40
Electricity prices (*rouble/KWH*)	4.5	7.7

* It's particularly important to measure prices in national currency, since a majority of the population make their economic decisions (which are imitated in the course of modelling) based on the national currency's purchasing power.

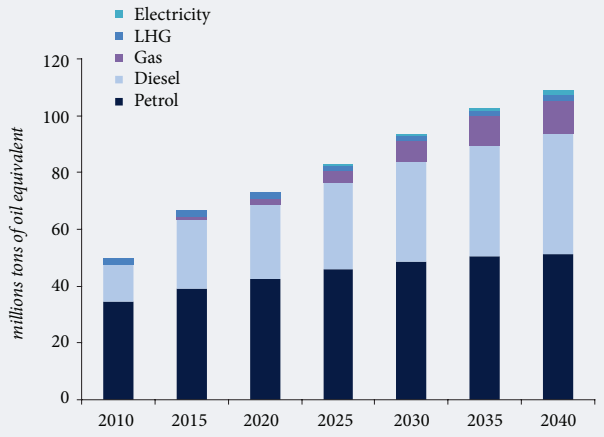
Source: composed by the authors.

Figure 2. **Number of motor vehicles by type, and total energy consumption in the road transport sector**



Source: composed by the authors.

Figure 3. **Demand for energy by fuel type under the "Basic" scenario**



Source: composed by the authors.

Additional steps to promote use of alternative fuels described in the "Promoting alternative fuel types" scenario lead to significant changes in the structure of energy demand by the road transport sector. The share of gas motor fuel in the total energy consumption increases by 2040 to 21%, or in absolute terms to 23 million tonnes of oil equivalent, displacing petroleum products and first of all the more expensive petrol types.

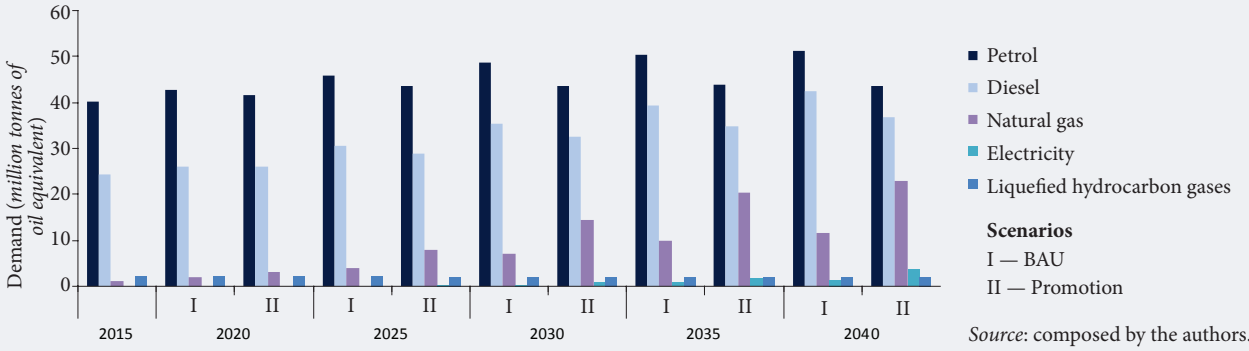
The share of electricity in the total energy consumption is expected to reach 3% by 2040, or in absolute terms 3.5 million tonnes of oil equivalent – compared with 1 million tonnes under the "Basic" scenario (figure 4). Note that under the "Promoting alternative fuel types" scenario, demand for petrol essentially remains at the level of the Russian refineries' current production capacity, due to substitution by alternative fuel types.

Conclusion

The study showed that Russia does have objective reasons to diversify the fuel mix of the country's road transport sector, specifically:

1. *Structural incentive*: as of 2015, imports of petrol (which dominates the Russian road transport sector's energy consumption) remained at a very low level, but Russian refineries have reached the ceiling of their production capacity. The potential to further increase production of petrol is limited, due to lack of investment resources and domestic technologies. Stepping up production capacities would require significant investments (at about $20 billion according to [*Kapustin,* 2011]), which is comparable with the investments in, e.g., developing gas motor fuel infrastructure, which, provided that all Russian petrol stations will be equipped with gas motor fuel facilities, are estimated at $12.6–31.5 billion [Promexpertisa, 2016]. If demand for this energy resource grows, and no new refinery capacities are built, Russia, despite being one of the world's largest producers of oil and petroleum products, would have to import fuel.

Figure 4. **Demand for energy by fuel type in the Russian road transport sector under the "Basic" (BAU) and "Fuel mix diversification" scenarios**



Source: composed by the authors.

2. *Environmental incentive*: petroleum products are the least environmentally friendly fuel among the alternatives under consideration; using CNG instead of conventional diesel and petrol would reduce harmful emissions of urban traffic into the atmosphere by a quarter, while switching to electric cars would reduce vehicles' direct emissions.
3. *Export incentive*: reduced demand for petroleum products in the domestic market would help Russia step up relevant exports. This has already been successfully accomplished by Iran, who has managed to convert a significant proportion of its motor vehicle fleet to use gas fuel by launching domestic production of such vehicles.
4. *Gas incentive*: growth of the domestic gas market may help Russian gas producers to create an additional niche for selling their products internally – which is particularly relevant given the currently limited demand at home and in the key European export markets, combined with significant gas production capacities [*Kulagin, Mitrova,* 2015].

All these incentives provide a good reason to consider where public support should be concentrated in to promote diversification of the fuel mix, and increase consumer appeal of specific fuel types. After all, it's consumer properties that ultimately determine whether customers decide to switch from the customary petroleum products to alternatives.

Analysis shows that theoretically, on the basis of its operational characteristics, gas motor fuel can already strongly compete with petroleum-based fuels in the Russian market. However, the degree of oil substitution would largely depend on regulation and promotion prospects, first of all regarding pricing of gas motor fuel, development of infrastructure, and subsidising conversion of conventional motor vehicles to use gas fuel.

Among other things the scenario analysis indicates that electric cars which are actively conquering the developed countries' markets, in particular in Europe, still have a rather limited potential in Russia – due to their very high basic prices compared with other car types. Accordingly, if gas motor fuel's success can be supported by regulatory measures, promotion of electric cars would require further technological development, to cut their production costs.

The Russian government has already introduced a number of measures to promote diversification of the fuel mix, but exclusively by encouraging use of gas motor fuel by large-capacity public transportation vehicles. Plus, calculations show that these measures won't be sufficient to achieve a significant substitution of petroleum products in the passenger car and medium-capacity vehicle segments.

Fully implementing Russia's potential to diversify the transport sector's fuel mix, and limiting the growth of demand for petroleum products requires taking integrated action to significantly extend consumer infrastructure (a network of gas filling stations), combined with reducing prices of vehicles powered by alternative fuels (in the case of gas-powered ones, by launching domestic assembly line production, or through provision of tax breaks).

Implementing such measures would help save up to 13 million tonnes of oil equivalent of petroleum products by 2040 (compared with the "Basic" scenario), which can be exported. Of course making these changes may turn out to be very expensive and require major investments which are hard to attract, especially during recession. However, the costs are comparable with those of, e.g., major upgrading of refineries, and in case an integrated government policy is implemented, they would be borne not just by oil producers but shared by gas and electricity generation companies, cities, municipal authorities, consumers, and automobile manufacturers. Not to mention that diversification of the fuel mix would make a major contribution to improving the environmental situation in large cities, and in the whole country.

The study was supported by the Russian Science Foundation grant, project №14-19-01459.

References

Analytical Center (2014) Energeticheskaya strategiya Rossii na period do 2035 goda (osnovnye polozheniya) [Energy Strategy of Russia for the period up to 2035 (main provisions)], Moscow: Analytical Center for the Government of the Russian Federation. Available at: http://ac.gov.ru/files/content/1578/11-02-14-energostrategy-2035-pdf.pdf, accessed 15.02.2016 (in Russian).

Analytical Center (2015) *Aktivnost' naseleniya v ispol'zovanii transportnykh uslug. Byulleten' sotsial'no-ekonomicheskogo krizisa v Rossii* [Activity of the population in the use of transport services. Bulletin of the social and economic crisis in Russia]. Issue 7 (November). Moscow: Analytical Center for the Government of the Russian Federation. Available at: http://ac.gov.ru/files/publication/a/7059.pdf, accessed 25.09.2016 (in Russian).

Autostat (2016) Za 10 let srednyaya tsena legkovogo avtomobilya v Rossii vyrosla v 3 raza [For 10 years the average price of a car in Russia has grown 3 times]. *Autostat.RU*, 09.06.2016. Available at: https://www.autostat.ru/news/26250/, accessed 25.09.2016 (in Russian).

Bobylev Yu.N., Prikhod'ko S.V., Drobyshevskii S.M., Tagor S.V. (2006) Faktory formirovaniya tsen na neft' [Factors of formation of oil prices], Moscow: Institute for the Economy in Transition (in Russian).

Braginskii O.B. (2012) *Prognozirovanie rossiiskogo rynka avtomobil'nykh vidov topliva. Doklad dlya Otkrytogo seminara "Ekonomicheskie problemy energeticheskogo kompleksa" 24 aprelya 2012 g.* [Forecasting the Russian market of automotive fuels. Report for the Open Seminar "Economic Problems of the Energy Complex", April 24, 2012], Moscow: RANEPA. Rezhim dostupa: http://ecfor.ru/wp-content/uploads/seminar/energo/z129.pdf, data obrashcheniya 18.04.2016 (in Russian).

Curran S.J., Wagner R.M., Graves R.L., Keller M., Green J.B. Jr. (2014) Well-to-wheel analysis of direct and indirect use of natural gas in passenger vehicles. *Energy*, no 75, pp. 194–203.

ERI RAS, Analytical Center (2014) Prognoz razvitiya energetiki mira i Rossii do 2040 goda [Forecast of the development of energy in the world and Russia until 2040] (eds. A. Makarov, L. Grigoryev, T. Mitrova, Moscow: The Energy Research Institute of the Russian Academy of Sciences, Analytical Center for the Government of the Russian Federation (in Russian).

Gazprom (2016) V tekushchem godu «Gazprom» postroit 35 novykh AGNKS [This year Gazprom will build 35 new CNG stations]. *Gazprom official website*. Available at: http://www.gazprom.ru/press/news/2016/august/article280185/, accessed 17.01.2017 (in Russian).

Glebova O. (2013) *Gas to Liquids: Historical Development and Future Prospects*, Oxford: Oxford Institute for Energy Studies.

Grushevenko E., Grushevenko D., Kulagin V. (2016) *Long-term impact of technological development on European road transportation sector's fuel mix: Focus on electric vehicles*. Paper presented at the 10th International Conference on Electric Power Quality and Supply Reliability. Available at: http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=7724107, accessed 20.07.2017.

Höök M., Aleklett K. (2010) A review on coal to liquid fuels and its coal consumption. *International Journal of Energy Research*, vol. 34, no 10, pp. 848–864.

IEA (2014) *World Energy Outlook 2014*, Paris: International Energy Agency.

Interfax (2016) EEK prodlila snizhennye poshliny na elektromobili do sentyabrya 2017 goda [ECE has extended reduced duties on electric vehicles until September 2017]. Available at: http://www.interfax.ru/business/518259, accessed 24.05.2017 (in Russian).

Kapustin N., Grushevenko D. (2016) Russia refines on. *Energy Focus*, no 26 (Spring), pp. 89–94.

Kapustin N.O., Osipova E.D. (2015) Sistemnyi analiz meropriyatii chetyrekhstoronnego soglasheniya [System analysis of the activities of the quadrilateral agreement]. Neft', gaz i biznes [Oil, Gas, and Business], no 6, pp. 13–18 (in Russian).

Kapustin V. (2011) Renessans v neftepererabotke otmenyaetsya? [Renaissance in oil refining is canceled?]. *Neftegazovaya vertikal'* [Oil and Gas Vertical], no 21. Available at: http://www.ngv.ru/magazines/article/renessans-v-neftepererabotke-otmenyaetsya/, accessed 17.01.2017.

Kulagin V.A., Grushevenko D.A., Kozina E.O. (2015) Effektivnoe importozameshchenie [Effective import substitution]. *Energetika i geopolitika* [Energy and Geopolitics], no 1 (49), pp. 49–57 (in Russian).

Kulagin V.A., Mitrova T.A. (2015) *Gazovyi rynok Evropy: utrachennye illyuzii i robkie nadezhdy* [Europe's gas market: Lost illusions and timid hopes], Moscow: ERI RAS, NRU HSE (in Russian).

Milovidov K.N., Korzhubaev A.G., Eder L.V. (2006) Neftegazoobespechenie global'noi ekonomiki [Oil and Gas Supply of the Global Economy]. M.: Centrlitneftegaz (in Russian).

Minenergo (2009) Energeticheskaya strategiya Rossii na period do 2030 goda (utverzhdena rasporyazheniem Pravitel'stva Rossiiskoi Federatsii ot 13.11.2009 g. № 1715-r) [Energy Strategy of Russia for the period up to 2030 (approved by Order of the Government of the Russian Federation of November 13, 2009 no 1715-r)], Moscow: Ministry of Energy of the Russian Federation. Available at: https://minenergo.gov.ru/node/1026, accessed 15.02.2016 (in Russian).

Mitrova T. (2016) Shifting Political Economy of Russian Oil and Gas. A Report of the CSIS Energy and National Security Program. Lanham; Boulder; New York; London: Rowman & Littlefield.

Mitrova T., Kulagin V., Grushevenko D., Grushevenko E., Galkina A. (2015a) Integrated method of petroleum products demand forecasting considering economic, demographic and technological factors. *Economics and Business Letters*, vol. 4, no 3, pp. 98–107.

Mitrova T.A., Galkina A.A. (2013) Mezhtoplivnaya konkurentsiya [Interfuel competition]. *Ekonomicheskii zhurnal VShE* [*The HSE Economic Journal*], no 3, pp. 394–413 (in Russian).

Mitrova T., Kulagin V., Grushevenko D., Grushevenko E. (2015b) Technology Innovation as a Factor of Demand for Energy Sources in Automotive Industry. *Foresight and STI Governance*, vol. 9, no 4, pp. 18–31. DOI: 10.17323/1995-459X.2015.4.18.31.

Moskva 24 (2016) Dve besplatnye stantsii zaryadki elektromobilei otkrylis' v Moskve [Two free charging stations for electric vehicles opened in Moscow]. *Moscow 24*, 22.04.2016. Available at: goo.gl/whb639, accessed 05.11.2016 (in Russian).

Mussatto S.I. (2016) A closer look at the developments and impact of biofuels in transport and environment; what are the next steps? *Biofuel Research Journal*, vol. 3, no 1, p. 331. DOI: 10.18331/BRJ2016.3.1.2.

NGV (2015) Mirovoi rynok KPG po sostoyaniyu na noyabr' 2015 g. [The world market of CNG as of November 2015]. *National Gas Vehicle Association website*. Available at: http://www.ngvrus.ru/statistics.html, accessed 17.01.2017 (in Russian).

Promekspertiza (2016) Pravitel'stvo RF obyazalo AZS prodavat' gazomotornoe toplivo [The government of the Russian Federation ordered the gas station to sell gas engine fuel]. Available at: http://promexpertiza.ru/pravitelstvo_rf_obyazalo_azs_prodavat_gazomotornoe_toplivo/, accessed 17.01.2017 (in Russian).

Sørensen B. (2012) *Hydrogen and Fuel Cells. Emerging Technologies and Applications* (2nd ed.), Amsterdam; Boston; Heidelberg; London; New York; Oxford; Paris; San Diego; San Francisco; Singapore; Sydney; Tokyo: Elsevier.

UN (2015) *World Population Prospects: 2015 Revision. UN Population Division Report*, Geneva: United Nations.

Voelcker J. (2014) *How Much Money Does The 2016 Toyota Mirai Lose? A Lot, Perhaps. Green Car Reports*. Available at: http://www.greencarreports.com/news/1095773_how-much-money-does-the-2016-toyota-mirai-lose-a-lot-perhaps, accessed 20.09.2017.

Voronov A., Tsinoeva Ya., Dyatel T. (2016) Elektromobili podzaryazhayut l'gotami [Electric cars are recharged with benefits]. *Kommersant*, issue 123 of 12.07.2016. Available at: https://www.kommersant.ru/doc/3036078, accessed 21.09.2017 (in Russian).