ISSN 2303-4521
Periodicals of Engineering and Natural Sciences *Review Article*
Vol. 9, No. 3, July 2021, pp.132-152

Trends and specifics of electric power industry development in the Russian Federation

Valery V. Bezpalov[1], Liudmila P. Goncharenko[2], Sergey A. Sybachin[2], Sergey A. Ionkin[2]
[1]Department of National and Regional Economics, Plekhanov Russian University of Economics
[2]Scientific Research Institute "Innovative Economics", Plekhanov Russian University of Economics

ABSTRACT

At the present stage, given the processes of globalization for the global economy, one of the key industries is energy. And with certainty, we can only talk about the growth of its consumption, despite the negative processes taking place in the economy in the last period. To meet the needs of production and municipal needs, there is a need for a constant increase in the production of energy feedstock, the production of electricity and its distribution. It should be noted that the amount of electricity generated corelates with the level of economic development of the country. However, some countries are forced to import energy resources from abroad without having their own. It is necessary to note such an aspect of energy development as an environmental factor. Indeed, energy is one of the biggest sources of anthropogenic emissions, it is about 42%. Aim of the paper is to study and analyze the trends and specifics of the development of the Russian electric power industry, as one of the main components of the energy complex. Such scientific methods were used, systematization, theoretical generalization and the method of comparison with the use of statistical analysis. Results of the study defines the integral concept of energy, image of the structure of energy complex in the Russian Federation, from various authors, defines the concept of electricity and factors of its development. Prospects for further research: due to further study of the issues of electric power industry development the in Russian Federation, for their subsequent study and search for solutions. Applied value of the material: lies in the possibility of working out problematic issues for further sustainable and effective development.

Keywords: Energy, Energy complex, Electric power industry, Electric power development factors, Specifics of electric power industry in the Russian Federation

Corresponding Author:

Valery V. Bezpalov
Department of National and Regional Economics
Plekhanov Russian University of Economics
117997,36 Stremyanny Lane, Moscow, Russian Federation
E-mail: bezpalov4690-6@uoel.uk

1. Introduction

Given the globalization of economic processes a constant energy demand increase can be predicted at the present stage of development. The main reasons for such processes are changes occurring in the energy complex itself, which are of a socio-ecological nature, structural and technological in nature. In addition, the reasons are the changes occurring in the economies of countries, in this situation we can talk about increased competition, crisis phenomena in the economy, cyclical instability and many other factors. It is in recent years that the active changes occurring in the energy sector are noticeable, which is due to transformational processes in relation to

people, safety and environmental acceptability, the emergence of new, more advanced energy production technologies. Provision of various types of primary resources is the basis for the development of the energy complex. Historically, people used clean types of energy resources (naturally-occurring resources) – animal power, waste, biomass and more. With the change in the resource base, water energy begins to be utilized. Currently, there is a significant expansion of the types of energy resources, but unambiguous preference is given to traditional types, which include oil (oil products), coal, gas. However, in view of growing trends regarding the ecological situation and the limited nature of traditional types of resources, more and more people are beginning to pay attention to non-traditional ones, which include the energy of the sun, wind, water (hydropower) and other types [1].

The electrical energy industry is one of the energy complex biggest elements. The level of energy availability, which is measured by the efficiency of use of the consumed resources, their quantity, and structure, is one of the main criteria of the country's economic potential. If we consider the electric power industry in the Russian Federation, it has significant resources and production potential, which in turn gives it the opportunity, in relation to the global fuel and energy market, to maintain a strong position [2]. However, the electric power industry has its own specificity, which consists in the impossibility of accumulating the products of this industry for its subsequent use, which leads to a correspondence in time and size of production and consumption of electricity (taking into account losses).

All of the foregoing, maintains the issue of researching trends in the Russian electric power industry, taking the specifics of its development. The research of issues regarding the electric power industry, the processes of its transformation has been and is being done by the following authors: D. Dyadkin, Yu. Usoltsev, N. Usoltseva [3]; A. Kopylov [4] and many other authors. It is necessary in this direction to note the work of V. Zubakin “An analysis of the trends in the transformation and development of the Russian electric power industry”, where the author describes four components in the development trends of the global electric power industry [5]. We can also note the work of foreign authors who conducted research in this direction: C. von Hirschhausen, C. Kemfert, C. Lorenz, P.-Y. Oei [6]; M. Child [7] and others.

The theoretical significance of the study lies in expanding and supplementing theoretical knowledge regarding the trends and specifics of the development of the Russian electric power industry. The practical significance lies in the fact that the problems in the electric power industry in the conditions of its transformation are quite relevant at the present stage, and the need to search for the main directions of development and optimal solutions determines the research of this issue. The purpose and logic of the research are predetermined by insufficient study, as well as by the theoretical and practical importance of the problem.

2. Literature Review

Energy is one of the important sectors of the economy, for any country and for the global economy as a whole. First of all, " concept of energy" and its components must be determined. The scientific literature has different approaches to the definition of a given industry, which is why it can be interpreted either very broadly or very narrowly. A narrow interpretation of energy implies that it refers to a field of activity related to electric and thermal energy generation for municipal or industrial consumption. This generation can be produced by power plants, thermal stations and boilerhouses, and generation can also be carried out on a small scale (small boilerhouses and means of generating electricity). That is, energy is the generation of electric and thermal energy, which, in particular, is written by M. Rapšík and co-authors, referring to energy as the electric power industry [8]. Often, in addition to the actual generation of energy, this also includes transportation and distribution of energy for various needs, for which different types of power transmission lines, distribution stations, heating lines (for distributing hot water for heating), energy facilities of enterprises and the public sector are created. A similar approach to the definition of energy as an industry is given in the works of such authors as E. Dyka, I. Mróz-Radłowska [9], P. Schwarz [10], N. Lyubimova and E. Petrovsky [11].

However, there is a broader interpretation of energy, when it refers to “the field of human economic activity, as

well as a combination of large natural and artificial subsystems that serve to transform, distribute and use various types of energy resources. The goal of energy is to provide energy production by converting primary, natural energy into secondary energy, for example, into electric or thermal energy" [12]. Energy generation (together with its distribution) and fuel production thereby form a single fuel and energy complex (FEC). The fuel and energy complex (FEC) are a set of industries that are interconnected with producing and distribution of energy in its various forms. The fuel and energy complex includes industries related to the extraction and processing of various types of fuel (i.e., the fuel industry), as well as the electric power industry, and enterprises for the transportation and distribution of electricity [13]. A similar approach, which treats energy as a fuel and energy complex, from the extraction of raw materials to the generation and distribution of energy proper, is followed by such authors as L. Melnik and I. Sotnik [14], P. Zweifel [15], L. Gawlik and E. Mokrzycki [16].
From here, we can imagine the composition of energy as a fuel and energy complex (Fig. 1).

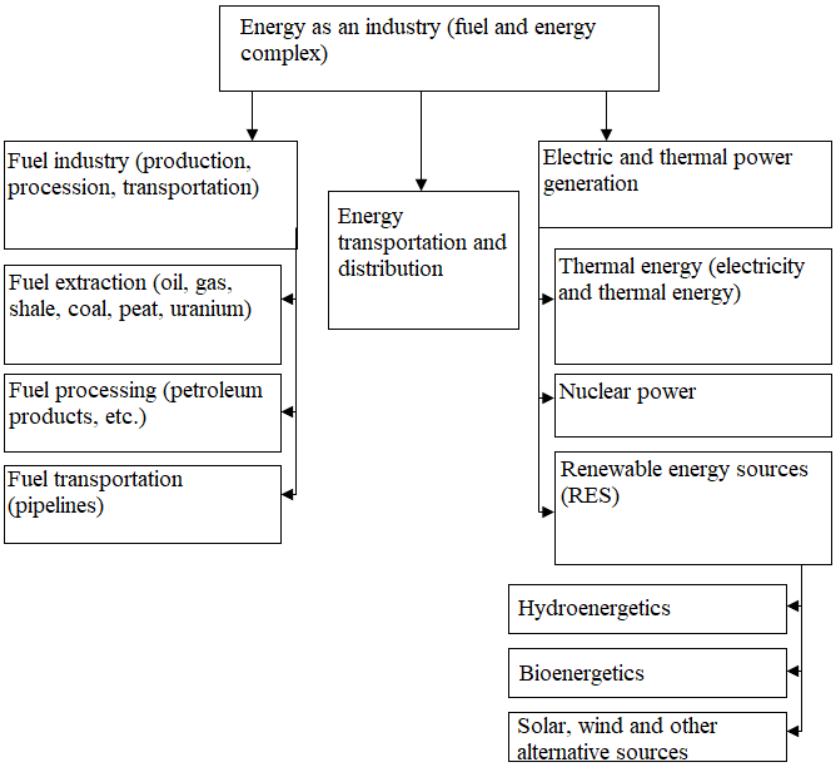


Figure 1. Composition of energy sectors (fuel and energy complex) [13, 14, 16]

It should be noted that one of the leading sectors of the energy sector is the electric power industry, which is represented in the form of three interrelated processes of production, transmission, and sales [17-33]. It is believed that this industry has a number of advantages relative to other types of energy, and so it is more important. These advantages include: the ability to convert into another type of energy (chemical, thermal, light, mechanical and other types); ease of transportation when considering significant distances; distribution between consumers (as one of the advantages) [34-48]. It can be argued that one of the distinguishing features of the electric power industry is the possibility of simultaneous generation and consumption, which is due to the speed of distribution (current distributes almost at the speed of light across networks) [49].
Process of converting various types of energy into electrical energy is called electricity generation. Basically, this process occurs within the framework of power plants, which can be divided depending on the conversion of the type of energy:

1. thermal – the generation of electricity through the energy of combustion of fossil fuels. The energy of combustion forms thermal energy, which is converted into electricity. Thermal power plants (TPP) included in the thermal power industry: cogeneration, condensation.

2. nuclear – the release of thermal energy occurs due to the fission of atomic nuclei in the reactor. The process of energy production is similar to thermal power plants, but still has a significant difference. Nuclear power is represented by nuclear power plants (NPP).

3. hydropower – in this situation, we can talk about kinetic energy (the energy of the flow of water), which through conversion is converted into electricity. This current is created artificially by creating an artificial difference in the surface levels of the water in the river, that is, it is created (mainly) using dams. In this situation, there is a natural movement of water (overflow), which drives the blades of the turbines located in the ducts of the dams. At the present stage, the direction for the use of sea currents is quite promising since it significantly exceeds the course of rivers. Electricity generation in this way is carried out at hydroelectric power plants (HPP).

4. alternative. This type of energy has become quite significant in recent years, taking into account the environmental situation throughout the world, as well as due to the limitations of traditional energy sources. The latter is an advantage of the alternative, as they are not limited. The main disadvantage is the high cost of technology (generators) and low power. But while alternative energy is not gaining significant distribution. Alternative sources of energy include: kinetic energy of the wind (wind energy); energy derived from sunlight (solar energy).

5. geothermal – within the given scenario, the Earth's natural heat is used to generate electricity. Conventional thermal power plants can also include geothermal ones; in thermal, a boiler or a nuclear reactor is used as a heat source for heating.

Wave energy, hydrogen and tidal are also types of energy generation.

Emerging trends in this area, processes associated with the introduction of cheaper electricity production, processes associated with the introduction of energy-saving methods, processes associated with the production of electrical equipment from materials that will have a higher reliability in comparison with traditional materials, will reduce energy losses, will have higher energy efficiency [50-67].

By V.A. Zubakin, these trends in the transformation of the electric power industry are considered as the "four D" principle [5]:

1. Diversification, is a gradual replacement of traditional energy sources with alternative ones, which finds its manifestation in the structure of the country's energy balance. If we consider some Western European countries, use of non-traditional types of energy, in some places it is more than 20%. This direction is quite relevant for energy-deficient countries.

2. Decorbonization – increasing the share of energy production and consumption without using crude hydrocarbons. The cause of this step for many countries was the growing environmental problems (emissions, global warming). Over the past thirty years there has been a decrease in the cost of renewable energy equipment, which makes it affordable for many poor countries, as well as makes this equipment competitive relative to traditional.

3. Decentralization – in this situation, a change in the hierarchical principle of building an energy system on a network can be noted. Violation of the traditional functional dependence due to the emergence of compact, low-power and efficient energy sources. In this situation, there is a saving in energy transportation and approaching the source of electricity to the consumer.

4. Digitalization – the possibility of intelligent control of power systems based on the widespread use of digital controlled devices. Digitalization allows us to solve the problem of the joint work of a huge number of distributed entities in the conditions of decentralization of architecture, taking into account the growing complexity of management due to the growing number of participants in the interaction.

By G.M. Yurkova, the data on the transformation trends in the electric power industry are reduced to the influence of factors [68]:

– climate change. This factor requires the use of high strength materials. To increase the reliability of power supply. The influence of this factor occurs through a direct effect (breaks on the lines), and indirect (due to an increase in the cost of servicing in places with severe climatic conditions);

– demographic factor that determines the shifts in the energy sector is mainly structural. In this situation,

we can talk about:

1) an increase in energy consumption in areas with a fixed population growth and overpopulation (for example, some Asian countries) and there is a decrease in energy conservation in countries with a decrease in population, in countries with the so-called “demographic pit” (for example, in some countries in Europe);

2) change in the load of existing electrical equipment due to increased global economic inequality, uneven population growth, and increased migration. A change in the load of electrical equipment leads to a lack of capacity in regions with population growth (electricity shortages), on the other hand, to a loss of electricity in regions with population outflows;

3) increase in energy consumption, which is due to the urbanization of the developing countries at the stage of industrialization [69-84].

– geopolitical factor, in this situation, the Kyoto Protocol is an example of an agreement on the regulation of environmental emissions, which was signed in 1997 as an additional protocol to the Framework Convention [85]. It regulates gas emissions for countries with economies in transition and industrialized countries (33 countries) by establishing a quantitative commitment to reduce emissions. Political factors include demand management, by regulating the pricing. This factor can be attributed to the long-term relative to the electric power industry.

– economic factor. At the present stage, there is a decrease in the rate of economic growth, which leads to a decrease in the consumption (mainly by enterprises) of electricity, respectively, the production of electricity, as well as its distribution, decreases. In this situation, we can also note the double influence of sanctions from Western countries, which on the one hand indicated the technological and investment dependence of the industry, on the other hand, the development of industries associated with high technologies was influenced.

– technological factor. The fact that the International Energy Agency (IEA) predicted an increase in energy consumption, and electric energy, relative to petroleum products, will become the most important energy carrier. The use of renewable energy sources (growth of generation by these sources) is also forecasted [68]. This is evidenced by the trends that occur with respect to inter-fuel competition, the emergence of technologies that contribute to the full switching between energy sources, also reduces the cost of non-traditional energy resources (the cost of own energy generation, namely the generation of electricity becomes close to the cost of connecting to a single energy system networks) [86-99].

A technological factor also includes new technologies in the energy sector development, taking into account the growing role of them in recent times.

At the same time, in most countries of the world, the basis of the electric power industry, in the near future, will be thermal power plants, state district power stations, nuclear power plants, hydroelectric power stations, that is, existing centralized power supply systems [100-118].

Summarizing the results of the analysis of literary sources, power industry is the main branch of the country's energy complex, presented in the form of three interrelated processes of production, transmission, and sales. Various factors like: demographic (structural changes), climatic (having both direct and indirect effects), economic, affect technological electric power industry development. Non-traditional sources, the introduction of energy saving methods, to the development and production of electrical equipment from materials that will have higher reliability compared to traditional materials, will reduce energy losses, will have higher energy efficiency.

Identifying effective policy instruments that can accelerate the ongoing transformation of the country's electricity industry.

3 Materials and methods

Analysis of trends requires the use of certain research methods, which include: the method of research of statistical data or statistical analysis. This method can be carried out both for the country as a whole and in relation to a certain territory.

In this context, we can use a system of indicators, which, in turn, will provide an opportunity to track the main trends in the country's power industry and see the specifics of the country's electric power industry:

– structure of the production of all energy in the Russian Federation;

– dynamics of changes in electricity consumption and maximum power consumption in the Russian Federation;

– primary performance indicators of the unified energy system of the Russian Federation;

– ECO (integrated energy systems) dynamics by region;

– dynamics of electricity production in Russia for the period 2015 - 2019;

– dynamics of power plants in the Russian Federation;

– structural changes relative to the power of electricity plants in the Russian Federation, calculated on the basis of dynamics indicators;

– dynamics of the specific consumption of equivalent fuel per one kilowatt-hour of electricity supplied to public power plants;

– dynamics of indicators of production, trade and electricity consumption in Russia;

– dynamics of investments in the electric power industry in Russia;

– investments in renewable power resources of the Russian Federation in comparison with countries.

Research period – 2015 - 2019.

As part of the analysis of statistical indicators, the use of dynamic analysis of data volumes is carried out.

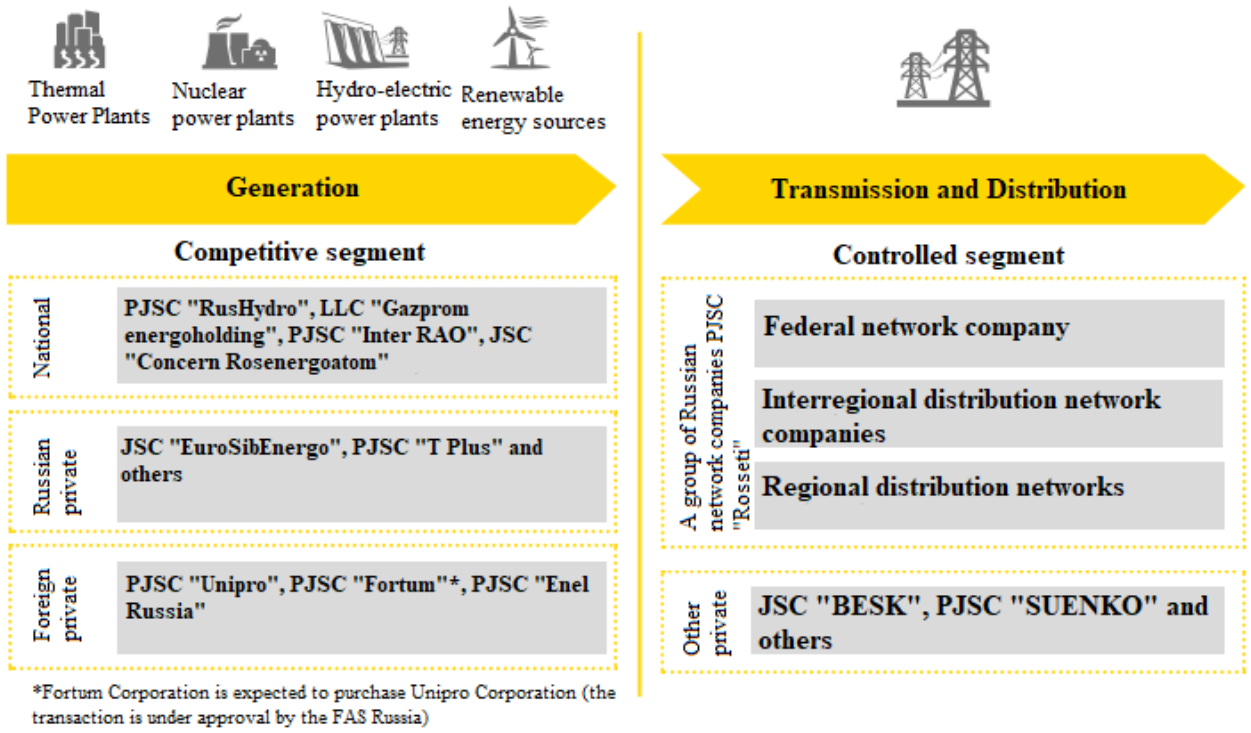
It is supposed to use the analysis of dynamics of indicators (horizontal analysis), as well as structural analysis (vertical analysis), as well as the use of comparative analysis.

The analysis also involves the use of data from world energy reports and national energy reports.

4 Results

The subject of the paper was the possibility of obtaining a general trend in the development of the electric power industry in the Russian Federation and its specific development.

The main segments of the electric power industry in Russia, in which the activity is carried out, are presented in the Figure 2.



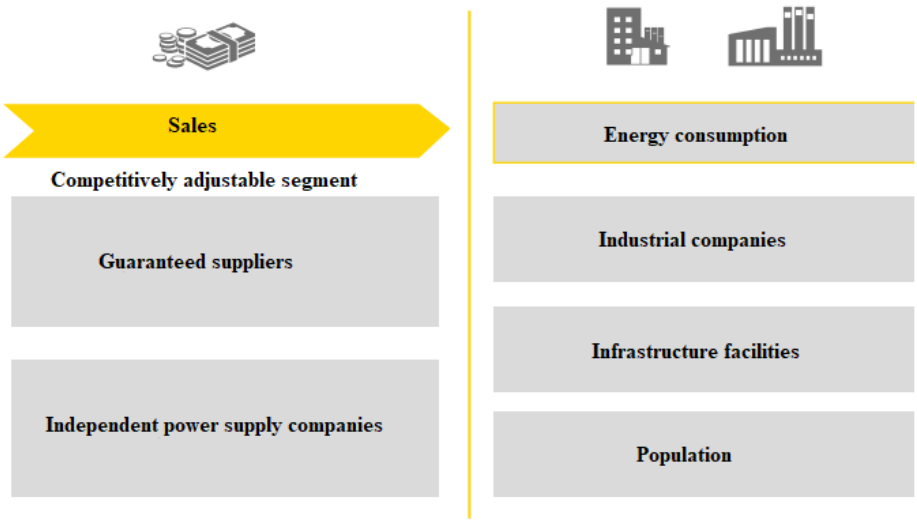


Figure 2. Segments of electrical energy industry in the Russian Federation

These segments can be attributed to regulated segments – such as transmission and sale of the electric power industry; competitive segments - electricity generation; competitively regulated - sales. If we consider the structure of the production of all energy in the Russian Federation, then we can imagine it as follows (Fig. 3):

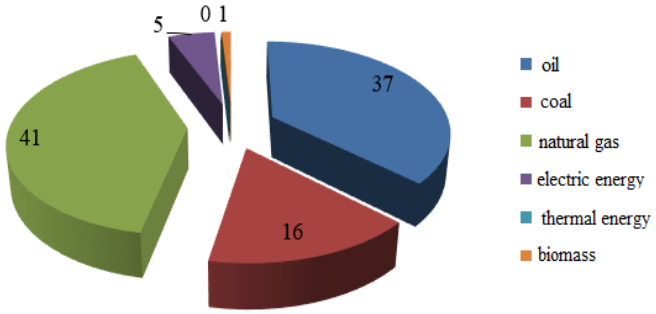


Figure 3. The structure of all energy production in Russia in 2019, %

Source: compiled by the author based on the materials [118]

If we consider the electric power as a separate industry, then it makes up 5% of the total aggregate of produced energy. One of the indicators characterizing the electric power industry development is electricity consumption. Figure 4 presents the dynamics of changes in electricity consumption and the change in maximum power consumption in Russia.

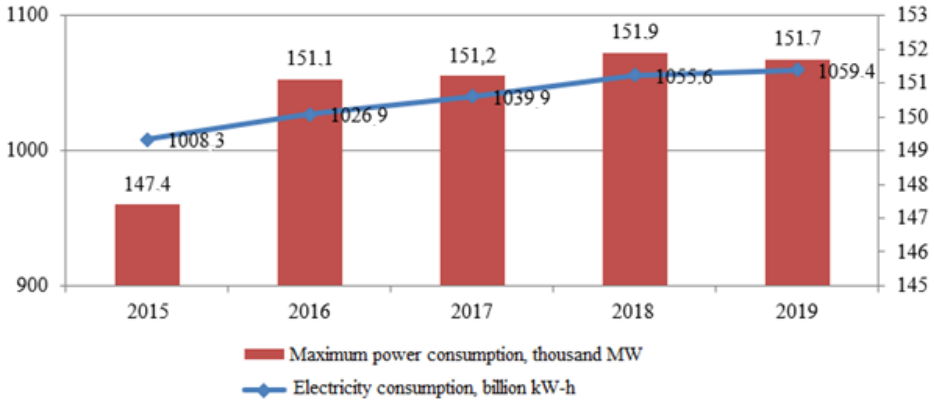


Figure 4. Dynamics of changes in electricity consumption and maximum power consumption in Russia

Source: compiled by the author based on the materials [119]

We should note a decrease in the maximum electricity consumption in 2019, while the total electricity consumption continues to grow. Table 1 presents the main performance indicators of the electric power industry in the Russian Federation (Table. 1). The increase in installed capacity was 4.6% over the research period, and intensive growth can also be noted in the available capacity of power plants at the annual maximum consumption. almost proportionally there is an increase in the generation and consumption of electricity. If we consider the context of integrated power systems (IES) by region, then the situation in 2019 for the main systems can be traced by the dynamics of the data in Table 2.

Table 1. Primary performance indicators of the integrated power system of the Russian Federation

Indicator	Years					Growth, %
	2015	2016	2017	2018	2019	
Installed capacity, million kW	235.3	236.3	239.8	243.2	246.3	4.67
The available capacity of power plants at the annual maximum power consumption, million kW	211.9	222.9	220.7	225.9	225.9	6.63
The load on power plants on the annual maximum power consumption, million kW	149.3	153.1	152.1	153.5	153.5	2.76
Electricity generation per year, billion kW-h	1026.8	1048.4	1053.86	1070.9	1080.60	5.24
Electricity consumption per year, billion kW-h	1008.25	1026.86	1039.9	1055.6	1059.40	5.07

Source: compiled by the author based on materials [119]

Table 2. The dynamics of the main indicators of integrated power system by region

Indicators	United energy system						
	Center	Middle Volga	Ural	Northwest	South	Siberia	East
Installed capacity, million kW	52. 64	27.49	53.69	24.47	24.85	52.1	11.08
The available capacity of power plants at the annual maximum power consumption, million kW	51.93	26.07	52.43	23.31	22.28	39.3	10.62
The load on power plants on the annual maximum power consumption, million kW	36.18	16.188	36.03	15.68	15.29	28.03	6.09
Electricity generation per year, billion kW-h	236.3	110.2	265.7	112.8	103.1	208.7	43.8
Electricity consumption per year, billion kW-h	241.9	109.1	260.4	95	101.3	211.4	40.3
	Structure, %						
Installed capacity	21.37	11.16	21.80	9.93	10.09	21.15	4.50
The available capacity of power plants at the annual maximum power consumption	22.98	11.54	23.20	10.32	9.86	17.39	4.70
The load on power plants on the annual maximum power consumption	23.57	10.55	23.47	10.22	9.96	18.26	3.97

Electricity generation per year	21.87	10.20	24.59	10.44	9.54	19.31	4.05
Electricity consumption per year	22.83	10.30	24.58	8.97	9.56	19.95	3.80

Source: compiled by the author based on materials [119]

In general, it should be noted that the main share of the power is in the Urals, Center and Siberia, in the same regions the main load of power plants goes, these zones account for the largest generation of electricity and electricity consumption. In this situation, we can see the prevailing regional proportions of the Russian economy.

The dynamics of electricity generation in Russia by type (Table. 3):

Table 3. Dynamics of electricity production in the Russian Federation for the period of 2015 - 2019, billion kW-h.

Indicators	Years				
	2015	2016	2017	2018	2019
Electricity production, billion kW-h	1026.8	1048.4	1053.86	1070.9	1080.6
thermal	614.1	614.3	671.3	681.8	679.9
hydroelectric	160.1	178.3	178.9	183.8	190.3
nuclear	194.9	196.1	202.9	204.4	208.8
wind	0.005	0.01	0.13	0.22	0.32
solar	0.007	0.061	0.56	0.8	1.3

Source: compiled by the author based on materials [119]

There is an increase in electricity production throughout the research period. On average, the increase over the entire period amounted to slightly more than 5%. The main growth is noted for renewable energy sources (non-traditional), as well as for hydroelectric power stations. The share of primary hydrocarbon use in electricity production, in general, and coal in particular in the overall structure of electricity production has been virtually unchanged since 2014, while emissions of polluting substances into the atmosphere from thermal power plants decreased by 19.6%, and greenhouse gas emissions - by 6.5% [120]. One of the main reasons for the emergence of positive dynamics in reducing emissions was the improvement of energy efficiency in electric energy production processes, an increase in the fuel utilization rate in the industry, and a decrease in the unit costs of standard fuel for supplying an ever-increasing volume of energy production.

Figure 4 shows the structural changes in electricity generation in the Russian Federation.

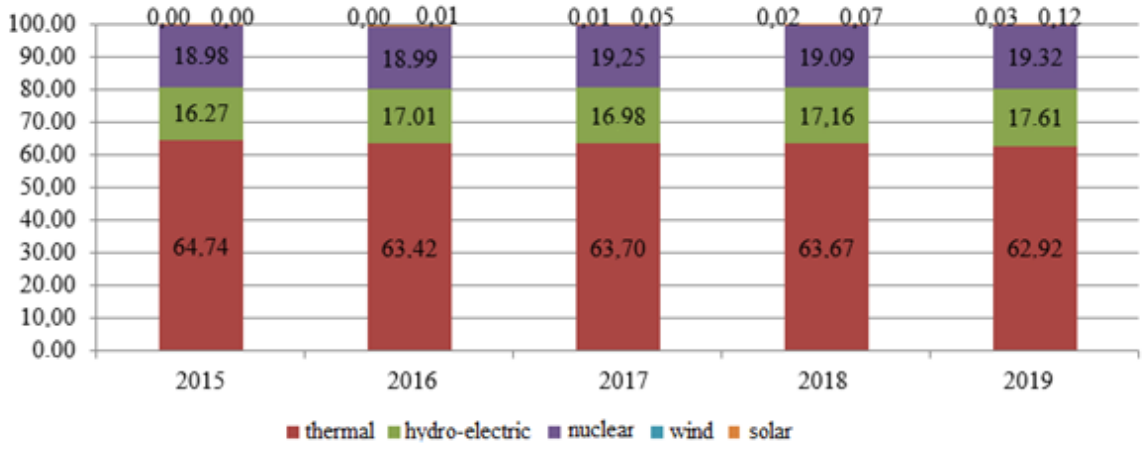


Figure 4. Structural changes in electricity generation in the Russian Federation, %

Source: [120]

It should be noted that thermal power plants account for the largest share, they bear the main burden associated with providing electricity to the population, nuclear and hydroelectric power stations can also be noted, however, an increase in the share of wind and solar power plants should be noted, which leads to a decrease in the share of thermal power plants. Such dynamics is due to global trends, with regard to the environmental problem, as well as the limited resource support (traditional energy sources). Table 4 presents the dynamics of the energy output of power plants in the Russian Federation by type.

Table 4. The dynamics of energy output of power plants, mln. KW-h

Indicators	Years				
	2015	2016	2017	2018	2019
Power of power plants, million kW	235,3	236,3	239,8	243,2	246,3
thermal	160,2	160,2	162,8	164,5	164,6
hydroelectric	47,8	48,08	48,4	48,5	49,8
nuclear	27,1	27,9	27,9	29,1	30,3
wind	0,07	0,08	0,6	0,9	1,4

Source: compiled by the author based on the materials [119]

There is an increase in the capacity of power plants, the most significant increase in capacity in nuclear power plants and renewable energy, as for thermal power plants, the growth is negligible. Structural changes regarding power plants are presented in the Figure 5.

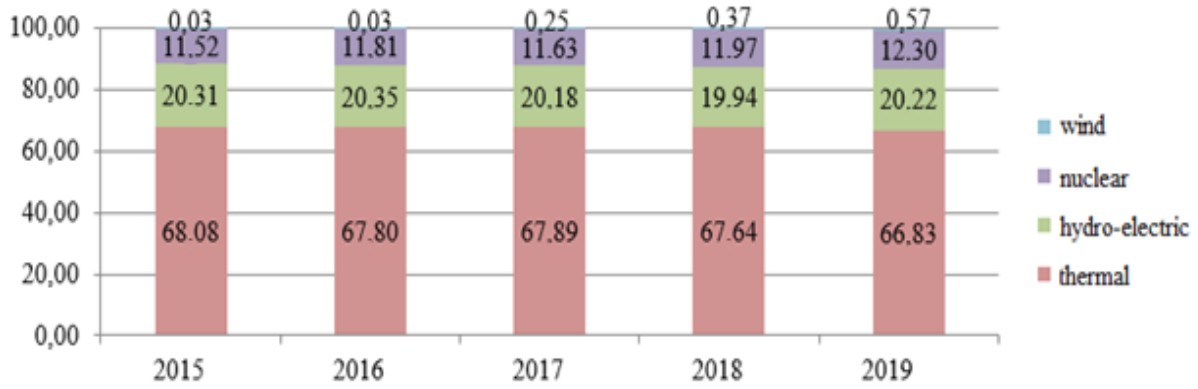


Figure 5. Structural changes regarding power plants in the Russian Federation, %

Source: [120]

So far, the power supply and generation are associated with thermal power plants, although the shares of nuclear and hydroelectric power stations have become quite large. It can also be noted that the development of green energy occurs more intensively in countries where the shortage of traditional energy sources is present, namely the resource one. Let`s consider the consumption of equivalent fuel units for the generation of 1 kW-h of electricity at power plants as an indicator of energy efficiency of generation (Fig. 6). In general, a decrease in specific fuel consumption is observed, which is due to changes in the generation structure, namely, there is a more rapid increase in hydroelectric power and the use of renewable energy sources. In addition, the change in the fuel balance in the thermal energy sector (increase in the use of natural gas) has an effect, a gradual replacement of power plant equipment occurs, in 2019 the commissioning of new equipment amounted to 3214 MW, which is significantly lower than in 2018 (5086.9 MW). As for equipment, the share of old equipment still remains significant. The wearing of equipment of thermal power plants, which is more than 40 years old, is especially significant [121].

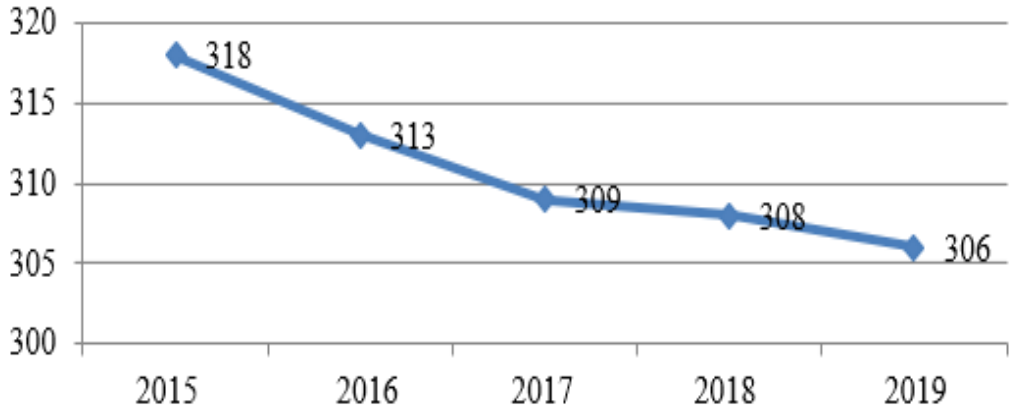


Figure 6. The dynamics of the specific consumption of equivalent fuel per one kilowatt-hour of electricity supplied to public power plants.

Source: [122]

Table 5 presents the dynamics of indicators of production, trade and consumption in Russia as a whole.

Table 5. Dynamics of indicators of production, trade and electricity consumption in Russia, billion kW-h.

Indicators	Years					Growth, %
	2015	2016	2017	2018	2019	
Produced	1026.8	1048.4	1053.86	1070.9	1080.6	5.24
Import	6.6	3.2	6.4	5.2	1.6	-75.76
Export	18.2	17.7	17	17.8	20	9.89
Consumption (net output)	920.2	941.2	948.56	964.4	973.7	5.81
Network losses	106.6	107.2	105.3	106.5	106.3	-0.28

Source: compiled by the author

The data presented in Table 5 allows us to state the positive security of energy supply of the country, which is typical when the export of electricity exceeds import and, in a situation, where the production is covered by electricity consumption, despite the losses in the networks. The fact that the basis of consumption is industrial production which is about 76% of all consumption, about 10% falls on losses and the rest of the electricity consumption falls on the population. Development of the electric power industry is investment (see Fig. 7). It was noted by the head of the ACRA research and forecasting group that the growth of investments and the financial recovery of the electric power industry was triggered by the launch of a mechanism for supplying capacity (guarantees for the return on investment of generations from increased payments by consumers), as well as the overall market reorganization of RAO UES.

Experts suggest that the market will peak at 2020 [123]. At that time, energy will show the maximum level of profitability, cash flow and dividends. This is due to the end of investment projects and the maximum payments for Capacity Supply Agreement. In order to preserve the long-term value of assets and prevent their depreciation after the end of the CSA, the revenues from this mechanism in other projects are actively invested in wind farms, in solar generation.

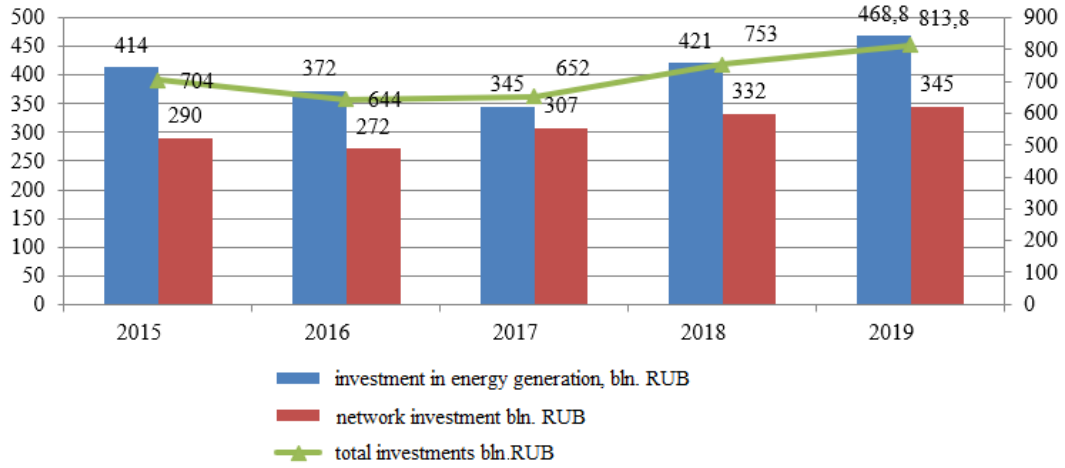


Figure 7. Dynamics of investments in the electric power industry in the Russia Federation, billion rubles.

The data for 2019 are forecasted. Investments in RES of Russia in comparison with countries are presented in the Figure 8.

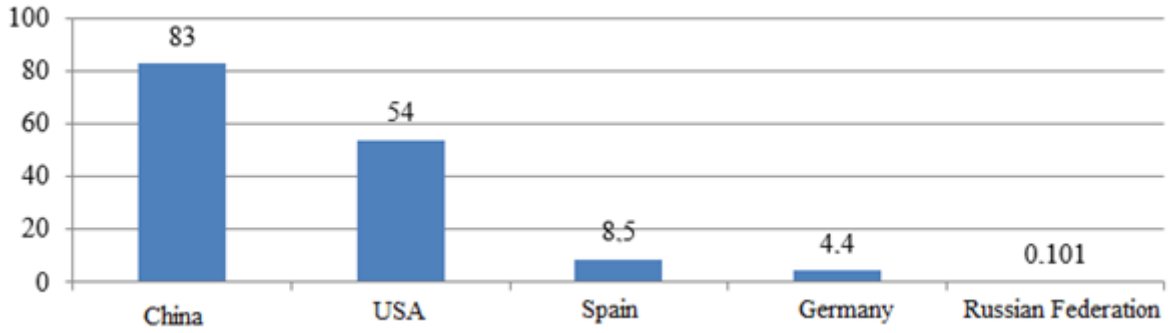


Figure 8. Investments in RES of Russia in Comparison with Countries

It should be noted that Russia, in the framework of investments green energy sources, has insignificant investments. However, if we consider the trends of recent years, they are gradually growing. While this is hampered by high requirements for the localization of equipment. As well as the crisis in the country's economy, in addition to supporting investment in renewable energy. In general, the beginning of investment activity in the electric power industry can be given by the adopted TPP modernization program, as well as network digitalization. Summarizing the results of the analysis, it should be noted that with an increase in electricity consumption, there is a significant aging of fixed assets, mainly for thermal power plants, which make up more than 60% of all electricity produced in the country. At the same time, it is necessary to note the insignificant investment activity in various segments of the electric power industry of Russia in comparison with other countries, which is also due to aging of fixed assets, on the one hand, in addition, government support for this industry and investment in it plays a significant part here.

4. Discussion

Studies of analytical material and expert comments allow us to conclude that the global process in the development of the electric power industry speaks of the “fourth energy transition” [124], the main trend of which is the commercialization of non-traditional energy resources and technologies. In turn, this transition can be represented as a transformational process that has global scales, and consists of such elements as energy efficiency, decarbonization, decentralization, digitalization [5]. The latter involves the use of: “smart grids” - integrating all elements of the energy sector; smart devices consuming energy (not only receiving, but often

also transferring energy to the network, for example, from renewable energy sources). To improve investment activity in this industry, it is necessary to formulate industrial base of innovative development within the framework of the new energy paradigm, as well as the scientific and technological base of innovative development. This will help to reduce losses by optimizing energy flows, network infrastructure and, accordingly, more efficient capacity management, and also subsequently reduce the financial burden on consumers. A breakthrough in the framework of the investment development activity relative to traditional energy sources may be the TPP modernization program adopted in 2019, as was noted in the study. Experts express the same opinion: the document stipulates that within the framework of the program for the modernization of generating facilities in 2022-2031, it is planned to upgrade about 39 gigawatts of installed capacity of generating facilities. There will also be a transition to competitive power take-offs for six years (now four years) and a phased indexation of the price parameters of competitive power take-offs in 2022-2024 [125]. It is also should be noted that against the backdrop of global trends, the transition to the use of renewable energy will be carried out, the development of the investment sector is impossible without investment signals from the state. The potential for RES development in Russia is huge, and in all segments, both in the wholesale and retail markets, and in the micro-generation segment. Given this, it is important to actively adapt market mechanisms to the introduction of renewable energy sources and other innovative technologies, energy storage devices [125]. As part of the energy market development, it is also important to note startups that set the development vector. In this situation, the international experience of such startups becomes quite useful, for example, the French company Electricity de France finances promising projects for novice entrepreneurs, innovative solutions and projects based on renewable energy sources. Every year, it holds an exhibition that, in format, is more like a public showing of budding newcomers. Thus, the corporation manages to go one step ahead of its competitors and to reveal trends in the electric power market earlier than others [126]. The development of renewable energy is very relevant in the international experience in the use of green certificates - a tool for accounting (confirmation of origin) and support for renewable energy in the electric power industry. Within the framework of this mechanism, two markets operate: a market with obligations and a market for voluntary certificates. As for obligations, it obliges a company to produce or consume energy on the basis of renewable energy sources to confirm achievement of established goals (for example, within the framework of the Standards for the application of renewable energy sources. The market for voluntary certificates for creating a positive climate image, the acquisition of certificates by companies in terms of share in renewable energy sources, regarding energy consumption or production. Currently, this concept is being developed for use in the Russian Federation.

5. Conclusion

The conducted study makes it possible to draw general conclusions. The study of theoretical materials regarding the electric power industry made it possible to specify the concept - the electric power industry is presented as the main branch of the country's energy complex, includes three processes that are in constant interaction: production, transmission, and sales. Various factors determine the main trends in the development of the electric power industry; these include demographic (structural changes), climatic (having both direct and indirect effects), economic, and technological. On a global scale, the use of green energy sources (non-traditional) is of particular relevance, in Russia this area also begins to play a significant role in the development of the electric power industry. One of the main trends in the development of the electric power industry is a shift towards the introduction of cheaper electricity production, the introduction of energy saving methods, and the development and production of electrical equipment from materials that will have higher reliability compared to traditional materials, reduce energy losses, and have higher energy efficiency.

An analysis of the trends and specifics of the development of the electric power industry in the Russian Federation led to the conclusion that there is an increase in electricity generation. In the general structure of electricity production, the share of the use of coal and primary hydrocarbons over the past five years has not changed. However, there is a decrease in the negative impact on the environment (emissions), which is due,

against the background of an increasing volume of energy production, to a decrease, a decrease in the unit consumption of equivalent fuel for energy supply, as well as an increase in the fuel utilization rate in the industry and some other factors.

Another positive factor is the reduction in energy losses, which is due to the intensive development of the network infrastructure. However, further work is needed to reduce losses; the development of digitalization of technologies also contributes to this process. Also, one of the important tasks of the EnergyNet National Technology Initiative was the development of "reliable and flexible networks" due to the need of creating competitive technological solutions.

One of the negative aspects in the development of the electric power industry in Russia is the high depreciation of fixed assets against the background of increasing energy demand, which inhibits investment activity. Speaking about investment activity, it should be noted that Russia is currently one of the countries with minimal investments in renewable energy sources relative to the global trend in this segment.

The author's position regarding solutions to the problems is the need of study and further development of digital energy, which requires legal study of the issue, as well as stimulation of technology development by the state. As part of the development of renewable energy sources, we can also talk about working with startups, which also requires a certain study of the legal space. The use of green certificates will also be a certain stage in the development of the energy sector of the Russian Federation.

Acknowledgements

This article was prepared as part of the government contract as requested by the Ministry of Science and Higher Education of the Russian Federation on the subject formulated as "Structural changes in economy and society as a result of achieving the target indicators of National projects, which provide opportunities to organize new areas of social and economic activity, including commercial, both in Russia and abroad", No FSSW2020-0010.

References

[1] R. V. Okorokov, "Trends and Consequences of the Development of the Global Fuel and Energy Complex," *Bulletin of the IGAU*, vol. 1, pp. 75-86, 2018.

[2] V. P. Samarina "Innovative Economy: Prospects for Development and Improvement," *E3S Web Conferences*, vol. 5, no. 15, pp. 133-138, 2016.

[3] D. Dyadkin, Yu. Usoltsev, N. Usoltseva, "Smart Contracts in Russia: Prospects for Legislative Regulation," *Universum: Economics and Jurisprudence*, vol. 5, no. 50, pp. 1-9, 2018.

[4] A. Kopylov, Economics of RES, Moscow: Publishing Solutions, 2015.

[5] V.A. Zubakin, "Analysis of the Trends of Transformations and Development of the Russian Electric Power Industry." *Scientific and Technical Statements of SPbSPU. Economic Sciences*, vol. 12, no. 6, pp. 104-115, 2019.

[6] C. Gerbaulet, C. von Hirschhausen, C. Kemfert, C. Lorenz, P.-Y. Oei, "European Electricity Sector Decarbonization Under Different Levels of Foresight," *Renewable Energy*, vol. 141, pp. 973-987, 2019.

[7] M. Child, "Flexible Electricity Generation, Grid Exchange and Storage for the Transition to a 100 % Renewable Energy System in Europe," *Renewable Energy*, vol. 139, pp. 80-101, 2019.

[8] M. Rapšík, M. Smola, M. Boháč, M. Mucha, Basics of Energy, Bratislava: STU, 2013.

[9] E. Dyka, I. Mróz-Radłowska, "Economics in energy,*" Lodz University of Technology Publishing House*, vol. 2, no. 256, 2015.

[10] P. Schwarz, Energy Economics, London: Routledge, 2017.

[11] N. G. Lyubimova, E. S. Petrovsky Economics and Management in the Energy Sector, Moscow: Yurayt, 2017.

[12] E. V. Ametistov, A. D. Truhniya, Fundamentals of Modern Energy, Moscow: MPEI Publishing House, 2015.

[13] V. S. Samsonov, Economics of the Energy Sector Enterprises. Moscow: Higher School, 2015.
[14] L. G. Melnik, I. M. Sotnik, Energy Economics. Sumy: University Book, 2015.
[15] P. Zweifel, A. Praktiknjo, G. Erdmann, Energy Economics – Theory and Applications. London: Springer, 2017.
[16] L. Gawlik, E. Mokrzycki, "Fossil Fuels in the Domestic Energy Sector – Problems and Challenges," *Energy Policy Journal,* vol. 6, no.4, pp. 6-26, 2017.
[17] M. Kuprikov, L. N. Rabinskiy, "Vertical take-off and landing aircrafts: myth or reality of modern aviation," *Journal of Mechanical Engineering Research and Developments,* vol. 41, no. 4, pp. 46-52, 2018.
[18] M. Kuprikov, L. N. Rabinskiy, "Influence of Infrastructure Constraints on the Geometrical Layout of a Long-Haul Aircraft," *Journal of Mechanical Engineering Research and Developments,* vol. 41, no. 4, pp. 40-45, 2018.
[19] G. A. Ganiyeva, B. R. Ryskulova, S. S. Tashpulatov, "Selection of special clothes design parameters on the basis of optimisation of dynamic conformance parameters," *International Journal of Applied Engineering Research,* vol. 10, no. 19, pp. 40603-40606, 2015.
[20] M. Kuprikov, L. N. Rabinskiy, "Cross-Polar Routes as a Factor that Changed the Geometric Layout of Long-Haul Aircrafts Flying Over Long Distances," *Journal of Mechanical Engineering Research and Developments,* vol. 41, no. 4, pp. 53-57, 2018.
[21] M. Y. Kuprikov, N. M. Kuprikov, L. N. Rabinskiy, "The Dependence of the Appearance of the Aircraft on the Conditions of the Arctic Basing," *INCAS Bulletin,* vol. 11, pp. 115-123, 2019.
[22] O. V. Egorova, Y. K. Kyaw, "Solution of Inverse Non-Stationary Boundary Value Problems of Diffraction of Plane Pressure Wave on Convex Surfaces Based on Analytical Solution," *Journal of Applied Engineering Science,* vol. 18, no. 4, pp. 676-680, 2020.
[23] A. G. Getmanov, L. N. Rabinskiy, "Assessment of Durability of Coatings in Difficult Stress Conditions," *Periodico Tche Quimica,* vol. 16, no. 33, pp. 490-497, 2019.
[24] V. A. Zagovorchev, O. V. Tushavina, "The Use of Jet Penetrators for Movement in the Lunar Soil," *INCAS Bulletin,* vol. 11, pp. 121-130, 2019.
[25] V. A. Zagovorchev, O. V. Tushavina, "Selection of Temperature and Power Parameters for Multi-Modular Lunar Jet Penetrator," INCAS Bulletin, vol. 11, pp. 231-241, 2019.
[26] S. Vakhneev, E. Starovoitov, "Damping of Circular Composite Viscoelastic Plate Vibration under Neutron Irradiation," *Journal of Applied Engineering Science,* vol. 18, no. 4, pp. 699-704, 2020.
[27] Y. Sun, M. Y. Kuprikov, E. L. Kuznetsova, "Effect of Flight Range on the Dimension of the Main Aircraft," *INCAS Bulletin,* vol. 12, pp. 201-209, 2020.
[28] Y. Li, A. M. Arutiunian, E. L. Kuznetsova, G. V. Fedotenkov, "Method for Solving Plane Unsteady Contact Problems for Rigid Stamp and Elastic Half-Space with a Cavity of Arbitrary Geometry and Location," *INCAS Bulletin,* vol. 12, pp. 99-113, 2020.
[29] E. L. Kuznetsova, G. V. Fedotenkov, E. I. Starovoitov, "Methods of Diagnostic of Pipe Mechanical Damage using Functional Analysis, Neural Networks and Method of Finite Elements," *INCAS Bulletin,* vol. 12, pp. 79-90, 2020.
[30] D. A. Kozorez, E. A. Dolgova, A. V. Korneenkova, A. V. Rumakina, M. Sha, "Higher Education Institutions Educational Process Digitalization in the Context of the Necessity to Provide a Model for Students' Choice of Training Areas and Academic Specialties," *International Journal of Criminology and Sociology,* vol. 9, pp. 3033-3039, 2020.
[31] R. R. Anamova, L. V. Bykov, D. A. Kozorez, "Algorithm for Designing Professional Retraining Programs Based on a Competency Approach," *Education Sciences,* vol. 10, no. 8, pp. 1-9, 2020.
[32] E. V. Akimov, D. A. Kozorez, D. M. Kruzhkov, "Navigation Solution Concept and its Practical Approach Development for Lunar Missions," *Russian Engineering Research,* vol. 40, no. 7, pp. 605-607, 2020.

[33] N. S. Kudryavtseva, A. E. Sorokin, "Comparative Reliability Assessment and Costing of Life Support Systems for Extended Interplanetary Missions," *Aviakosmicheskaya i Ekologicheskaya Meditsina,* vol. 54, no. 2, pp. 30-37, 2020.

[34] E. E. Galkina, A. E. Sorokin, "Quality Management and Sustainable Economic Development," *Russian Engineering Research,* vol. 40, no. 7, pp. 577-578, 2020.

[35] V. V. Bodryshev, L. G. Nartova, L. N. Rabinskiy, "Digital Interpretation of Gas Dynamics Problems as a Means of Optimizing Fundamental General Engineering Education," *Asia Life Sciences,* vol. 2, pp. 759-774, 2019.

[36] V. V. Bodryshev, A. A. Larin, L. N. Rabinsky, "Flaw Detection Method for Radomes in Weakly Anechoic Conditions," *TEM Journal,* vol. 9, no. 1, pp. 169-176, 2020.

[37] V. V. Bodryshev, N. P. Korzhov, L. N. Rabinskiy, "Grapho-Analytical Analysis of Video Frames of Supersonic Flow Around Two Solid Revolutions Using the Digital Image Processing Method," *TEM Journal,* vol. 9, no. 2, pp. 449-459, 2020.

[38] V. S. Terentieva, A. N. Astapov, "Conceptual Protection Model for Especially Heat-Proof Materials in Hypersonic Oxidizing Gas Flows," *Russian Journal of Non-Ferrous Metals,* vol. 59, no. 6, pp. 709-718, 2018.

[39] V. S. Terentieva, A. N. Astapov, L. N. Rabinskiy, "State in the Field of Heat-Resistant Coatings for Heat-Proof Nickel Alloys and Steels," *Periodico Tche Quimica,* vol. 16, no. 33, pp. 561-572, 2019.

[40] V. A. Pogodin, A. N. Astapov, L. N. Rabinskiy, "CCCM Specific Surface Estimation in Process of Low-Temperature Oxidation," *Periodico Tche Quimica,* vol. 17, no. 34, pp. 793-802, 2020.

[41] V. A. Pogodin, L. N. Rabinskii, S. A. Sitnikov, "3D Printing of Components for the Gas-Discharge Chamber of Electric Rocket Engines," *Russian Engineering Research,* vol. 39, no. 9, pp. 797-799, 2019.

[42] N. S. Severina, "Software Complex for Solving the Different Tasks of Physical Gas Dynamics," *Periodico Tche Quimica,* vol. 16, no. 32, pp. 424-436, 2019.

[43] A. V. Babaytsev, L. N. Rabinskiy, K. T. Aung, "Investigation of the Contact Zone of a Cylindrical Shell Located between two Parallel Rigid Plates with a Gap," *INCAS Bulletin,* vol. 12, pp. 43-52, 2020.

[44] A. V. Babaytsev, L. N. Rabinskiy, "Design Calculation Technique for Thick-Walled Composite Constructions Operating under High-Speed Loading," *Periodico Tche Quimica,* vol. 16, no. 33, pp. 480-489, 2019.

[45] A. V. Babaytsev, Y. K. Kyaw, S. N. Vakhneev, T. Zin Hein, "Study of the Influence of Spherical Inclusions on Mechanical Characteristics," *Periodico Tche Quimica,* vol. 17, no. 35, pp. 654-662, 2020

[46] A. Baklanov, O. Baklanova, S. Grigoryeva, S. Kumargazhanova, I. Sagynganova, Y. Vais, G. Györök, "The development of hybrid IP architecture for solving the problems of heating networks (Using pipeline-parallel data processing technology)," *Acta Polytechnica Hungarica,* vol. 17, no. 1, pp. 123-140, 2020.

[47] A. V. Babaytsev, A. A. Zotov, "Designing and Calculation of Extruded Sections of an Inhomogeneous Composition," *Russian Metallurgy (Metally),* vol. 2019, no. 13, pp. 1452-1455, 2019.

[48] A. V. Babaytsev, A. A. Orekhov, L. N. Rabinskiy, "Properties and Microstructure of $AlSi_{10}Mg$ Samples Obtained by Selective Laser Melting," *Nanoscience and Technology,* vol. 11, no. 3, pp. 213-222, 2020.

[49] N. V. Denisova, V. A. Gavrilov, R. R. Khusnutdinov, The History of the Development of the Electric Power Industry, Kazan: Kazan State Energy University, 2014.

[50] J. K. Bhattacharjee, S. Z. Mirzaev, U. Kaatze, "Does the Viscosity Exponent Derive from Ultrasonic Attenuation Spectra?," *International Journal of Thermophysics,* vol. 33, no. 3, pp. 469-483, 2012.

[51] V. V. Bodryshev, A. V. Babaytsev, L. N. Rabinskiy, "Investigation of Processes of Deformation of Plastic Materials with the Help of Digital Image Processing," *Periodico Tche Quimica,* vol. 16, no. 33, pp. 865-876, 2019.

[52] V. A. Korolenko, Y. Li, V. N. Dobryanskiy, Y. O. Solyaev, "Experimental Studies and Modelling of Fracture Toughness of the Epoxy Samples with Eccentric Cracks," *Journal of Applied Engineering Science,* vol. 18, no. 4, pp. 719-723, 2020.

[53] M. Sha, O. A. Prokudin, Y. O. Solyaev, S. N. Vakhneev, "Dependence of Glare Destruction Mechanisms on the Elongation of Samples in Tests to Three-Point Flexural," *Periodico Tche Quimica,* vol. 17, no. 35, pp. 549-558, 2020.

[54] A. Babaytsev, V. Dobryanskiy, Y. Solyaev, "Optimization of Thermal Protection Panels Subjected to Intense Heating and Mechanical Loading," *Lobachevskii Journal of Mathematics,* vol. 40, no. 7, pp. 887-895, 2019.

[55] S. A. Lurie, P. A. Belov, Y. O. Solyaev, E. C. Aifantis, "On One Class of Applied Gradient Models with Simplified Boundary Problems," *Materials Physics and Mechanics,* vol. 32, no. 3, pp. 353-369, 2017.

[56] Yu. G. Evtushenko, V. I. Zubov, S. A. Lurie, Yu. O. Solyaev, "Identification of Kinetic Parameters of the Model of Interphase Layer Growth in a Fibrous Composite," *Composites: Mechanics, Computations, Applications,* vol. 7, no. 3, pp. 175-187, 2016.

[57] E. L. Kuznetsova, A. V. Makarenko, "Mathematic Simulation of Energy-Efficient Power Supply Sources for Mechatronic Modules of Promising Mobile Objects," *Periodico Tche Quimica,* vol. 15, no 1, pp. 330-338, 2018.

[58] Y. K. Kyaw, E. L. Kuznetsova, A. V. Makarenko, "Complex Mathematical Modelling of Mechatronic Modules of Promising Mobile Objects," *INCAS Bulletin,* vol. 12, pp. 91-98, 2020.

[59] A. Vlasyuk, V. Zhukovskyy, N. Zhukovska, H. Rajab, "One-Dimensional Modeling of Contaminant Migration in Unsaturated Porous Media with Dispersed Catalyst Particles," in *Proceedings – 2nd International Conference on Mathematics and Computers in Science and Engineering, MACISE 2020,* Madrid, Spain, pp. 197-201, 2020.

[60] V. V. Ryndin, "Application of the postulate of nonequilibrium to calculate the nonequilibrium of systems of dissimilar gases and liquids," *Periodico Tche Quimica,* vol. 17, no. 34, pp. 998-1011, 2020.

[61] V. I. Ivin, V. V. Ryndin, "Unsteady flow in branched ducts of inlet pipes of internal combustion engines," *Izv Vyssh Uchebn Zaved Mashinostr,* vol. 9, pp. 100-105, 1976.

[62] O. Zh. Rabat, D. Absametov, M. M. Kunelbayev, E. L. Hasanov, D. V. Mykhalevskiy, R. N. Abdrashitova, Y.I. Salnikova, "Performance calculation of solar water heating unit at a petrol filling station," *Periodico Tche Quimica,* vol. 15, no. 30, pp. 589-598, 2018.

[63] K. S. Nadirov, G. Z. Moldabayeva, S. E. Baibotayeva, Y. V. Zeygman, A. S. Sadyrbayeva, "Reagent preparation for oil treatment and its use in the process of dehydration," *Journal of Industrial Pollution Control,* vol. 33, no. 1, pp. 1075-1084, 2017.

[64] Y. S. Oryngozhin, G. Z. Moldabayeva, I. B. Igembaev, "Innovative method of high-viscosity oil production," *12th International Multidisciplinary Scientific GeoConference and EXPO - Modern Management of Mine Producing, Geology and Environmental Protection, SGEM 2012,* vol. 2, pp. 463-470, 2012.

[65] G. Moldabayeva, R. Suleimenova, A. Karimova, N. Akhmetov, L. Mardanova, "Experimental support of field trial on the polymer flooding technology substantiation in the oil field of western Kazakhstan," *Periodico Tche Quimica,* vol. 17, no. 35, pp. 663-677, 2020.

[66] D. Y. Savon, A. V. Aleksakhin, O. O., Skryabin, A. A. Goodilin, "Occupational health and safety digitalization in the coal industry," *Eurasian Mining,* vol. 2019, no. 2, pp. 70-72, 2019.

[67] S. A. Montayev, A. S. Montayeva, N. B. Adilova, A. B. Shinguzhiyeva, N. S. Montayeva, A. T. Taskaliyev, "Prospects of creating the technology of composite adsorbent for water purification based on the composition of siliceous and clay rocks of Kazakhstan," *International Journal of Mechanical Engineering and Technology,* vol. 9, no. 1, pp. 805-813, 2018.

[68] 18G. M. Yurkova "Factors Affecting the Development of the Electric Power Industry", *Scientific and Practical Electronic Journal Alley of Science,* vol. 8, no. 24, pp. 1-5, 2018.

[69] S. A. Montayev, N. S. Montayeva, A. B. Shinguzhiyeva, K. Zhanabaevichdosov, M. Zhanaidarovichryskaliyev, "Possibility of producing sintered fine porous granulated ceramic filler using

ash of thermal power stations in combination with clay rocks," *International Journal of Mechanical and Production Engineering Research and Development,* vol. 9, no. 4, pp. 1087-1096, 2019.

[70] M. Y. Kizatova, Y. B. Medvedkov, A. A. Shevtsov, A. V. Drannikov, D. A. Tlevlessova, "Experimental-statistical analysis and multifactorial process optimization of the crust from melon pulp separation process," *Journal of Engineering and Applied Sciences,* vol. 12, no. 7, pp. 1762-1771, 2017.

[71] M. K. Alimardanova, D. A. Tlevlesova, Z. Simov, D. Dimitrov, A. I. Matibayeva, "Incorporating Allium odorum as a vegetable ingredient of processed cheeses," *Research Journal of Pharmaceutical, Biological and Chemical Sciences,* vol. 6, no. 3, pp. 330-338, 2015.

[72] A. Kairbayeva, V. Vasilenko, S. Dzhinguilbayev, L. Baibolova, L. Frolova, "Development of the mathematical model for the process of oil raw materials pressing," *International Journal of Engineering and Technology (UAE),* vol. 7, pp. 145-149, 2018.

[73] R. R. Anamova, L. V. Bykov, D. A. Kozorez, "Algorithm for designing professional retraining programs based on a competency approach" *Education Sciences,* vol. 10, no. 8, pp. 1-9, 2020.

[74] K. Sultanov, B. Khusanov, B. Rikhsieva, "Underground pipeline reliability under longitudinal impact load," *IOP Conference Series: Materials Science and Engineering,* vol. 869, no. 5, 052008, 2020.

[75] I. Cherunova, S. Tashpulatov, A. Merkulova, "Development of automation algorithm for step of designing technology of static electricity protection clothing," *2018 International Russian Automation Conference, RusAutoCon 2018,* vol. 1, 8501821, 2018.

[76] R. R. Anamova, A. V. Ripetskiy, "Waveguide Transmission Lines: Some Issues of Automated Designing," in *CriMiCo 2013 – 2013 23rd International Crimean Conference Microwave and Telecommunication Technology, Conference Proceedings,* Sevastopol, Ukraine, pp. 626-627, 2013.

[77] K. Sultanov, B. Khusanov, B. Rikhsieva, "Shear waves around an underground pipeline," *IOP Conference Series: Materials Science and Engineering,* vol. 869, no. 5, 052016, 2020.

[78] I. K. Sagynganova, A. I. Kvasov, A. A. Kalinin, "Comprehensive methods to obtain and process information flows in centralized heat supply systems," *IOP Conference Series: Materials Science and Engineering,* vol. 972, no. 1, 012074, 2020.

[79] I. Cherunova, S. Tashpulatov, S. Kolesnik, "Automation of deformed fibrous materials thermal characteristics accounting process in garments production," *2018 International Russian Automation Conference, RusAutoCon 2018,* vol. 1, 8501795, 2018.

[80] G. A. Ganiyeva, B. R. Ryskulova, S. Sh. Tashpulatov, "Ergonomic studies of dynamic compliance of parameters within the man-special clothing system for workers of the oil industry," *Izvestiya Vysshikh Uchebnykh Zavedenii, Seriya Teknologiya Tekstil'noi Promyshlennosti,* vol. 2015, no. 3, pp. 151-154, 2015.

[81] A. B. Baibatsha, M. K. Kembayev, E. Z. Mamanov, T. K. Shaiyakhmet, "Remote sensing techniques for identification of mineral deposit", *Periodico Tche Quimica,* vol. 17, no. 36, pp. 1038-1051, 2020.

[82] A. Baibatsha, "Geotectonics and geodynamics of paleozoic structures from the perspective of plume tectonics: A case of Kazakhstan," *International Journal of GEOMATE,* vol. 17, no. 71, pp. 194-202, 2020.

[83] O. V. Chernets, V. M. Korzhyk, G. S. Marynsky, S. V. Petrov, V. A. Zhovtyansky, "Electric arc steam plasma conversion of medicine waste and carbon containing materials," *GD 2008 – 17th International Conference on Gas Discharges and Their Applications,* vol. 1, pp. 465-468, 2008.

[84] Y. Borisov, V. Korzhyk, S. Revo, "Electric and magnetic properties of thermal spray coatings with an amorphous structure," *Proceedings of the International Thermal Spray Conference,* vol. 1, pp. 687-691, 1998.

[85] Kyoto Protocol to the Framework Convention on Climate Change, 1997. Available: https://treaties.un.org/doc/source/RecentTexts/kyoto-en.htm

[86] E. S. Temirbekov, N. S. Zaurbekov, G. N. Zaurbekova, "Strength of bearing elements of falsework PMD-5.2M," *Izvestiya Vysshikh Uchebnykh Zavedenii, Seriya Teknologiya Tekstil'noi Promyshlennosti,* vol. 2016, no. 4, pp. 125-130, 2016.

[87] A. Aidosov, G. Aidosov, N. Zaurbekov, N. Zaurbekova, G. Zaurbekova, I. Zaurbekov, "Mathematical modelling of atmospheric pollution in an industrial region with a view to design an information system software for ecological situation," *Ekoloji*, vol. 28, no. 107, pp. 349-358, 2019.

[88] S. Z. Mirzaev, I. Iwanowski, U. Kaatze, "Dynamic scaling and background relaxation in the ultrasonic spectra of the ethanol-dodecane critical mixture," *Chemical Physics Letters*, vol. 435, no. 4-6, pp. 263-267, 2007.

[89] I. A. Kapitonov, "Legal support for integration of renewable energy sources in the energy law of the countries from the international legal position," *Kuwait Journal of Science*, vol. 46, no. 1, pp. 68-75, 2019.

[90] Z. A. Sabirova, S. S. Tashpulatov, A. P. Parpiev, "Evaluation of form-resistance of fully-formated semi-finished furniture sewing products with content of polymer composition," *Journal of Engineering and Applied Sciences*, vol. 13, no. 23, pp. 10141-10144, 2018.

[91] S. S. H. Tashpulatov, I. V. Cherunova, E. G. Andreeva, B. G. Alimukhamedova, G. A. Ganieva, "Research and comprehensive assessment of the performance properties of thread connections in the system Adras + polymer composite," *Izvestiya Vysshikh Uchebnykh Zavedenii, Seriya Teknologiya Tekstil'noi Promyshlennosti*, vol. 2018, no. 6, pp. 150-153, 2018.

[92] Z. D. Moldagozhieva, R. O. Zhilisbayeva, K. Zh. Kucharbaeva, A. T. Toktarbayeva, S. Sh. Tashpulatov, "Development of new fire-resistant packages for welfare overalls," *Izvestiya Vysshikh Uchebnykh Zavedenii, Seriya Teknologiya Tekstil'noi Promyshlennosti*, vol. 371, no. 5, pp. 65-69, 2017.

[93] S. Turabdzhanov, Z. Nazirov, D. Turaeva, L. Rakhimova, "Perspective wastewater treatment from Cu2+ ions in the mining industry," *E3S Web of Conferences*, vol. 105, 02025, 2019.

[94] N. Mukhtarova, B. Aliev, S. Turabdzhanov, L. Rakhimova, "Studies of factors affecting stability and efficiency of anion exchanger," *E3S Web of Conferences*, vol. 177, 03020, 2020.

[95] I. A. Kapitonov, A. A. Shulus, M. V. Simonova, D. A. Sviredenko, R. T. Shreyner, "Green energy revolution perspectives in modern Russian economy," *International Journal of Economic Perspectives*, vol. 10, no. 3, pp. 166-175, 2016.

[96] I. A. Kapitonov, T. G. Filosofova, V. G. Korolev, "Development of digital economy in the energy industry-specific modernization," *International Journal of Energy Economics and Policy*, vol. 9, no. 4, pp. 273-282, 2019.

[97] Z. M. Orynkanova, R. A. Baizholova, A. Z. Zeinullina, "Improving the energy efficiency of Kazakhstan's economy," *Journal of Environmental Management and Tourism*, vol. 11, no. 1, pp. 44-53, 2020.

[98] I. A. Kapitonov, G. A. Taspenova, V. R. Meshkov, A. A. Shulus, "Integration of small and middle-sized enterprises into large energy corporations as a factor of business sustainability," *International Journal of Energy Economics and Policy*, vol. 7, no. 2, pp. 44-52, 2017.

[99] A. Z. Skorokhod, I. S. Sviridova, V. N. Korzhik, "Structural and mechanical properties of polyethylene terephthalate coatings as affected by mechanical pretreatment of powder in the course of preparation," *Mekhanika Kompozitnykh Materialov*, vol. 30, no. 4, pp. 455-463, 1994.

[100] S. Oleksandra, K. Krayushkina, T. Khymerik, B. Andrii, "Method of increasing the roughness of the existing road," *Procedia Engineering*, vol. 165, pp. 1766-1770, 2016.

[101] A. Mustafin, A. Kantarbayeva, "Opening the Leontief's black box," *Heliyon*, vol. 4, no. 5, e00626, 2018.

[102] A. Bieliatynskyi, E. Krayushkina, A. Skrypchenko, "Modern technologies and materials for cement concrete pavement's repair," *Procedia Engineering*, vol. 134, pp. 344-347, 2016.

[103] A. Onishchenko, L. Stolyarova, A. Bieliatynskyi, "Evaluation of the durability of asphalt concrete on polymer modified bitumen," *E3S Web of Conferences*, vol. 157, 06005, 2020.

[104] A. Kantarbayeva, A. Mustafin, "A biologically inspired fluid model of the cyclic service system," *Mathematical Modelling and Analysis*, vol. 25, no. 4, pp. 505-521, 2020.

[105] R. Dinzhos, N. Fialko, V. Prokopov, Y. Sherenkovskiy, N. Meranova, N. Koseva, V. Korzhik, O. Parkhomenko, N. Zhuravskaya, "Identifying the Influence of the Polymer Matrix Type on the Structure

Formation of Microcomposites when they are Filled with Copper Particles," *Eastern-European Journal of Enterprise Technologies,* vol. 5, no. 6-107, pp. 49-57, 2020.

[106] O. M. Alekseev, S. O. Alekseev, L. A. Bulavin, M. M. Lazarenko, O. M. Maiko, "Phase Transitions in Chain Molecular Polycrystals of 1-Octadecene," *Ukrainian Journal of Physics,* vol. 53, no. 9, pp. 882-888, 2008.

[107] V. P. Privalko, R. V. Dinzhos, E. G. Privalko, "Melting behavior of the nonisothermally crystallized polypropylene/organosilica nanocomposite," *Journal of Macromolecular Science – Physics,* vol. 43B, no. 5, pp. 979-988, 2004.

[108] O. M. Alekseev, M. M. Lazarenko, G. O. Puchkovs'ka, T. V. Bezrodnaya, A. A. Sendzyuk, "Peculiarities of the thermal motion in crystals formed by cetyltrimethylammonium bromide molecules," *Ukrainian Journal of Physics,* vol. 55, no. 9, pp. 973-979, 2010.

[109] A. Lapidus, T. Bidov, A. Khubaev, "The study of the calibration dependences used when testing the concrete strength by nondestructive methods," *MATEC Web of Conferences*, vol. 117, 00094, 2017.

[110] K. I. Hnatiuk, R. V. Dinzhos, M. S. Simeonov, A. N. Alekseev, S. A. Alekseev, V. V. Sirko, Yu. F. Zabashta, N. S. Koseva, M. M. Lazarenko, "Melting of 1-octadecene inside the pores of open-morphology silica gel: thermodynamic model and experimental studies," *Journal of Thermal Analysis and Calorimetry,* vol. 141, no. 3, pp. 1243-1250, 2020.

[111] V. P. Babak, S. V. Babak, M. V. Myslovych, A. O. Zaporozhets, V. M. Zvaritch, "Principles of construction of systems for diagnosing the energy equipment," *Studies in Systems, Decision and Control,* vol. 281, pp. 1-22, 2020.

[112] V. P. Babak, V. V. Shchepetov, S. D. Nedaiborshch, "Wear resistance of nanocomposite coatings with dry lubricant under vacuum," *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu,* vol. 1, pp. 47-52, 2016.

[113] V. Toporovskiy, A. Kudryashov, V. Samarkin, J. Sheldakova, A. Rukosuev, A. Skvortsov, D. Pshonkin, "Bimorph deformable mirror with a high density of electrodes to correct for atmospheric distortions," *Applied Optics,* vol. 58, no. 22, pp. 6019-6026, 2019.

[114] A. Lapidus, A. Khubaev, T. Bidov, "Organizational and technological solutions justifying use of non-destructive methods of control when building monolithic constructions of civil buildings and structures," *MATEC Web of Conferences*, vol. 251, 05014, 2018.

[115] A. A. Skvortsov, D. E. Pshonkin, M. N. Luk'yanov, "Influence of Constant Magnetic Fields on Defect Formation under Conditions of Heat Shock in Surface Layers of Silicon," *Key Engineering Materials,* vol. 771, pp. 124-129, 2018.

[116] A. Lapidus, A. Makarov, "Statistical Learning Problem of Artificial Neural Network to Control Roofing Process," *MATEC Web of Conferences,* vol. 117, 00100, 2017.

[117] A. A. Lapidus, I. L. Abramov, "Systemic integrated approach to evaluating the resource potential of a construction company as a bidder," *IOP Conference Series: Materials Science and Engineering,* vol. 603, no. 5, 052079, 2019.

[118] Statistical Yearbook of World Energy. Available: *https://yearbook.enerdata.ru/total-energy/world-energy-production.html*

[119] The system operator of the unified energy system (SO UES of Russia). Available: https://www.so-ups.ru/index.php?id=ees.

[120] Ministry of Energy of the Russian Federation. Available: https://minenergo.gov.ru/node/532

[121] Operation Report on the functioning of the UES of Russia in 2019, 2019. Available: ttps://www.so-cdu.ru/fileadmin/files/company/reports/disclosure/2020/ups_rep2019.pdf

[122] Rosstat. Available: https://www.gks.ru/folder/10705

[123] N. Prokhorova, ACRO evaluated the results of energy reform over 10 years, 2019. Available: https://www.ruscable.ru/news/2018/07/25/AKRA_otsenilo_itogi_energoreformy_za_desyaty_let/

[124] V. N. Knyaginin, D. V. Kholkin, Digital Transition in the Electric Power Industry of Russia. Moscow: Center for Strategic Research, Energy, 2017.

[125] N. D. Gotova, "Picture of the Year in Figures and Facts," *Energy and Industry of Russia*, vol. 18, no. 3, pp. 379-380, 2019.

[126] A. Metelnikov, Energy of Russia between the past and the future, 2018. Available: https://novostienergetiki.ru/energetika-rossii-mezhdu-proshlym-i-budushhim/