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N. K. POPADYUK¹, Professor, Doctor of Economic Sciences, NKPopadyuk@fa.ruT. V. BRATARCHUK¹, Associate Professor, Doctor of Economic SciencesL. K. BABAYAN¹, AssistantA. M. LAFFAKH¹, Assistant¹Financial University under the Governmental of the Russian Federation, Moscow, Russia

THE GREEN TRANSITION AND DEVELOPMENT PROBLEMS OF FUEL AND ENERGY SECTOR IN RUSSIA

Introduction

In 2022 against the background of geopolitical transformations, the European Union accelerated the green transitions in view of the enforced rejection of buying oil and gas in Russia [1]. The ecologization trend originated in the EU more than thirty years ago but changes in the energy sector accumulated gradually, and that allowed a space for the in-service and strategic maneuvering in the sphere of meeting the energy requirements of the European society and economy [2]. The events in the end of February to early March 2022 spurred the pace of changes in the energy sector of a united Europe, which showed up as the diversification of supplies of fossil energy sources, first, and, second, as the higher rate launching and implementation of programs aimed to modify the Pan European concept of energy security based on the green transition.

At the same time, the European green transition offers the Russian economy the objective prospects (rejection of the resource rent income, i.e. a resource-based model of social and economic development) together with the objective difficulties both on macro-economic and sectorial scales [3]. However, the export production potential of the Russian fuel and energy sector implacably lowers and it is going to be a long-term trend. The prospects for growth remain for the mineral mining and processing companies on the domestic market, on the markets in the CIS countries, and on the Asian–Pacific and Middle East markets. This brusque diversification of the fuel and energy sector of Russia in the context of hydrocarbon and energy sales activity is connected with certain risks. For this reason, this article analyzes the prospects of the Russian fuel and energy sector against the background of the European green transition together with the hazards which can affect initiation and development of energy producers in Russia in the medium and long term.

Materials and methods

This article presents a sampling analysis of factors that influence the domestic and foreign economic activity of the Russian fuel and energy sector, and identifies the key challenges that highly probably necessitate the strategic and operational diversification of oil and gas companies in Russia. The data for the statistical analysis were collected from the Russian official statistics (Rosstat, Ministry of Energy) and from the foreign energy statistics (*Enerdata*, France). The data were subjected to the dynamic and structural analysis, as well as to the statistical mathematical analysis and time series forecasting. The analysis of the trend in the sphere of crude oil and natural gas recovery, processing and sales on the domestic and foreign markets uses the Hurst exponent H [4]:

$$H = \frac{\log(r/s)}{\log(aN)},$$

where r is the time series range; s is the standard deviation of values of a time series; a is a constant (assumed to be equal to one in the calculations below); N is the number of observations.

The article discusses sustainable development of the Russian fuel and energy sector with regard to the green transition in the European energy policy. This interdisciplinary research integrates procedures used in the analysis of production, cost effectiveness and statistics. The analytical research shows that the Russian fuel and energy sector generally and, particularly, its key oil and gas sector demonstrates an extensive trend of development, which is hard to assume to be stable. The European green transition and retargeting of sales of hydrocarbons and energy products from the European market to the markets in Asia and Middle East have adversely affected development of the fuel and energy sector in Russia. For another thing, the extensive trend is affected by the ecologization of the demand for energy products on the domestic and foreign markets. Three identified hazards (the green transition, retargeting of sales markets, sales ecologization) are addressed from the viewpoint of the consequences and growth prospects for the Russian fuel and energy sector. The main solutions toward sustainable development in the fuel and energy sector of Russia are the integration of natural gas and natural hydrogen recovery and production of energy products at high added value for the gas industry, and the rejection of oil recovery and replacement of oil by renewable resources, for instance, biomass.

Keywords: gas, oil, power generation sector, green transition, oil and gas companies, economy, energy technologies, Russian fuel and energy sector, diversification, ecologization

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For collecting and exposing the article materials, as well as for shaping a frame for the discussion of the results, the methods of the content and scientific synthesis were used, which allowed defining possible pathways for the strategic and operational activity diversification of the Russian oil and gas companies on the domestic and foreign markets.

Results

The data on the production, consumption and trade balance (import minus export) per extractive and processing industries in the Russian fuel and energy sector are shown in **Fig. 1**.

Having reached the maximum of production and export of gas (2018), oil and oil products (2017 — export and 2019 — production), the Russian fuel and gas sector demonstrates a stable decrease in the production and export potential in terms of these indicators in the recent five–six years.

Actually, the descending trend originated before 2020, but the pandemic and the systemic sanctions against the fuel and energy sector of Russia definitely conditioned the drop of the trend in 2022. At the same time, production and internal consumption of gas demonstrate a little yearly average increase in the time period under analysis, +0.35% and +0.88%, respectively, while export of gas reduced by 1.9% on the average during the last eleven years. The export potential (trade balance dynamics) lowers by 0.1% in the mid-annual calculus with the 2022 data taken into account, but without regard to the 2022 data, the dynamics is upward, vice versa, at the level of 0.9% on the average per year.

Using the plotted time series for gas, oil and oil products, the authors calculated the Hurst exponent and determined the key trend (**Fig. 2**).

The value of the Hurst exponent > 0.5 means that the trend is not going to change, and the value of the exponent < 0.5 shows that the trend is to change. From the analytical evidence, we can tell that:

a) the gas trend can change to the opposite trend in the sphere of production and, consequently, instead of the minimal yearly average increase, there can be a minimal yearly average decrease. In the sphere of internal consumption of gas, there is no trend of change, and the decreasing trend in the sphere of gas export stays on;

b) regarding oil and oil products, there is no trend of change in the sphere of production, so it is expectable that the output volume remains at the current level. In the sphere of internal consumption, the decreasing trend is probably to remain, and in the sphere of export, it is possible that the trend can change (the observed decrease in export in the trade balance can change to an increase).

Thus, evidently, the accelerated green transition in Europe, and diversification of export of hydrocarbons and energy products (reduced deliveries to European markets because of the sanctions, and redirection of deliveries to the markets in Asia and Middle East) endangers development of the fuel and energy sector in Russia. The lack of the structural balance between production, internal consumption and export can lead to both deficit and excess of hydrocarbons and energy products on the domestic and foreign markets. The shortfall on the foreign markets can be useful in the short term as it allows expecting a rise in the export prices, but the surplus, on the contrary, will affect profitability of the fuel and energy sector of Russia, which, in its turn, can lead to a growing budget deficit in the country. On the domestic market, deficiency (or cost escalation for the internal users) of hydrocarbons and energy products can bring an economic collapse, an increase in inside prices and a faster inflation — and the early signs of these are already traceable.

For another thing, in the medium and long term, the world economy and the global society will gradually reject using fossil fuel and energy resources as the geared up green transition in Europe shows that hydrocarbon rejection in power generation can be balanced by renewable energy sources and nuclear power. So, there appears another hazard for the development of the Russian fuel and energy sector in the medium and long term, and it is connected with the unconditional refusal of hydrocarbons and energy produced from it. Accordingly, the challenge of the physical and economic preservation and sustainability of the fuel and energy sector of Russia in the future urgently needs efficient and eco-friendly solutions as early as today.

Discussion

The presented analysis and its results point at the objective challenges the Russian fuel and energy sector is faced with. The first challenge is the European green transition and politics, including invariable geopolitical trends against the Russian Federation. This entails the loss of the large and solid markets in Western and, partly, in Eastern Europe for the Russian fuel and energy sector.

The second challenge is the turn of the Russian fuel and energy sector toward Asian and Middle Eastern markets. The consequences of such turn is the expanded contention between oil and gas companies in Russia and their focusing at the markets of sufficient size but lower paying capacity, not to mention the problematic mutual exchanges using non-convertible or partially convertible currencies.

The third challenge is the ecologization of domestic and foreign consumption and, accordingly, of the demand for energy products, which means an indispensable and healthy increase in the increment in the green and renewable power generation. Consequently, the increase in the capital and operating costs can in the medium and long term exceeds the income and profit of fuel and energy companies in Russia.

For all Russian oil and gas companies, these heavy challenges require solutions, and the most rational solutions should aim at:

Building new business models using the ESG concept. This concept assumes that the development strategy and, accordingly, operating, investment and financial activities of companies in the fuel and energy sector meet the high *Ecological / Environmental* and *Social* standards maintained by the high-quality corporate *Governance*;

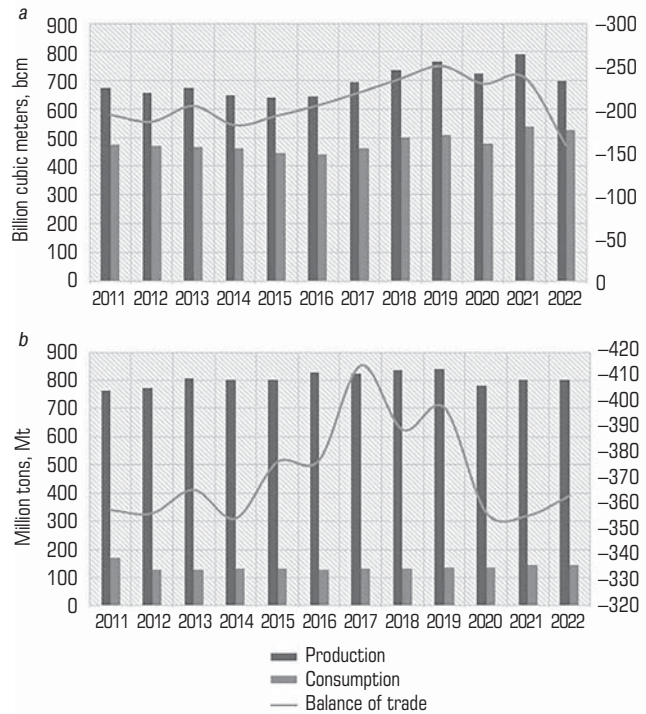


Fig. 1. Dynamics of production, consumption and balance of trade of gas (a), oil and oil products in Russia (b) [5]

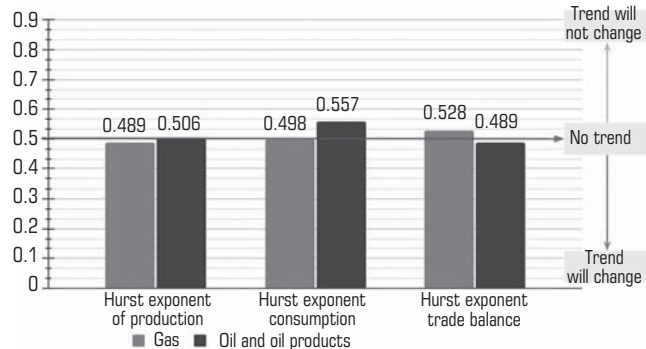


Fig. 2. Analytical tendency of change in production, consumption and balance of trade (calculated by authors)

Strategical and operational diversification of oil and gas companies in the Russian fuel and energy sector, which follows from the previous point, along the whole value chain — from mining of a mineral raw material, to processing and sales of this material and energy products made of it.

Sufficient effort is spent by Russian and foreign scientists to business modeling in mineral mining and processing using the ESG concept. For this reason, the present authors avoid a detailed discussion of this solution all the more so that transition to the environmentally and societally responsible business models in the sphere of power engineering is impossible without the second-solution strategic and operational diversification. This area of activities demands more attention.

Strategic and operational diversification should involve, first of all, business processes connected with production and processing of energy resources, i.e. with manufacture of energy products. In this context, it is advised to identify, first, solutions implementable in the short and medium term, and, second, solutions implementable in the long term. The former solutions are connected with the transition of the oil and gas companies within the Russian fuel and energy sector to hydrogen power. The latter solutions are associated with the partial or total transition of these companies to the

Diversification of oil and gas companies in fuel and energy sector of Russia [6, 7]

Business process	Direction of diversification	Comments
Gas industry		
Exploration and recovery of energy sources	Mining of natural hydrogen	Gathering of natural hydrogen flow in the Earth's crust ($2.5 \cdot 10^{11}$ m ³ of natural hydrogen leaves the crust annually)
	Geothermal drilling	Combination of production of natural gas and geothermal energy generated during natural gas recovery
Processing of energy sources, production and sales of energy products	Liquefied natural gas and liquefied hydrogen	Transition to more environmentally friendly processing methods (liquefaction of gas and hydrogen) and logistics of energy products in reservoirs which decrease pipelining-caused risks (leaks, physical vulnerability, etc.)
	Liquefied hydrogen for heating	Transition from distributing systems of gas supply of domestic and economic sectors to supply with liquefied hydrogen as an alternative of electric heating
Oil industry		
Production of energy and chemical feedstock	Pyrolysis method of biomass	Thermochemical decomposition of organic matters (wood, organic and solid domestic waste, etc.) to non-condensable gases, condensable liquids and solid residue
	Pyrolytic gases	Non-condensable pyrolysis-generated gases usable in hydrogen power generation (biogas)
Production of energy and chemical products	Biochar	Solid pyrolysis residue usable in power generation and chemical production
	Pyrolysis bio-oil	Liquid pyrolysis residue usable as replacement of conventional fuel (mazut, diesel), or as component in production of oil derivatives
	Bioplastics and conventional plastics	Biodegradable polymers obtained by polymerization, or chemical, fermentative or other method processing of biomass. Bioplastics is a polymer produced from plant materials; conventional biodegradable plastics is polymers obtained from oil with addition of decomposition accelerators

pyrolysis method of biomass. Both directions of the strategic and operational diversification of mining and processing of raw materials and energy production from them are interrelated (Table).

It follows from Table that the green transition in Europe and the ecologization of the domestic and foreign demand for energy products are concurrently the challenges and new spurs for the economic growth in the fuel and energy sector in Russia. It should be understood that strategic and operational diversification is implementable faster in the gas industry than in the oil industry. First, natural hydrogen recovery uses existing technical and engineering solutions approved by European practices. Second, the energy supply equipment is available in the domestic and economic sectors. In particular, the present-day electricity production possesses combination-cycle gas turbines which mix natural gas and natural hydrogen at different proportions. Third, the processes of recovery of natural gas and natural hydrogen can be united using the geothermal drilling method, for instance.

In recovery and processing of natural gas and natural hydrogen, and in logistics and sales of energy products (liquefied natural gas, liquefied hydrogen), there are certainly extra expenses but they are expectedly low thanks to the available technical and engineering solutions on the markets of production facilities for gas companies. Therefore, the investment risks are probably lower in the gas industry than in the oil industry [8]. Furthermore, recovery and use of natural gas as a resource or energy product are the less environmentally hazardous types of economic activity [9]. The oil industry is conversely more harmful for the environment. Moreover, the technical and engineering solutions usable in strategic and operational diversification in oil production and manufacture of oil derivatives mostly aim at gradual but

complete rejection of oil as a main resource (while it is not so in the gas industry).

According to Table, the oil industry to overcome the present challenges should transit from oil-driven power generation to bioenergetics. The main energy source in bioenergetics is biomass (wood substance and refuse wood, agrowaste, organic and solid domestic waste, etc.). The main and eco-friendly approach to processing such materials is pyrolysis used to produce biogas, biochar and bio-oil. Moreover, in chemical reactions of polymerization, conventional oil can be totally or partially replaced by a specially prepared biomass.

Biomass can be prepared and converted at refineries. It should be emphasized that, while bioplastics production is provided with the required technical and engineering solutions, which are unhazardous for the environment and allow mass production, industrial facilities in biogas, biochar and bio-oil making require:

First, more careful and curious theoretical and practical research on potential ecological and social risks associated with preparation and processing of biomass;

Second, finding methods of scaling of technologies such that enable efficient recycling of biomass, on the one hand, without deferred adversities in the future, on the other hand.

Consequently, strategic and operational diversification in oil recovery and manufacture of oil products is the long-term prospects for the Russian fuel and energy sector. On the other hand, recovery and accumulation of associated gases during oil recovery may become a source of additional profit for oil companies already at present. Furthermore, oil and gas companies can diversify marketing by means of satisfying gas demand on the domestic market. In this manner, gas companies, with a view of sales diversification, can use the domestic market capacities to obtain additional economic profit and to form an investment fund to support diversification of extraction and processing of raw materials (natural / associated gas and natural / associated hydrogen), and manufacture of energy products at high added value (liquefied gas and liquefied hydrogen).

Oil companies, in the short term and in order to accumulate an investment potential to switch to a new strategy of development, can diversify their operating activities and optimize marketing by manufacturing energy products at high added value. The latter may be benzene, kerosene and diesel fuel. This implies that oil producing and refining companies should accumulate sufficient investment potential for the business diversification [10–12] which is unbiasedly required against the apparent geopolitical fluctuations and unopposed trends in global energy, that affect sustainability of the fuel and energy sector in Russia. Evidently, such impact will have the medium-dated and dormant effects, and, for this reason, it is critical for the Russian fuel and energy sector to launch immediate implementation of solutions aimed at sustainable development in the long term.

Conclusions

The accomplished research and analysis of the trends, objective laws and prospects for the Russian fuel and energy sector in whole and for its individual companies has shown that:

First, the faster European green transition governed by geopolitical fluctuations affects the export and production potential of the fuel and energy sector in Russia. The energy turn to the Asian and Middle East markets is hard to admit a fairly fruitful strategic and operational maneuver;

Second, in the sphere of gas production, the odds are that the growth trend is to change for decrease, and the gas export reduction trend is to remain. In the sphere of oil recovery and manufacture of oil products, no changes are expected, and the current volumes of recovery and production are anticipated to keep the same in the short term. Probably, the decreasing export trend may change to a growing trend;

Third, the domestic consumption of gas, oil and oil products exhibits no any pronounced tendencies of growth or reduction. This indifference of the trend means that there is a possibility to replace the

forfeited foreign markets by the domestic market, regarding the fact that the pattern of the demand ecologization becomes increasingly more noticeable;

Fourth, three ascertained challenges facing the Russian fuel and energy sector (the green transition, retargeting of sales markets, demand ecologization) offer both adverse after-effects and new growth sources which can facilitate better sustainability of the fuel and energy sector in Russia. In the gas industry, this means integration of natural gas and natural hydrogen recovery and manufacture of energy products at high added value. In the oil industry, this means a gradual rejection of oil recovery and replacement of oil by renewable sources, for instance, biomass.

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B. R. RAKISHEV¹, Academician of NAS RK, Professor, Doctor of Engineering Sciences, b.rakishev@satbayev.university

¹Satbayev Kazakh National Research Technical University, Almaty, Kazakhstan

MINERAL–INDUSTRIAL MEGA COMPLEX — THE BASIS OF SCIENTIFIC AND TECHNOLOGICAL PROGRESS

Introduction

Industrialized mining countries establish mining-related sectors connected with minerals, oil and gas, metallurgy, chemistry, fuel and energy, nonmetals and construction. These sectors deal with geological exploration, extraction and processing of raw materials for production of feedstock for manufacturing industries. Operations in all these sectors start with extraction of mineral reserves from the subsoil. Technologies and equipment used in mining and processing of minerals are the same in principle but have different designs to be adaptable to various industries.

Similar in essence but different in purpose, mineral mining and processing works should be integrated to single mineral industry mega complex (MIMC). Such approach can help objectively estimate the role of MIMC in advancement of science and technology, and effectively control production of process feedstock for the high-tech manufacturing industries.

History of civilization exhibits its direct connection with the use of mineral resources of the Earth. Depending on the level of processing of mineral raw materials to be used as implements, ancient sophists identified the Stone, Bronze and Iron Ages [1–5].

Starting from the mid-18th century, civilization developed under the influence of the science and technology progress based on the mass use of

The mineral–industrial mega complex (MIMC) in Kazakhstan is described. The place of the complex in the world mineral resources and reserves is shown, and the volumes of the main products of MIMC during the last years are given. The high-priority objectives of MIMC in modern conditions are highlighted. The mathematical models of mineral raw materials at each stage of mining and processing are given. On this basis, recommendations on integrated and comprehensive utilization of mineral resources are given. The technical and economic criteria are substantiated for selecting effective methods for extraction of rare earth metals (REM) from multi-component ores. It is shown that new technologies and equipment adaptable to natural and process properties of a raw material from a particular mineral object can provide high level of REM extraction in order to worthily represent MIMC in the world market of rare earth metals.

Keywords: mineral–industrial mega complex, scientific and technological progress, civilization stages, process raw materials, rare earth metals, mathematical models of mineral raw materials, innovative technologies

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widely ranged high-quality metals and alloys for creating production tools—various-purpose machines.

Having taken its rise in the middle of the 20th century, the scientific and technological revolution worked greatly on the pace of industrial development. It became possible to transit to high technologies and equipment based on the use of earlier unknown diverse alloys of ferrous, nonferrous, noble and rare earth metals extracted from minerals [6–17].

As seen, at all civilization stages, the product of the mineral–industrial mega complex is a physical and technological basis of the scientific and technological progress. The science and technology progress, in its turn, is what