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RUSSIAN FUEL AND ENERGY COMPLEX TECHNOLOGY POLICY AT THE MOMENT OF ENERGY TRANSITION

The objectives of utilizing the most out of scientific, technical and production potential of Russian Fuel and Energy Complex (FEC) to safeguard technological independence and economic development at the state of energy transition is reviewed in the paper. Main trends for the required multidimentional technical development of the FEC: local R&D and manufacturing for conventional industries, Industry 4.0 and energy transition technologies (including all aspects of reduce, reuse, recycle and remove greenhouse gases), industrial safety and environmental protection are covered. The author have reviewed the global innovation index and global investments market in R&D, presented an analysis of Norwegian, American and Chinese experience to flourish country investments in technical development. Some of the key priorities for the further development of conventional upstream sector have been identified and includes permafrost monitoring, reservoir digital twins, hard to recover reservoirs technologies, permanently deployed well monitoring systems, energy harvesting and energy efficiency technologies, CCUS. Specific suggestions to expand the public private partnership are presented as the ways to streamline technology development in Russian FEC.

Keywords: *Fuel and energy complex, technology policy, energy transition, technology cooperation, innovations, renewable energy*

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Current Challenges for Fuel and Energy Complex Development

Introduction

One of the key issues for the formulation of a long-term strategy for the technological development of the fuel and energy complex of Russia is the declared trend towards decarbonization of the world's leading economies, which directly affects the demand for energy and the consumption patterns. Today, more than 120 countries have already presented their long-term decarbonization strategies and their number will only grow. The principle of reconciliation of three benefits: economic, social and environmental has become common.

Over the longer term, achieving the ambitious goal of zero emissions requires the development of completely new industries in terms of technology – hydrogen energy, Carbon Capture Utilization and Storage (CCUS). According to IEA, these industries should account for at least 30% of the emission reductions by 2050 to achieve carbon neutrality by 2050. At the same time, the technology readiness level for many hydrogens and CCUS applications is very low, and the economic efficiency of projects is now beyond profitability. Therefore, many Governments are actively involved in technology development projects, especially in financing at the R&D stage. Thus, in the latest EU program "Fit for 55", the volume of public investment in hydrogen technologies and infrastructure by 2030 should be at least 37 billion. euro. Special funds have been created in the EU, the USA and China to finance green projects.

At the same time, the analysis shows that all estimates of the world's leading agencies do not imply a complete abandonment of the use of oil and gas even until 2050.

The most radical "net zero" scenario presented by BP assumes a reduction in the consumption of liquid hydrocarbons to 79 million barrels/day by 2035 (–21% by 2018) and up to 31 million barrels/day by 2050 (–69% by 2018), gas up to 3.5 billion. m3 by 2035 (–13% by 2018) and up to 2.5 billion. m3 by 2050 (–34% by 2018) [1]. OPEC and the IEA are traditionally more positive towards traditional fuels in their scenarios [2].

The most extreme "net zero" scenario presented by BP assumes a reduction in liquid hydrocarbons consumption to 79 MMBD by 2035 (–21% compared to 2018) and to 31 MMBD by 2050 (–69% compared to 2018), reduction in gas consumption to 3.5 BCM by 2035 (–13% compared to 2018) and to 2.5 BCM by 2050 (-34% compared to 2018) [1]. OPEC and the IEA are usually more positive towards conventional fuels in their scenarios [2].

As a result, in the long run, the exports of hydrocarbons will shrink and competition between producing countries will grow to conquer growing markets – Asia, Africa, etc. This means that resource rents and prices will decrease, and producers offering the most efficient supply will remain on the market. Moreover, it will be necessary to ensure the "carbon neutrality" of products, which is likely to increase in costs.

For the medium-term, there may be diametrically opposite trends. The Covid-19 pandemic and the ensuing price collapse have led to a significant disinvestment in hydrocarbon exploration and production worldwide. Thus, according to estimates, investments in the segment decreased by 30% in 2020–2021 [3]. As a result, countries with high production costs (the USA, Canada, Venezuela, Brazil, etc.) will be restricted in their ability to increase output to meet the growing demand in 2022+. And the market balance will depend on the ability of OPEC+ to supply additional volumes to the market.

Thus, the current market situation requires multi-vector technological development from the Russian Fuel and Energy Complex, the main directions of which should be:

- **Domestic Equipment and Technologies for Conventional Fuel and Energy Complex**

At the moment, Russian companies are still critically dependent on imports for a whole range of equipment and its components, which creates risks to project implementation and reduces the multiplier effect of oil and gas investments for the Russian economy.

- **Digital Transformation and Industry 4.0 Technologies Development**

Increasing the efficiency of the oil and gas industry and maintaining its position on the supply curve in the face of shrinking demand is impossible without mainstreaming digital solutions across business processes. According to various estimates, the introduction of digital solutions will reduce CAPEX for exploration and production by 10–15%, OPEX by 5–10% for comparable categories of reserves and assets. OPEX in logistics and sales may be decreased by 5–10%, by reducing losses and optimizing logistic routes. Modern modeling methods will improve the quality of design and engineering, which in turn will reduce the commissioning period for major projects by up to 40% [4].

- **Technological Competencies in All Key Areas of the Energy Transition: Renewables, Energy Efficiency, Electric Vehicles, Hydrogen, CCUS**

According to the most negative forecasts, revenues from energy carrier exports may fall by 50–80% as a result of reduced demand, sanctions and drop in prices. However, it should be understood that these forecasts assume the constant development of the domestic Fuel and Energy Complex which has considerable competencies in this area.

- **Technologies for Industrial Safety and Environment**

In addition to the risks to energy exports, global warming also poses significant challenges to the Russian FES in respect of industrial safety. The developed infrastructure of capital fuel and energy facilities in Russia and the actively developing infrastructure of renewable energy facilities require the creation of an innovative system of geotechnical monitoring.

Temperatures in the Arctic zone where most of the oil and gas production facility is located rises well above the global average. As a result, thawing permafrost may lead to man-made disasters and requires significant investment in infrastructure strengthening.

Permafrost soils (hereinafter referred to as PFS) occupy 65.5% of the country's area. Possible damage from predicted warming may amount to about 7 trillion rubles for industrial and civil facilities by 2050 in the Arctic Zone of the Russian Federation alone [5, 6]. With that, no damage assessment has been carried out for fuel and energy facilities.

Status quo of Innovative Development in Russia

Russia, which is one of the top 3 world energy producers, spends significantly less on R&D than the world leaders. According to the Federal State Statistics Service, the country-wide investments in energy R&D in 2020 will amount to 140 billion rubles. ($1.7 billion at the average rate of 2020). On average, government spending on science has been consistently around 1% of GDP over the past 10 years, several points below the top 30 countries in the Global Innovation Index 2021.

For comparison, according to the International Energy Agency, global investments in R&D in the Fuel and Energy Complex reached $120 billion by 2020. The leadership here belongs to the United States, where the government budget for R&D in the energy sector alone reached $9 billion in 2020. They are immediately followed by Japan, where in 2020 the state spent more than $3 billion on energy research [3]. The same countries are leaders in patents for inventions. They account for more than 60% of the total.

In Russia, at least 1.4 million people are employed in exploration, production, processing, transportation and distribution of hydrocarbons and at least 300 thousand people work at oilfield service companies, with a total annual turnover of at least 350 billion US dollars. An increase in R&D in this segment could be a significant driver for the development of the national economy. Russia's share in the global market for high-tech products is less than 0.3%. This suggests that the modern model of Russia's economy does not contain a modern competitive mechanism that stimulates innovation on a large scale.

For instance, in the Global Innovation Index 2020, Russia is ranked 45th, and the 29th in Europe. Expectedly, developed countries in Europe and the USA are ahead (Switzerland, Sweden and the USA are in the top three), and Asian countries are already in the lead: South Korea (5th), Singapore (8th), China (12th), Japan (13th); in the top 20 one country from the Middle East – Israel (15th). Large burgeoning low- and middle-income economies lag behind, including Turkey (41st), India (46th), Mexico (55th), Brazil (57th), Iran (60th), South Africa (61st), Saudi Arabia (66th), and Indonesia (87th) [7].

In 2019 and in 2021, industry surveys were conducted of the 50 largest fuel and energy companies in Russia from the oil and gas, electric power and coal industries, designed to reflect the technological needs of each industry, as well as plans for technological development of enterprises divided by time periods up to 2035, the possibility of import substitution in the main innovative areas, as well as the readiness of enterprises for technological cooperation. Companies were asked to evaluate 900 technologies in different directions, including companies were asked to choose the most relevant decardization technologies.

One of the main objectives of this study was to select the technologies that are most relevant and promising for each branch of the fuel and energy sector and to continue an integrated approach to prioritizing state projects for the development of technologies and import substitution programs. So surveys have shown that there are a number of reasons for the low level of technology development in Russia:

- 80% of fuel and energy companies do not consider technology as a necessary component of commercial success. Lack of economic motivation of corporations to innovate, monopoly position in the relevant market segment does not require intensive investments in innovations;
- Almost 80% of fuel and energy companies do not consider it possible to develop a high–tech solution with Russian partners in the form of academic institutes, universities, development institutes, originally designed to be at the forefront of technological development – to generate, combine and develop new innovative technological solutions. When developing new technologies, enterprises are most interested in working directly with equipment developers within the framework of joint ventures or consortia;
- There are high risks of introducing domestic innovative solutions (including the lack of insurance coverage) that have not been proven before;
- Significant difficulty in finding domestic technology solutions and ordering custom-made products, unreadiness to engage in the targeted development of domestic suppliers;
- Teaching Russian students on foreign equipment and using foreign technologies by default. Extreme deficiency of teachers with the skills of practical innovations and implementation of developments;
- Policy of isolationism and duplication in development projects among large Russian corporations;
- The need for multiple repetition of pilot tests in companies due to the lack of industry methods and practice of mutual recognition of tests;
- Conclusion of multi-year R&D contracts is problematic under 44-FZ and 223-FZ Federal Laws on procurement;
- Insufficient number of pilot production facilities capable of creating full-scale prototypes on a contractual basis, testing and certifying them, debugging the regimes for serial production.

In Russia, there is a multiplier for writing off R&D costs when calculating profit tax. However, the multiplier is not differentiated by types of technologies and amounts to 1.5. A single multiplier for all types of R&D in all industries is an additional indicator of the state's “indifference” to the direction of innovative development, although it is obvious that the potential return to the state from R&D investments, even in different industries, both in terms of economic development and budgetary efficiency, differs significantly. At the same time, the multiplier value at a relatively low profit tax does not give a significant incentive effect. For example, in Russia this effect will be equal to 30 kopecks for each invested ruble, while for Norway –0.91 (i.e. 1.3 x 0.7).

Thus, Russia currently has a number of structural problems along the entire technology value chain in the Fuel and Energy Complex (**Table 1**), related to the historical development of the country. Therefore, the active involvement of the State in the processes is essential.

Over the past 10 years, the Government has been actively working to create incentives and conditions for the development of technology. Thus, the Ministry of Industry and Trade of Russia has introduced a number of mechanisms to support R&D and pilot testing within the framework of the Industrial Development Fund and other programs. The need for technology development in the Fuel and Energy Complex is reflected in the strategic documents:

- Fundamental Research Program until 2030.
- Energy strategy of Russia until 2035.
- Socio-Economic Development Strategy until 2030.

However, at the moment Russia needs to form a unified technology policy in the Fuel and Energy Complex, which would allow technology consumers to form their priorities, as well as allow manufacturers to understand the potential demand for their products and risks.

International Experience in Supporting R&D Investments

The success of new technology depends on the maturity of each stage of the innovation chain (Research, Development, Pilot Testing and Production). All stages are interrelated. In particular, incentives to conduct R&D are weak if there is no possibility to adjust the technology at the pilot testing stage, and/or its commercialization potential at the "Production” stage is low. Therefore, state policy in the field of fuel and energy innovation plays an important role in the technological continuity of these. The extent to which the State is required to engage in the R&D phases, and in particular the pilot testing, via direct financing and/or the provision of various regulatory incentives, is largely determined by the overall development of the country's institutional environment that facilitate the creation and commercialization of innovation.

Given the long-term investment cycle in the fuel and energy industries, the state participation at the stage of fundamental research and project implementation with low technology readiness (less than TRL7) is a priority in all countries. For this purpose, priorities and goals of long-term scientific and technological development are formed at the state level, direct financing of R&D by the state is carried out, and a test infrastructure (test sites) is created.

USA

The main priorities of the USA government policy in the field of innovation, including in the energy sector, are defined by “A Strategy for American Innovation”, approved in 2009. However, before that, the country had already created a significant infrastructure to support R&D in the energy sector under the leadership of the US Department of Energy.

For example, the success of the U.S. shale revolution is largely due to active government support. In 1976, at the request of the U.S. Congress, the Energy Research and Development Administration launched the Eastern Gas Shales Project (EGSP) program. Subsequently, the program was taken over by the US Department of Energy. The objectives of this program were to determine the recoverable shale gas reserves in Devonian deposits and to select and develop the most effective technologies for its production. The budget of the program during its validity period from 1976 to 1992 amounted to approximately $185 million at 2011 prices. Subsequently, the studies were financed from the royalty trust fund [8].

The National Laboratory System, created also under the auspices and at the expense of the US Department of Energy in the early 1940s, plays an important role in coordinating R&D and Pilot Testing in the USA. It was supposed to work on issues related to national security, including energy, environment and fundamental science.

Currently, there are 17 national laboratories in the United States, which employ about 30.000 scientists in the following areas:

- Scientific laboratories (Princeton Plasma Physics Laboratory, Pacific Northwest National Laboratory, etc.);
- National Nuclear Security Management Laboratory;
- Energy Efficiency and Renewable Energy Laboratory (National Renewable Energy Laboratory, NREL);
- Laboratory of Atomic Energy, Science and Technology;
- Environmental Management Laboratories;
- Fossil Energy Laboratory (National Energy Technology Laboratory, NETL).

Tax incentives for research in the United States are provided at the federal, regional and local levels. At the federal level, there is a 100% deduction from the corporate income tax base for 100% of research and experimentation costs that are related to the taxpayer's trade or business, except for the costs of acquiring or improving land or property (§ 174 of the Internal Revenue Code). If the deduction for research and experimentation costs has not

Problems of Institutional Development in Russian Fuel and Energy Complex

RESEARCH	DEVELOPMENT	PILOT TESTING	PRODUCTION
Lack of R&D priorities	Poor market institutions and infrastructure	Poor communication / long learning	Low commercialization potential
· The oil industry provides 40–50% of federal budget revenues – an indicator of R&D priority, which is poorly considered. · High scientific potential and relatively high research costs are "dispersed" in various areas.	· Weak venture capital market. · Tight credits. · High dependence on imported service and equipment. · Weak competitive environment in the service. · Poor industrial infrastructure. · Weak fiscal incentives for R&D.	· Small number of companies working on similar technologies. · Low level of information communication between companies. · Rigidity of subsoil use conditions. · Lack of sites for technology maturation. · Duplication in development projects among large Russian corporations.	· High tax burden (even taking into account tax abatements for formations). · Lack of targeted incentives for technology application.

been used by the taxpayer, such costs may be amortized over 60 months [9].

In addition, federal legislation provides an additional deduction for research costs, which is as follows:

- 20% of the increase in "qualified research expenses", which are understood as both in-house R&D expenses and a certain share (65–75%) of the "contract research expenses" to third-party organizations for research work performed above the "base amount" which is calculated either as the average research costs over the last four years, or as the product of revenue and the share of research costs in the period 1984–1988. At the same time, the "base amount" cannot be lower than 50% of the "qualified research expenses";
- 20% of payments for fundamental research;
- 20% of the amounts paid or incurred by the taxpayer in carrying on any trade or business of the taxpayer to an energy research consortium for energy research (§ 41 of the Internal Revenue Code).

The R&D exemptions provided for in § 174 and § 41 of the Internal Revenue Code are duplicated at the level of almost all states in relation to the regional corporate tax.

There are also subnational and local government exemptions on sales tax and property tax for research organizations.

Norway

Norway has also laid out priorities in the National Petroleum Technology Strategy "Oil and gas for the 21st century" (OG 21), which aims to ensure a sustainable profitability of the petroleum industry and optimize the resources of the Norwegian Continental Shelf (NCS), as well as to identify technology "gaps", assist in the commercialization and scaling up of technologies and knowledge. The strategy consists of two documents – a medium-term development plan, updated every 4–5 years, and an annual in-depth analysis of the industry, which brings up topical technological problems.

Funding for programs and private projects is provided through the Research Council of Norway (RCN). In total, there are 7 government programs at this level, two of which are directly related to the development of upstream oil and gas technologies at the R&D and pilot testing stages – DEMO 2020 and Petromarks. Petromaks is solely responsible for supporting projects at the research and development stage. DEMO 2000 is a large-scale program initiated by the Norwegian Ministry of Petroleum and Energy in 1999 to support the creation of test and pilot technology projects (test sites) to successfully take the technology through the pilot testing stage.

Thanks in large part to the Petromaks 1.2 and DEMO 2000 programs, 4000 new technology projects have been implemented in Norway today, and about 30 test and pilot demonstration centers are in operation, most of which are private organizations [10].

In addition to providing targeted incentives for priority technology areas, developed countries' policies are aimed at creating a generally favorable environment for technology development projects at all stages from R&D to commercialization. The key tool for this is the tax policy of the state.

China

China offers significant incentives to R&D taxpayers. Since 1996, R&D costs have been deducted from the corporate tax base in an increased amount. In 2018–2020, the deduction is 175% of R&D costs, the government plan for the 14th Five-Year Plan (2021–2025) proposes to maintain this incentive, and for manufacturing companies the deduction is expected to increase to 200% of R&D costs [8].

"Technology-based service companies" and "high and new technology enterprises" can have their corporate tax rate reduced from 25% to 15%. The benefit is granted for "current investments" for a period approved by the authorities after reviewing applications for it.

For "high and new technology enterprises" established not earlier than January 1, 2008 in one of the five Special Economic Zones or in the "new zone" of the Shanghai Pudong District, two-year vacations or a halved rate may be granted for three years from the start of production activities or the appearance of operating profit. Also, for such enterprises, tax losses can be carried forward for up to 10 years beginning January 1, 2018.

Tax incentives at the federal, regional and local levels can also be provided for residents of Technological Development Zones.

Conventional FES and Energy Transition – The Main Drivers of Scientific and Technological Development of the Country

Paradoxically for the external observer, the conventional FES, namely the creation of domestic innovative technologies based on the relevant applied scientific and technological developments and the results of fundamental research in the oil and gas industry, in the electric power industry, in the nuclear industry and the coal industry, including in the entire mining and processing industry, is a key driver of the practical step-by-step implementation of the energy transition in Russia on the time horizon until 2060 [11].

Thus, in the Russian oil and gas industry, in the upstream sector, seven areas of development until 2035 are distinguished in order of priority and efficiency for the innovative technological development of the industry as a whole. The profound transformation of the upstream sector to meet the challenges of the energy transition will entail an intensive development of equipment and technology of oil and gas transport and processing.

The first two priority areas are equipment and technology for well construction and production stimulation.

Creation of Russian fleet of hydraulic fracturing equipment is the most well-known and already actively implemented project involving relevant federal ministries, state-owned enterprises and private companies. In 2021, the first prototype of the local hydraulic fracturing fleet was manufactured. The hydraulic fracturing fleet project was created by JSC "Corporation "Moscow Institute of Heat Engineering" and manufactured at JSC "Federal Research and Production Center "Titan-Barrikady". More than 1.000 enterprises are involved in the creation of equipment package [12].

In the future, the equipment and materials elaborated to increase the oil recovery and develop hard-to-recover reserves may be used to prepare reservoirs for the conversion and storage of carbon dioxide and other greenhouse gases.

Technologies of thermochemical impact on source rocks are promising for wide development of hard-to-recover reserves, including those in the producing fields with extensive infrastructure. One of the technologies being developed is the generation of supercritical water and its subsequent injection into the formation at a temperature of 600 °C and a pressure close to 40 MPa for desorption of heavy hydrocarbons and the generation of synthetic oil from kerogen. This technology can make production of hard-to-recover reserves in Western Siberia and the Volga region profitable for 3–5 years.

Difficulties in these projects are related to the creation of domestic high-tech materials: steel, polymers, etc., as well as to the development of manufacturing technologies, the creation of energy-efficient and small-sized complex equipment units, such as an internal combustion engine with a power of 2500–3000 hp, which requires comprehensive applied scientific research.

From a technological and engineering point of view, the main problem in the development of deep oil and gas formations in brown fields, which also belong to hard-to-recover reserves, is the search, development and testing of high-tech methods for the construction of deep exploration and production wells to vertical depths of 4.000 to 7.000 meters at a price comparable to the cost of construction of directional wells in Jurassic deposits in Western Siberia, the vertical depth of which does not exceed 3.000 meters.

It is required to develop a highly automated digital drilling facility with a capacity of 320–450 tons, light-alloy drill pipes comparable to steel pipes in strength properties, a bottom hole assembly with equipment designed for operating temperatures over 90–100 °C.

Having achieved the stated goals for well construction equipment and technology, in addition to a several-fold increase in the energy efficiency of the HTR development, it will be possible to start development of one of the most promising branches of renewable energy – deep geothermal energy. For example, one of the promising technologies is deep closed-loop geothermal systems, which require wells with a vertical depth of 5 to 10 km with bottomhole temperatures of 250 °C to 350 °C and extremely high pressures. One well in this case can produce up to 55 MW almost anywhere in Russia and the world [13].

The third priority is the well logging metrology, namely, solving the problem of the lack of rock reference standards. Availability of the reference standards in leading geophysical enterprises in Russia ranges from 10 to 35%, which directly affects the reliability of state accounting of crude hydrocarbons. The oil recovery factor in the Russian Federation is currently estimated with an error of at least 10%, which in some cases reaches 50%.

Lack of a number of reference standards, in particular such as porosity standards for dolomitic oil-saturated and gas-saturated rocks, does not allow Russian geophysics to develop fundamentally new well logging methods and equipment, such as magnetic-resonance formations imaging, sonic scanners showing fractures in formations, spectroscopy, etc.

The fourth priority may include dedicated software (hereinafter referred to as SW) for dynamic simulation of all types of reservoirs and fluids, SW for building integrated field models (reservoir—wells—gathering system—oil and gas treatment units) and others.

The fifth priority is field performance monitoring and evaluation technologies such as fiber optic inflow monitoring systems, microseismic monitoring and multiphase flowmeters.

The sixth priority is the development, testing and implementation of geotechnical control methods for the fuel and energy facilities and their territories using space remote sensing and surveying techniques in order to increase the control efficiency, expand the list of parameters monitored, reduce the amount of manual labor and costs of work, without compromising quality of the data obtained. As well as the creation of a state monitoring system to monitor changes in PFS and effective means of stabilizing and preventing emergency situations at fuel and energy facilities, such as an environmental disaster in May 2020 in Norilsk.

In the seventh block of priorities, it is possible to distinguish the technology of reinjection of associated petroleum gas into source rocks to increase oil recovery, technological equipment which in the future will almost completely meet the task of injecting carbon dioxide into formations.

As a result of the implementation of the first RES support program, valid until 2024, a separate industrial sector was created in the Russian Federation, including companies that develop separate innovative solutions and enterprises that serially produce equipment for “green” energy.

The second stage of the RES support program is aimed at increasing the equipment local manufacturing content. In the period from 2023 to 2035, more than 6.7 GW from renewable energy generating facilities will be commissioned, including 2.4 GW from solar power plants, 4.1 GW from wind power plants and 0.2 GW from small hydropower plants.

As a result, Russia has created a manufacturing base for the production of RES equipment, which has led to a decrease in construction costs. The construction costs for the 1 kW of solar power plants dropped from 115.7 thousand rubles in 2013 to 49.8 thousand rubles in 2019, and these for wind power plants dropped from 155.1 thousand rubles in 2015 to 65 thousand rubles in 2019–2020 [14].

The current global political situation in recent years directly affects the export industrial policy of most of the world’s RES raw material supplying countries and manufacturers of equipment and components.

Thus, suppliers of rare metals and rare-earth elements (hereinafter referred to as RM and REE) play a key role for all priority technologies of the energy transition, namely photovoltaic technologies for solar power, technologies for the manufacture of wind power plants with high efficiency, technologies for the hydrogen production through electrolysis, and energy storage technologies [15].

Russia, with its extensive base for RM and REE production, is not a significant player in the REE market; moreover, the domestic REE industry is experiencing a profound decline: it only produces semi-finished products (collective REE concentrates). Raw materials and primary RM and REE are included in the value chain of Western countries, with China dominating the global REE market.

In order to increase, both in terms of quality and quantity, the local manufacturing content for renewable energy equipment, the government, together with business community, over the next 10 years should focus on the development and manufacture of converter equipment, including power electronics, in addition to restoring RM and REE production. The development must be comprehensive, from the manufacture of materials, mastering of chemical technologies to integrated management systems for complex systems of energy generation, storage and distribution.

In addition to the development of wind and solar energy, Russia has broad prospects in the global market of hydrogen energy and rapidly growing geothermal power generation.

State Technology Policy

In the next three years, it would be advisable for the government to increase its attention to the innovative development of the Fuel and Energy Complex (hereinafter—FES), a key sector in the economy, given the breadth of coverage of related industries, primarily to ensure the anticipated growth rate of industrial production at 3.3% in 2022, 2.4% in 2023 and 2.2% in 2024 for Russia as a whole.

Now the main task for large fuel and energy companies, within the current market economy model, is to implement business processes based on promptly found or, more often, existing solutions, as well as to use the services of foreign service companies to carry out critical types of work.

At the state level, the main efforts are focused on ensuring the technological self-sufficiency of already developed and applied technologies, as well as on providing various tax incentives and preferences in the mineral resource economic sector due to the deteriorating quality of the conventional resource base.

For the purposes of import substitution, there are a wide range of disparate, often unrelated within individual federal agencies, government measures to support the scientific and technological development of individual industries, including FES which undoubtedly constitutes the basis and the main driver of industrial growth. At the same time, at the federal level, little attention is paid to the creation of a holistic scientific and technical policy for the development of the country's economy [16].

It is worth noting that in the world practice innovative solutions are formed by a vast layer of venture capital companies. For example, multinational vertically integrated oil companies typically take the lead or often co-invest in venture capital projects of various forms. In the perimeter of one company, it is impossible to provide a solution to state scientific and technological problems.

Drawing parallels with Norway, where FES plays a similar role in the country's industrial development as in Russia, we can highlight the process of allocating the right to use subsoil areas. The rights are issued by competition, and not by auction. The process of granting rights is aimed at forming a competitive environment to increase the scientific and technological potential of their own industry as a whole by creating new competencies, for example in the oil and gas industry. As a rule, one license is granted for three or four companies, including 50% plus one share to Equinor, state-owned company, 25% to foreign companies, and 24% directly to the state. Also the obligations on personnel, development of national science are defined, including fundamental science, creation and localization of technologies. Now in Norway the actual domestic content in deliveries of the equipment exceeds 70%. With that, the oil and gas sector provides knowledge-intensive services and equipment worth more than 60 billion USDIt is certainly not possible to fully replicate practices that have been tested in other countries. But it is necessary to establish meaningful and practical interaction between economic, industrial and science and technology policies within the country right now.

Because of the wide range of economic, technological, structural and legal issues in Russia, the state participation at all stages of innovation is important for the development of the oil and gas technologies; and it is necessary to create favorable economic and administrative conditions for the operation of technology companies. For this purpose, a unified technology strategy for development of the Fuel and Energy Complex and related industries should be formed and consolidated at the Government level, which would set priorities and create mechanisms for the technology development. The mechanisms can be tentatively divided into 4 blocks: economic incentives, infrastructure development, removal of administrative barriers (regulatory environment), and human resource development.

Based on the analysis of domestic barriers and international experience, the following enabling mechanisms can be considered as **economic incentives**:

- Providing grants on a competitive basis to small, medium and large companies in the priority areas of the industry development;
- Improving tax incentive tools for innovative activity of enterprises;
- Introduction of accelerated depreciation (2–3 times) subject to mandatory replacement with a domestic product / technology;
- Provision of tax credits (a share of investments, in the USA 25% is provided); also, in case of annual growth of R&D costs (from 5%), a multiple exclusion of such costs from the enterprise profits is proposed;
- Direct funding programs for priority activities.

Infrastructure development:

- Support for the development of research and production consortia in the priority areas of the industry development;
- Improving the system for supporting the export of high-tech products through the creation of specialized marketplaces;
- Establishment of federal testing centers – test sites;
- Formation of public-private metrological testing centers.

Regulatory Environment:

- Direct administrative stimulation of large public sector companies, as well as companies operating in the field of natural monopolies, to formulate and implement innovative development programs;
- Formulation of the "right to error" mechanism when launching pilot projects, creation of test sites;
- Enshrining the developers' ownership of their intellectual work in obtaining state support for financing of research work;
- Revision of localization requirements and introduction of localization requirements for R&D when issuing permits for subsoil use;
- Improvement of standards. For example, right now, fully robotic and human-controlled equipment may not be located on the same site at the same time.

Human Resources:

- Development of training plans and programs, arrangement of educational, methodological and logistical support;
- Development of master's degree programs and additional retraining courses in renewable energy with mandatory visits to production facilities;
- Introduction of the best Russian equipment and software in the educational process on a mandatory basis;
- Creating comfortable conditions for scientific and practical activities for university students: convenient infrastructure inside the academic and research centers, transport accessibility and others;
- Extensive use of capabilities of scientific and educational centers (SEC);
- Digital transformation of education (creating a digital university and knowledge banks);
- Active interaction between fuel and energy companies and leading Russian and foreign universities for arranging international internships and targeted student recruitment to meet the prospective demand for qualified personnel.

Conclusions

Against the background of a new round of tough sanctions policy by countries with developed industrial technology – holders of at least 70% of all the world's technologies in the energy sector, the state needs to increase attention to the socio-economic and fundamental and technological development of the Fuel and Energy Sector as a whole, a key sector in the economy, given the breadth of coverage of related industries.

The creation of new market directions and the qualitative expansion of existing industrial sectors is only possible by solving some increasingly complex and increasingly less conventional engineering and technological problems and tasks. The key role in this process is played by fundamental science and its direct connection with applied science and directly production.

The joint work of the state and business should result in serial innovative equipment and technology solutions for the implementation of a gradual energy transition of the entire Russian economy, namely:

- technologies that increase energy efficiency / digital technologies for conventional complex energy-saturated systems used in the Fuel and Energy Complex, including for the oil and gas industry: drilling rig 2.0 – a robotic drilling platform, a hydraulic fracturing fleet with an electric drive, the introduction of permanent-magnet electric motors in all technological systems, technologies for the development of hard-to-recover reserves that have no analogues in the world, the widespread use of electric energy storage systems together with the power supply of autonomous facilities by gas-turbine power plants, the growing use of mini LNG plants for the development of new territories;

• in turn, the use of energy-efficient robotic and digital technological systems in drilling, along with the introduction of new hydrocarbon production technologies, should ensure the fulfillment of objectives set in the Energy Strategy of the Russian Federation until 2035 – to maintain the current high levels of oil production in the Russian Federation in the long term. First of all, this should be ensured by increasing the oil recovery factor at the producing oil fields up to 40% within 15 years, the beginning of wide industrial development of marginal fields and ensuring cost-effective extraction of hard-to-recover heavy oil from low-permeability formations, from great depths, in the shelf area of the Arctic seas;

• dedicated software plays an increasingly significant role in the transformation of the oil and gas industry. Without this software it is impossible to solve the problems of hydrocarbon production and implementation of import substitution plans [17]. Modern software is beginning to use modules with artificial intelligence (AI) elements, in particular, to optimize field prospecting and exploration, determine reservoir properties, plan well designs, optimize the drilling process, model hydraulic fracturing, optimize oil production, and analyze risks in reservoir engineering;

• one of the areas of decarbonization of the global economy is hydrogen energy technologies which has received additional impetus for development in connection with the climate agenda and the commitment of countries around the world to a low-carbon transition [18]. According to various estimates, by 2050, the share of hydrogen in the world energy balance may increase many times and reach 4 to 24% of end-use energy demand. For Russia, in addition to hydrogen energy technologies, it is worth highlighting the prospects of deep geothermal energy, primarily due to high competencies in well construction and the use of superheated steam in the energy sector;

• the predicted continued relevance of fossil carbon-bearing raw materials in the energy and chemical industries makes the introduction of carbon capture, utilization and storage technologies one of the most important ways to reduce emissions. Traditionally, CO_2 disposal technologies include injection into various types of geological reservoirs, such as salt-bed underground storage, depleted reservoirs due to oil production, disposal in coal seams, and others. There are many geological systems that naturally retain and store CO_2 for thousands of years. In addition, the oil and gas industry has long used CO_2 to increase oil recovery.

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