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Innovation Processes in the Energy Sector of the Arctic Region

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Abstract. Moving forward, striving for perfection of any human activity is associated with innovative development of technologies, manufactured products, labor relations and other factors. The study presents the results of the joint activities of educational, scientific and industrial organizations in the energy sector of the country. It has been established that with the acceleration of scientific and technological progress, innovations and investment technological processes are becoming key components of government and business activities that contribute to the development of energy sector companies to ensure their long-term competitiveness, which is especially important when implementing Arctic projects. The importance of developing and creating an innovative technological product is especially acute in the energy industry that provides life support for people, businesses, and the country. The energy sector is a rather conservative industry in terms of innovations (this is due to the long life cycle of the main equipment, which is several dozens of years), created by domestic enterprises using exclusively domestic components. Modernization and construction of new facilities in the Arctic zone of the Russian Federation in the energy sector requires significant investments with long payback periods, which is a significant factor in decision-making. Small and medium-sized businesses operating in the energy sector are set to make a profit in the short or medium term, but such companies are characterized by a low level of research and development. Nevertheless, the reconstruction of the energy sector is an urgent topic for the industry today, due to the fact that the wear and tear of equipment exceeds its service life. The key results of investment activities and key trends in the development of the energy sector, including in the Arctic, are highlighted. The purpose of the study is to identify long-term trends in innovative technological solutions in various areas of the country's energy sector and to determine methods for their application in Arctic projects.
Keywords: *economics, energy, technology, Russian Arctic zone, innovation, investment, renewable energy source, nuclear energy, scientific and technological progress, generation*

Introduction

Energy supply for industrial and socio-economic exploration and development of territories is a key issue, and for the Arctic zone of the Russian Federation (AZRF) it is particularly significant and of paramount importance: heat and electricity are the main necessity for life [1, 2]. Conceptually, the processes of technological development and security of the energy sector in the Arctic need to be considered from the perspective of such key aspects as:

- The Arctic territory and water area is the dominant source of fossil energy for the economic interests of the entire state;
- AZRF as a vast area where large economic activities take place, requiring impressive energy resources;

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- The energy sector of the Arctic zone is a major investment project of the state and business.
- It is useful to consider these aspects together and in line with the general trends that have emerged since the February events in the energy sector and the country.

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The objective reality of the current stage is the division of the world into “friendly” and “unfriendly” countries, which leads to stagnation of international cooperation in all political, economic and socio-cultural aspects between these countries. Companies from “unfriendly” countries are leaving Russia, losing their profitable business in a market built over decades, which had the status of one of the most important and in-demand in the global economy, and suffering great financial losses. A situation with Russian business leaving the markets of these countries is mirror-like. Joint economic and scientific projects are put on pause; in extreme cases, they are closed. The energy sector of Russia, as the “sharpest indicator”, has demonstrated the failure of the theory of the international division of labor (with “unfriendly” countries), and Russia relies on its own resources in its development [3]. Nevertheless, Russia does not put down the “iron curtain”, but, on the contrary, makes serious efforts to maintain ties with the leading economies of the Eastern world in order to create and possess innovative competencies and technologies [4].

High-tech processes in the energy sector of the country form the global competitiveness, and consolidation and exchange of scientific developments based on innovative competencies are becoming a determining indicator in the implementation of unique technologies.

Innovations and innovative technologies

Unique technological innovation systems (TIS) are widely used in the development of innovations, increase the reliability of heat and power supply, improve the economic performance of energy systems, and determine the political and social factors of the citizens of the country-developer [5].

Federal Law No. 127-FZ “On science and state scientific and technical policy” [1] defines the basic concepts (Article 2) in the field of scientific, innovative activities, etc.

Innovative activity — activity (including scientific, technological, organizational, financial and commercial ones) aimed at the implementation of innovative projects, as well as the creation of innovative infrastructure and ensuring its activities.

Innovative infrastructure — set of organizations that contribute to the implementation of innovative projects, including the provision of management, logistics, financial, information, consulting and organizational services.

[1] Federal'nyy zakon ot 23.08.1996 g. № 127-FZ «O nauke i gosudarstvennoy nauchno-tekhnicheskoy politike» [Federal Law No. 127-FZ of August 23, 1996 “On Science and State Science and Technology Policy”]. URL: http://www.kremlin.ru/acts/bank/9973 (accessed 05 January 2023).

Innovation — new or significantly improved product (good, service) or process, new method of sales or new organizational method in business practice, workplace organization or in external relations.

Technological innovations are developed and used in the widest range of the energy sector: generation, transportation, conversion, diagnostics, system mode control, automation and digitalization, etc.

The determining condition is the level of research and development (R&D) and the level of scientific and technological progress (STP), in particular in the energy sector, in the broadest sense, of the country as a whole [6, 7].

Key results of investment activity in 2020

According to the results of the study "Innovative development of the Russian Federation in 2020" by the Federal State Budget Scientific Institution RI FRCPECS [2] data on macroeconomic indicators, innovative potential, infrastructure and human resources are presented, as well as financial support of innovation, results of the innovation activity of the Russian Federation in 2020.

Analyzing macroeconomic indicators, we note the key ones:

- population: as of January 1, 2021, the population of the Russian Federation amounted to 146,171.0 thousand people (in 2020, compared to 2021, the population decreased by 577.6 thousand people);
- industry: in 2020, the industrial production index decreased and amounted to 97.9% compared to 2019. Growth was noted in the Central (+ 9%) and North Caucasus (+ 8.4%) federal districts;
- investments: in 2020, 20,302.9 billion rubles of investments were attracted to develop the economy and social sphere of the Russian Federation. The dynamics of investments in fixed assets for comparable purposes in 2020 amounted to 99.5% compared to 2019;
- infrastructure potential: in 2020, 11386 organizations were involved in innovative activities in the Russian Federation, which is 15.7% more than in 2019;
- financial support for innovations: financing of internal costs for R&D in 2020 in the Russian Federation amounted to 1,174,534.3 million rubles; in the structure of internal expenditures in 2020 in the Russian Federation, 92.9% accounted for internal current costs and 7.1% — for capital ones; in terms of socio-economic goals in 2020, R&D in the field of industrial production was the most financed — 28%, and the general development of science — 19.1% of the total domestic research and development costs (Table 1); expenses for technological innovations (innovative activity) in 2020 in the Russian Federation amounted to 2,134.0 billion rubles (Table 2);

[2] Federal State Budgetary Scientific Institution "Research Institute – Republican Research Scientific and Consulting Center of Expertise". URL: https://www.miiris.ru/digest/analitika_RF.pdf (accessed 05 January 2023).

- results of innovative activities: in 2020, enterprises and organizations of the Russian Federation shipped innovative goods, works, services worth 5,189,046.2 million rubles; the following intellectual property objects were used: 20636 inventions, 16920 computer programs, 7098 utility models, 2825 industrial designs, etc.; the coefficient of inventive activity in the Russian Federation in 2020 amounted to 1.63 patent applications filed per 10 thousand people. Since 2015, the innovative activity of scientists has decreased by 18.5%.

Table 1

Internal expenditure on research and development in the Russian Federation for socio-economic goals in 2020, million rubles; %

Scientific research and development	Million rubles	%
Industrial production	329 248.2	
General development of science	223 783.0	19.1
Production, distribution and rational energy use	32 888.6	2.8
Social purposes	70 988.4	6.0
Use of space for peaceful purposes	48 882.6	4.2
Agriculture, forestry, fishing	30 140.8	2.6
Exploration and use of the Earth and atmosphere	44 365.8	3.8
Other purposes	394 236.8	33.6

Table 2

Spending on technological innovations by socio-economic goals in the Russian Federation in 2020, million rubles; %

Scientific research and development	Million rubles	%
Research and development of new products, services and methods of their production (transfer), new production processes	945 623.9	44.3
Purchase of machinery, equipment, other fixed assets	713 523.8	33.4
Engineering	149 772.7	7.0
Development and purchase of computer software and databases	87 331.9	4.1
Other costs related to innovation activities	237 786.2	11.1

The energy industry of Russia is undergoing its rebirth, developing and introducing new technologies, it is being modernized at a rapid pace, since the population of the country is concerned about energy security, economical and safe use of energy resources [8].

Electricity production

In the Murmansk Oblast, which is fully included in the AZRF, the Arktika hydroelectric power plant (HPP) is being built as part of the concept of development of environmentally friendly electricity generating capacity with a minimal “carbon footprint” (the design capacity of the plant will be 16 MW). PJSC TGK-1 (“Territorial Generating Company No. 1”) [3] plans to launch the HPP using the latest technologies in 2026. HPP “Arktika” will be the eighth station of the Pazskiy cascade. Construction on the Paz River (Patsoyoki), flowing from Inari Lake (Finland) in the northwestern part of the Kola Peninsula, began in 1955 as part of the Soviet-Finnish-Norwegian cooperation involving the joint use of water resources [9, 10].

[3] PJSC TGK-1 (Territorial Generating Company No. 1). URL: https://www.tgc1.ru/about/ (accessed 05 January 2023).

State Corporation "Rosatom" [4] implements the concept of two-component nuclear energy using high-power reactors with a closed nuclear fuel cycle (CNFC) [11]. In 2022, Russian nuclear scientists brought the 4th power unit of the Beloyarskaya NPP in the Sverdlovsk Oblast to a 100% capacity level with a full load of innovative MOX fuel [5,6]. This fact demonstrates a technological breakthrough towards the closed nuclear cycle, and the use of MOX fuel will make it possible to increase the fuel base of nuclear energy by several times — reuse, after appropriate processing, the irradiated nuclear fuel of other NPPs and accumulated in nuclear "repositories" (storage facilities in Russia contain approximately 14.000 tons of SNF, which can be used for the production of MOX fuel and fast neutron reactors) [7].

In this case, the "peaceful atom" will work for the benefit of mankind and will be able to provide consumers with cheap electricity without harming the environment. The concept, for which the BN-800 was designed, was implemented. A unique power unit and automated fuel production at the mining and chemical plant (MCP) were built [8]. Beloyarskaya NPP plans to begin testing the BN-1200M reactor in 2023, which can become a serial project and close the nuclear fuel cycle in Russia's nuclear power industry.

Unique technologies in the nuclear power industry are being used by Rosatom in the Proryv project with the BREST concept [9] (Natural Safety Fast Reactor / Natural Safety Fast Reactor with Lead Coolant), which has the properties of eliminating accidents requiring evacuation, taking significant areas out of economic use, through unique design methods.

At the current stage, small modular nuclear reactors (SMRs) represent a promising development of nuclear energy. Existing SMRs and new ones under construction allow us to talk about their projection application.

- Operating. In 2020, the Russian floating power unit (FPU) Akademik Lomonosov was delivered to the Arctic sea port of Pevek in 2020 for the sustainable development of the northern remote territories with electricity and heat. A floating nuclear thermal power plant (FNPP) is a new class of mobile energy sources based on modern Russian nuclear technologies; its launch has become a real breakthrough in the generation of electricity and heat. It includes a network of unique infrastructure: FPU — equipped with two KLT-40S reactors; special hydraulic structures — to provide safe anchorage in the seaport;

[4] Gosudarstvennaya korporatsiya po atomnoy energii «Rosatom» (Goskorporatsiya «Rosatom») [State Corporation for Atomic Energy "Rosatom" (State Corporation "Rosatom")]. URL: https://www.rosatom.ru/index.html (accessed 05 January 2023).
[5] MOX fuel (Eng. Mixed-Oxide fuel) is nuclear fuel containing several types of oxides of fissile materials.
[6] Reaktor BN-800 polnost'yu pereshel na MOKS-toplivo [The BN-800 reactor has completely switched to MOX fuel]. URL: https://strana-rosatom.ru/2022/09/09/reaktor-bn-800-polnostju-pereshel-na-moks/ (accessed 05 January 2023).
[7] Chamuet G. Beskonechnaya energiya: v Rossii pridumali sposob sdelat' atomnye elektrostantsii «vechnymi» [Infinite energy: in Russia they came up with a way to make nuclear power plants "eternal"]. URL: https://hi-tech.mail.ru/review/59791-beskonechnaya-energiya-v-rossii-pridumali-sposob-sdelat-atomnye-elektrostancii-v/#a03_59791 (accessed 05 January 2023).
[8] Mining and chemical plant. URL: https://ru.wikipedia.org/wiki/Горно-химический_комбинат (accessed 05.01.2023).
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onshore platform with special facilities — to ensure the delivery of electricity and heat to consumers. The Akademik Lomonosov is a completely Russian development, project 20870 with an electric power capacity of 70 MW, and a thermal power of 50 Gcal/h [1].

- New. OJSC Atomenergomash [10] plans to build four FNPPs for the Baimskiy Mining and Processing Plant in the waters of Cape Nagleingyn in the Chukotka Autonomous Okrug (fully part of the AZRF) with eight RITM-200M reactors, optimized floating power units capable of generating 100 MW of electricity and 350 Gcal/h of thermal energy. The operating life of the upgraded units is up to 60 years. In the Chukotka Autonomous Okrug, a project will be implemented for the electrification of an industrial cluster using FNPP in the field of "green" generation; this project is also a pilot project for the serial production of nuclear floating power units of different capacities and different designs. New floating power units will be produced for different climatic conditions — for the Far North and for tropical latitudes — based on the RITM-200 and RITM-400 (more powerful version) reactors [11]. In general, an innovative and breakthrough solution for connecting consumers to electrical and thermal energy in remote areas is expected.

The construction of facilities at the Biamskiy MPP for the development of the Peschanka copper-porphyry deposit is the northernmost of the world's largest deposits and may become one of the most technologically advanced.

Rosatom State Corporation is one of the technology leaders in the clean energy sector. The company is actively working to create a high-tech basis in all areas: for example, at the Kola NPP (Murmansk Oblast), a new electrolysis plant of Russian production generated the first hydrogen necessary for cooling turbine generators. This unit produces hydrogen with a purity of 99.999%, and a special deionization system and other technical solutions ensure the reliability and safety of operation. Hydrogen energy is a priority area of scientific and technological development of Rosatom, and the experience of the Kola NPP in handling hydrogen has made it a pilot site for hydrogen production in the country.

The plans of Rosatom include the construction of more than three dozen units in different countries. The plants of the state corporation at different stages of production have modern technological equipment for the Indian Kudankulam NPP, the Turkish Akkuyu, the Chinese Xudapu and Tianwan NPP, the Rooppur plant in Bangladesh, the Egyptian El Dabaa, etc. [12].

The World Nuclear Performance Report 2022 [12] summarizes the results of 2021 in the global nuclear industry, based on data compiled by the International Atomic Energy Agency (IAEA)

[10] OJSC "Nuclear and Power Engineering". URL: https://www.atomic-energy.ru/Atomenergomash (accessed 05 January 2023).
[11] Plavuchie AES: mobil'nye atomnye resheniya dlya energosistem budushchego. Energeticheskiy forum «Tomekspo-2022» [Floating Nuclear Power Plants: Mobile Nuclear Solutions for the Energy Systems of the Future. Energy Forum "Tomexpo-2022"]. URL: https://www.atomic-energy.ru/news/2022/11/24/130533 (accessed 05 January 2023).
[12] World Nuclear Performance Report 2022. URL: https://www.world-nuclear.org/our-association/publications/global-trends-reports/world-nuclear-performance-report.aspx (accessed 05 January 2023).

for reactors in operation today and those currently under construction. This Report assesses the contribution of nuclear power to the world's energy supply.

The following statistics in nuclear power are noted.

Nuclear reactors generated 2653 TW/h in 2021, an increase of 100 TW/h by 2020. In 2021, nuclear generation increased in Africa, Asia, Eastern Europe, Russia, and South America. Generation has increased in Western and Central Europe, but the overall trend in this region remains downward. In North America, generation declined for the second year in a row as more reactors were shut down in the USA.

The global average installed capacity utilization factor (ICUF) of plants was 82.4% in 2021 (80.3% in 2020). An increase in ICUF on average around the world is observed in reactors of all ages, and not only in reactors of modern design.

Analyzing the Report of the Unified Energy System of Russia [13], the following key indicators should be highlighted:

- volume of electricity generation by UES power plants in Russia in May 2022 amounted to 85,834.1 million kWh. The main load in meeting electricity demand was carried by thermal power plants, which generated 41,671.5 million kWh. The generation of HPPs for the same period amounted to 19,380.8 million kW/h, the generation of NPPs — 18,511.8 million kW/h, the production of electricity by renewable sources of WPPs, SPPs — 451.6 million kW/h and 307.2 million kW/h respectively, the production of power plants that are part of the technological complexes of industrial enterprises and are designed mainly to supply them with electricity (power plants of industrial enterprises) — 5,511.0 million kWh [13].
- structure of generating equipment inputs at power plants of the UES of Russia (Table 3).

Table 3

Structure of generating equipment inputs at power plants of the UES of Russia in 2020–2022 (MW)

Year	Total	TPP total	TPP gas	TPP coal	TPP other	HPP	APP	WPP	SPP
2020	1 865.2	636.9	310.0	327.0		20.9		843.4	364.0
2021	2 716.1	286.1	286.1				1 188.2	1 008.9	232.9
01.06.2022	214.6	112.0	12.0	100.0					102.6

As a result, nuclear energy is perceived as an important measure for climate protection — it is recognition of nuclear power's role in achieving decarbonization goals.

Construction of power lines, transformation of power equipment

Construction of power facilities in the Russian Arctic is carried out in the extremely difficult natural and climatic conditions; therefore, the approach to construction work in these conditions should be based on the implementation of the basic principles of environmental safety, economic

[13] Edinaya energeticheskaya sistema Rossii: promezhutochnye itogi [Unified Energy System of Russia: interim results]. URL: https://www.so-ups.ru/fileadmin/files/company/reports/ups-review/2022/ups_review_0522.pdf (accessed 05 January 2023).

efficiency and technical reliability. At the current stage, the construction of a new 100 kV power transmission line (PTL) “Pevek — Bilibino” is underway. It will replace the existing transmission line, which is characterized by high wear and tear, and will ensure reliable power supply to the largest infrastructure energy center in Bilibino. The first phase of the project involves the installation of a 490.6 km single-circuit TL, the construction of a 110 kV Komsomolskiy substation and a Bilibino distribution point. The second stage will include the installation of the second circuit of the transmission line, the construction of the Betta switching station and the reconstruction of the Yuzhnyy substation. The implementation of the project involves the application of innovative high-tech solutions that are widely used in various areas of the energy sector. In particular, during the construction of 110 kV substations that provide the energy capacities of the Amur Gas Chemical Complex, the Moscow Elektrozavod designed a new modern three-phase block transformer with increased power of 80 MW and 160 MW. Advanced design solutions and innovative manufacturing technologies were used in the production of this power equipment. As a result, electrical devices comply with domestic and international standards in terms of technical characteristics, the equipment has become more convenient in installation and operation, and Russian-made intelligent monitoring and diagnostic systems allow to control the parameters of power units and to form an online forecast about their technical condition in advance for timely maintenance. To ensure efficient operation of the new power lines, it is possible to use an integrated monitoring system for overhead lines, which was developed and implemented by employees of the Kazan State Power Engineering University. The electrical device included in the system operates autonomously on the energy of the power line wire, reads and transmits its parameters necessary for online dispatch control: short circuit, breakage, ice formation, temperature measurement and much more.

In the Murmansk Oblast, proposals for the construction of a power transmission line for the technological connection of objects of the priority development area (PDA) “Capital of the Arctic” and the Arctic zone on the western coast of the Kola Bay are being worked out; according to preliminary calculations, approximately 3 billion rubles are needed.

When implementing the Vostok Oil project (north of the Krasnoyarsk Krai) [14], energy facilities are of key importance. It is planned to build 13 power plants with a total installed capacity of about 3.5 GW, about 200 electrical substations and more than 7000 km of transmission lines. These power supply facilities of the largest investment project of the Russian economy will be built using high-tech solutions to ensure maximum use of reliability and environmental safety conditions.

In the Arctic zone of the Russian Federation, the implementation of projects is mainly aimed at using “clean” energy with zero greenhouse gas emissions [15]. Companies implementing projects in the Russian Arctic strive to use wind energy globally. In the Murmansk Oblast, in December 2022, the first stage (capacity 170 MW) of the largest wind power plant in Russia, the Kolskaya WPP, was put into operation with a design capacity of 201 MW (the commissioning of the second final stage of the remaining capacity is scheduled for the 1st quarter of 2023). The pro-

ject is implemented by PJSC Enel Russia, more than 65% of the equipment and works were produced in the Russian Federation by local plants and specialized companies. On an area of 257 hectares, 57 wind turbines have been installed; for the technical connection of the project to the Unified Energy System (UES) of Russia, a 150 kV transmission line with a length of about 70 km was built, the blades of wind turbines are equipped with ice detection systems that allow early detection of the risk of ice formation and automatic stopping the rotation; SG 3.4-145 wind generators with a nominal capacity of 3.465 MW and a rotor diameter of 145 meters (manufactured by Siemens Gamesa) were installed.

Automated control systems have been widely used in the construction of power equipment of power stations and substations — one of the areas of breakthrough technologies application. Increased implementation of intelligent electrical devices, introduction of flexible monitoring systems open up opportunities to raise the economic effect of power facilities [16, 17]. Advanced technologies allow for greater use of mechatronic service devices, pick-and-place robots and drones. In particular, advanced robotic solutions are used in large oil transformers — a compact device with remote control — a robot with a hermetic trunk, the functionality of which allows to shoot the transformer from the inside and to transmit video to the operator via wired communication channels, which enables a rapid analysis of the problem with the involvement of highly specialized professionals. The undeniable advantage of implementing automated devices using innovative technologies is the economic component — the robot can operate 24/7 [18].

Science and higher education

Active participation of domestic science in developing knowledge-intensive products, services and ensuring the competitiveness of our country in the field of high technologies makes it possible to materialize the solutions demanded by the economy and introduce unique samples of industrial products. One of the most important areas where breakthrough scientific discoveries are needed to strengthen technological sovereignty is electronics [19]. The Government of the Russian Federation has set objectives for the development of its own specialized electronic engineering industry, production of components, technological and auxiliary equipment; an updated concept for the development of Russian microelectronics until 2030 has been developed [14], and funding of about 2.74 trillion rubles has been allocated. Nevertheless, leading scientific institutions are already working on solving problems related to the launch of new technologies [20].

Scientists from the A.V. Rzhanov Institute of Semiconductor Physics SB RAS and the A.V. Nikolaev Institute of Inorganic Chemistry SB RAS have developed a technology for creating a new generation of electronics devices. The innovative technology makes it possible to grow high-quality M-phase VO2 single crystals. M-phase crystals are capable of switching from the semiconductor state to the metallic state at close to room temperatures. Russian scientists have been able

[14] Minpromtorg podgotovil kontseptsiyu razvitiya otechestvennoy mikroelektroniki do 2030 goda [The Ministry of Industry and Trade has prepared a concept for the development of domestic microelectronics until 2030]. URL: https://www.gazeta.ru/business/news/2022/09/13/18549703.shtml (accessed 05 January 2023).

to synthesize not only single nanocrystals and their arrays, but also more complex VO2 structures in the form of three-dimensional arrays of nanorings. As a result of the research, a nanodevice formation technology was created for nanophotonics, which has found application in the creation of logical nanoelements in “smart” materials, neuromorphic computers, sensors and optical photonic devices [15].

Zelenograd Nanotechnology Center (ZNTC) is a resident of the Technopolis Moscow special economic zone (SEZ); it plans to launch the production of photonic integrated circuits and modules for telecommunications equipment. Photonic technologies are in demand among leading manufacturers and customers of high-speed equipment; they allow increasing the speed of information transfer by more than 100 times [16].

Scientists of Tomsk State University have studied photoconductive dipole antennas and characteristics of terahertz radiation [17]. As a result, the researchers of the Faculty of Radiophysics managed to increase the power of terahertz radiation by five times. The method of irradiating a terahertz antenna with high-energy electrons will expand the field of application of the developed antennas. These antennas have been successfully used in industry for spectroscopy to diagnose material quality; in medicine — for tomography; in communications — for creating terahertz wireless communication systems, etc. The frequency spectrum of submillimeter THz radiation is between the infrared and microwave ranges. Therefore scientists aim to discover new ways to improve its characteristics, which will create the opportunity to qualitatively increase and significantly expand the range of application of antennas.

National Research Center “Kurchatov Institute” — Central Research Institute of Structural Materials “Prometey” developed polymeric composite materials (PCM) for the energy industry — hydroelectric power plants (HPPs), nuclear power plants (NPPs), oil and gas, space industries, shipbuilding and other important strategic areas of industry and economy.

At the Innoprom–2022 exhibition, the Roselectronics holding of Rostec State Corporation demonstrated a sample of monocrystalline silicon created from Russian materials — an innovative technology that will completely replace foreign raw materials in the production of electronic power devices.

The discoveries of Russian science — the high-tech materials, electronic and electrical devices, other unique technological equipment — form a new model for the implementation of Arctic projects in the new economic realities.

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[15] Novosibirskie uchenye sozdali tekhnologiyu formirovaniya priborov dlya elektroniki budushchego [Novosibirsk scientists have created a technology for the formation of devices for the electronics of the future]. URL: https://scientificrussia.ru/articles/razrabotana-tehnologiya-formirovaniya-nanopriborov-dlya-nejromorfnyh-sistem-i-nanofotoniki (accessed 05 January 2023).

[16] Rezident OEZ «Tekhnopolis Moskva» nachnet seriynoe proizvodstvo fotonnykh chipov [Resident of the SEZ "Technopolis Moscow" will start mass production of photonic chips]. URL: https://technomoscow.ru/press/rezident-oez-tekhnopolis-moskva-nachnet-seriynoe-proizvodstvo-fotonnykh-chipov/ (accessed 05 January 2023).

[17] V TGU nashli sposob v pyat' raz uvelichit' moshchnost' teragertsovykh antenn [TSU found a way to five times increase the power of terahertz antennas]. URL: https://rossaprimavera.ru/news/8c1158d6 (accessed 05 January 2023).

Conclusion

Russian modern energy industry is undergoing a serious transformation; it is being modernized at a rapid pace, as this is required by the country's economic growth and consumer demand, as well as the economical and safe use of resources. The process of renewal and improvement is carried out in close cooperation between scientific organizations and industrial enterprises. The development and implementation of innovative technologies in the energy sector open up new opportunities to improve efficiency in the operation of plants, lines, heat supply, control and monitoring in the energy sector. New automatic and automated control systems, network technologies and microgrid complexes will enable efficient management of solar panels, wind turbines, tidal and geothermal energy, biogeneration and low-power nuclear power plants, climate control systems, smart homes, heating elements, etc.

In St. Petersburg, PJSC Gazprom Neft opened a Production Control Center at the Prirazlomnaya offshore oil platform in the Russian Arctic. The high-tech complex provides more efficient management of operations at the Prirazlomnoe field. The digital model and IT tools ensure online control over the main stages of oil production and offloading to tankers, efficient and safe operation of the platform on the Arctic shelf, monitoring of equipment integrity and tracking of vessel movement, taking into account ice conditions, and allow increasing the speed and efficiency of decision-making on management of the platform in the Barents Sea [21].

The leading research institutes [22], advanced enterprises and corporations are constantly working on the creation of new electrical technologies for different sectors of the economy. Modern innovative developments will mark the beginning of a new technological era and the technological sovereignty of Russia.

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