ISSN 2303-4521
Review Article
Periodicals of Engineering and Natural Sciences
Vol. 9, No. 3, July 2021, pp.218-235

Formation of an intelligent control system in the field of electric power industry based on the technological development of power supply components

Valery V. Bezpalov[1], Natalia A. Solopova[2], Marina G. Shilina[3], Svetlana A. Avtonomova[3], Tatiana V. Gorina[4]
[1] Department of National and Regional Economy, Plekhanov Russian University of Economics
[2] Department of Management and Innovation, Moscow State University of Civil Engineering (National Research University)
[3]Department of Advertising, Public Relations and Design, Plekhanov Russian University of Economics
[4]Department of Economics and Innovative Entrepreneurship, Institute of Economics and Law, MIREA –Russian Technological University

ABSTRACT

The relevance of the paper is determined by the fact that the digital transformation of the country is recognized as one of the priorities for the economic development of the state. It is necessary to remove barriers for the digital transformation in the most promising areas of production and life by stimulating the introduction of digital technologies and attracting investments, overcoming the digital divide, deepening cooperation between states in the digital sphere and developing the country's digital innovation infrastructure. The novelty of the study is determined by the fact that the transition to a new level of digital functioning of electric systems is possible in the context of formation of a smart energy supply system and the introduction of modern information technologies. The authors show that the introduction of new energy meters is the basis for creating an innovative infrastructure of the fuel and energy complex of the national economy. The authors believe that this is the basis for the transition to a new level of energy supply and the introduction of new economic mechanisms for demand management and further development of energy markets. This in turn contributes to the integration of energy systems of different countries. The practical significance of the study is determined by the possibilities of stratification of the economic assessment of the energy industry and the formation of a sustainable assessment of the formation of energy supply systems. It is proposed to determine the needs of industry in sustainable energy supply.

Keywords: Power supply, Industrially developed countries, Industry 4.0, Economic crisis phenomena.

Corresponding Author:

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

1. Introduction

Development of energy industry is associated with the reduction of greenhouse gas emissions, deregulation and integration of energy markets, introduction of innovative technologies in the energy sector. Based on the analysis of materials on the development of global energy mix, current trends and features in these areas are identified, among which the main ones are: a gradual increase in the share of electricity in energy balances, deficiency of energy storage systems and flexible generating capacities, price volatility and unstable supplies of primary energy sources, disordered access to the grid of new participants in the electricity market, the transition from a narrow-branch principle of strategic planning to integrated resource planning for the development of the

energy sector of the national economy [1]. The indicated trends are accompanied by the development of digital energy, which creates new challenges for the further development of national electrical systems [2; 3].
Today, the world economy cannot be imagined without the development of energy and energy efficiency [4]. The formation of the energy sector is increasingly influenced by both socio-economic, geopolitical and environmental factors. It should also be noted the important impact of innovation not only on the economic development as a whole, but also on the energy sector [5]. According to scientists and leading international organizations engaged in research in this area, in the long term, the dynamics of the development of the world economy and energy markets should be considered within the framework of a unified approach. That is, not only from an economic point of view, but also from an energy and environmental point of view. The main contradictions in the development of the world economy led to large-scale crisis phenomena that affect the development of the economy and power supply, in particular [6]. Thus, the accumulation of problems in resource and financial support, environmental and other social problems lead to a change in views on the development of certain sectors of the economy [7]. In some cases, the exacerbation of economic crises led to a change in trends in the development of both the world economy and the energy and energy efficiency sectors [8]. The economic crisis phenomena that have occurred in the world over the past century have had a significant impact on changing trends in the development of world energy and even on changing views regarding the development of the economies of individual countries [9].
In world's major economies, mastering the innovative technologies of Industry 4.0, digital transformations are considered as a strategic direction for increasing the competitiveness of national economies in the context of globalization and localization of world trade at the same time [10]. The peculiarities of the development of information and communication technologies (ICT) determine their convergence primarily in the network spheres of economic activity: communications and mass media, electricity and gas supply, transport infrastructure [11]. Basically, it is the condition and safety of critical infrastructure facilities that is the key to economic efficiency and competitiveness of the national economy as a whole [12].
Accordingly, it is advisable to study questions regarding the further development of energy systems in the context of digital transformations, deregulation and integration of electricity markets. It is also important to consider energy trends in the context of sustainable development as they relate to the above conditions [13].

2. Literature review

The first economic crises affecting the energy sector manifested at the beginning of the last century [14]. There has been an increase in government regulation in the energy sector in the leading countries of the world, especially in the United States of America and Germany. In the twentieth century, there was a process of industrialization of the economy. All of these processes have led to an increase in electricity consumption and the use of oil for fuel production [15]. The aggravation of the geopolitical situation in the Middle East and a new stage of relations between the world's major countries led to the energy crisis of the 1970s [16]. This is how the oil crisis of 1974-1979 took place, which influenced the development of nuclear energy and the intensification of the politics of energy supply diversification [17]. During this period, there have been changes in state regulation in the energy sector. In the USA and Western Europe, the prerequisites for the transition from an industrial to a post-industrial economy appeared, and private entrepreneurship was developing [18]. This led to an increase in demand for natural gas by small and medium-sized businesses and an increase in the use of energy resources in the housing and communal sector [19].
At the beginning of the 21st century, the processes that led to climate change and the economic crisis changed the views on the development of global energy sector. The new system of views or paradigm involves intensification of state regulation, transferring hydrocarbon deposits under the control of national energy companies, developing international and national energy security, developing energy conservation, increasing energy efficiency in various spheres of the national economy, actively changing the energy balance, namely, increasing renewable energy sources [19]. From the above facts, it can be assumed that large-scale crisis phenomena in the world economy have a significant impact on the dynamics of the development of both the global energy sector and its individual industries [20]. This is due to changes in the demand for various types of energy resources, as well as approaches to government regulation in the energy sector. The directions and rates of development of energy systems depend on changes in a number of factors of a political, economic, technological nature [21-30].
In order to determine the patterns and trends in the development of energy systems, it is advisable to consider the main prerequisites that determine the changes in these systems. So, starting with the industrial revolutions,

the use of various types of fuel and energy resources has become increasingly important for the development of industry, transport, and housing and utilities infrastructure. This, in turn, led to changes in the economies of different countries and society.

3. Materials and methods

The speed of technological research and development, their implementation in the electric power industry has become lower than in other industries. The development and implementation of technologies require significant acceleration by overcoming subsequent barriers [7].
1. There are no relevant standards, norms and rules to support the implementation of smart energy systems technologies. It is advisable to develop universal communication standards and common architecture that will support the interoperability of devices, technologies that allow various communication technologies to work as a unified system. Interoperability will allow information from virtually any source to be used by virtually every application [31-43].
2. An open communications and exploitation system can be vulnerable to cybersecurity issues. Open systems are more flexible and improve the basic characteristics of equipment, they are not as secure as the company's own systems. To ensure the safety of energy systems when replacing existing technologies with new ones, it is advisable to use harmonized standards and protocols for the operation of new equipment [44-59].
3. The introduction of digital technologies in the energy sector requires an appropriate analysis with regard to their application in existing systems. The advantages from the simultaneous use of different technologies are higher in comparison with the use of separate technologies in that there is a synergy effect. For example, for the collection, transmission and processing of significant amounts of data on the functioning of the energy system, it is advisable to introduce integrated information and communication systems. Individual technologies often fail because they have not been properly integrated with existing systems [60-73].
4. The problem of low competitiveness of new technological solutions. To increase the degree of implementation of certain digital technologies in the process of modernizing existing energy systems, it is advisable to reduce their cost. This requires looking for opportunities to reduce the volume of investments or increase their efficiency [74-88].
5. The issue of potential possibilities of different modes of operation of distributed energy systems remains insufficiently studied. Further research on the interaction of various systems for the distribution of electrical energy is expedient [89-102].
6. The increase in the number of entities in the electricity market is a prerequisite for the emergence of problems with regard to the safety and reliability of the functioning of energy systems. Physical and cybersecurity measures should be considered by both distributed energy owners and independent power producers. Customers with automatic measuring devices (meters) also need to consider safety issues [103-118].
7. Problems of staffing and the use of new knowledge. In the energy sector, there are problems in transferring experience. This problem occurs when there are miscalculations in staffing. Technical analysis is more often carried out with the help of computer technology, as a result of which the professional level of the staff about the fundamental knowledge and understanding of the principles of the power system operation is reduced.
8. The possibilities of storing electricity are still limited. The discovery of a “breakthrough” technology will significantly speed up the process of network modernization [10-13].
In such conditions, a fundamental change in the architecture of the energy systems of the future, it is necessary to take into account the risks and threats to which it is advisable to include:
1) failure to take into account the quality and reliability of electrical energy supply;
2) asymmetry of information on the electricity market;
3) the use of inadequate energy management methods;
4) outdated regulatory framework for the functioning of the electricity market;
5) exclusion from the development and implementation of new technologies, norms and rules for the functioning of energy supply systems for stakeholders [119-120].
When the architecture of energy systems changes, certain risks arise. Accordingly, the author systematized the main groups of risks arising in the process of digital modernization of the energy system (Fig. 1).

Figure 1. Systematization of the risks for an intelligent power system development

It is necessary to consider the most possible and feasible provisions and approaches to the application and development of the concept of an intelligent power system in the energy sector.

4. Results and discussion

Based on the results of the analysis, as well as on the experience of the development and implementation of digital technologies in industrialized countries, we can say that the development of this can be considered much broader – as a whole complex of interrelated tasks: scientific and technological, business tasks (determining the development strategies of companies and regions), economic, social, associated with increasing the economic efficiency of the operation of enterprises in the energy sector, creating new jobs. The development of conceptual provisions for the development of intelligent power systems can serve as the basis for organizing an effective system of interaction between science and business in the field of the electric power industry, as well as the development of an appropriate innovation infrastructure. Consolidation of efforts of the state, science and business is a prerequisite for creating a platform for discussion, development and solution of the main conceptual, scientific, methodological and technological issues of the energy sector development [18].

Based on the foregoing, we can conclude that a possible approach to the development of an intelligent power system should take into account the following provisions:

1. The problem of the development of the domestic electric power industry goes beyond the sectoral program and is considered as a national innovation program, in conjunction with other national projects and programs.
2. The main strategic goal of the industry development is a fundamental, qualitative change and development of the intellectual and technological potential of the electric power industry, which meets the global trends of social and technological development.
3. The technological platform as an element of the innovation infrastructure should ensure the establishment of a long-term vector of development, link research and development, business projects, public and state interests.
4. Conceptual foundations for the development of an intelligent power system should ensure the continuity of the development of the electric power industry. They should take into account the level of existing organizational, economic, technological and resource potential.

The overall effect of the introduction of smart grid technologies is presented in the Table 1.

Table 1. The effect of technology implementation

Level	Smart metering effect	
	Theoretical effect	Practical short-term effect
State	Reducing power consumption by 20%; Transparency of electricity consumption structure	Ensuring the stable functioning of the national energy system
Generation	Potential reduction in the volume of new generating capacity by 20%; peak load smoothing	Reduced need for investment. More optimal operating mode of thermal generation enterprises

Networks	Reduction of electricity losses by 50%; Reduced operating costs for equipment maintenance and repairs by 10%	Reduction of electricity losses by 50% due to commercial losses; Reduced operating costs by 10%
Sales	Improvement of debt circulation by 30%; Reducing the number of consumer calls by 30%	Reduced operating costs by 5%
Consumer	Improving the level of power quality; The ability to manage the volume and cost of your own electricity consumption based on the collected data	Reduced cost of electricity

As part of the development of a comprehensive national program for the innovative development of the electric power industry on the basis of Smart Grid, the following tasks must first be solved:
1) form a strategic vision of the future innovative development of the electric power industry;
2) determine the basic requirements and functional properties of the energy system based on the concept of smart grids and the principles of their implementation;
3) determine the main directions of development of all elements of the energy system: generation, transmission and distribution, sales, consumption and dispatching;
4) identify the main components, technologies, information and management solutions in all of the above areas;
5) ensure the coordination of modernization (bridging the technological gap) and innovative development in the electric power industry [5].
The calculation results for the implementation of digital management methods of electricity demand are shown in Figure 2 and were calculated based on the project analysis methods.

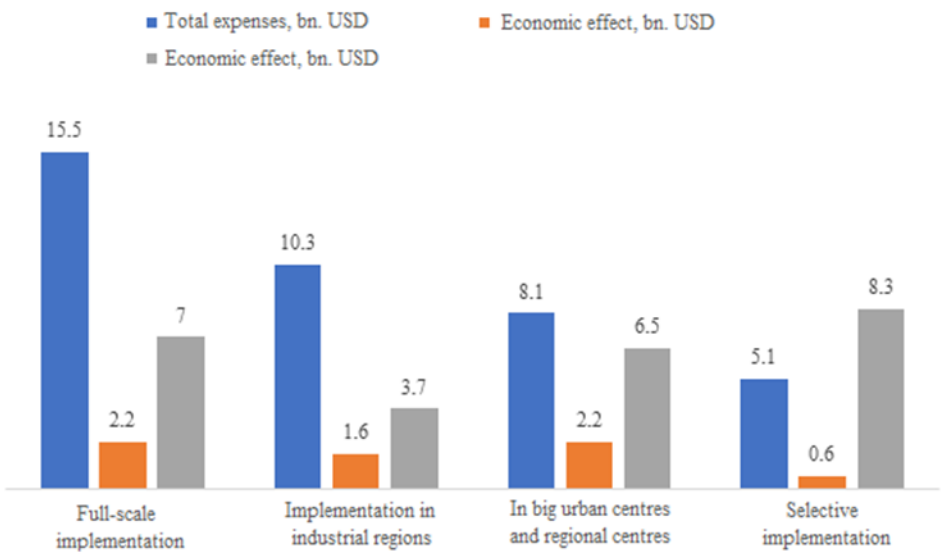

Figure 2. Economic effects of using intelligent electricity metering systems

Calculations include various options for implementing commercial metering systems for electricity, smart energy meters, on the basis of which it is possible to use demand management methods based on differentiated tariffs and real-time tariffs. The variety of options is determined on the basis of data on the possibility of using similar methods and systems with various acceptable economic effects and scale of implementation. The effect of using these systems is especially noticeable at enterprises with high consumption of electricity and in densely populated areas or regions.
The directions and stages of the integration process of information and communication technologies and electric power grids provide for carrying out the appropriate technological forecasting (energy foresight), determining the effects of the introduction of technologies, determining the bifurcation points, that is, the timing of replacement of traditional energy technologies with alternative energy sources, when the structure of the energy balance will change and develop intelligent power system architecture.
To obtain results on the transition to a new qualitative state of the system's functioning, that is, the determination of bifurcation points, and the calculation of the cost under various conditions of the use of progressive smart metering technologies and flexible AC transmission systems in the backbone grids, modelling was carried out

to equalize the imbalance of generation and consumption of electricity. The existing model for calculating the cost and determining the development of macrotechnologies in the field of energy efficiency was adapted for modelling. Since the introduction of electricity demand management methods especially affects the operation of thermal power plants, the main effect is to reduce the use of 200 and 300 MW units by 20-30% and save fuel within 4060 million tons of fuel equivalent per year by smoothing the daily load schedule, as well as passing the heating season [20].

The displacement diagrams of one technique for another are S-shaped curves. If the question is not about replacing old technology with a new one, but about using new technology that performs functions that were not previously performed by them, then we still have the same type of growth curve. A model-scenario analysis of the development of energy technologies and an assessment of their impact on the structure of electricity demand provides for:

– presentation of relevant aspects in the global energy systems;
– formalization of models, data entry;
– an overview of the possible development of technologies using scenario analysis of the constructed models.

The components of the model-scenario analysis of energy technologies development are shown in Fig. 3, and the conceptual diagram of the model is shown in Fig. 4.

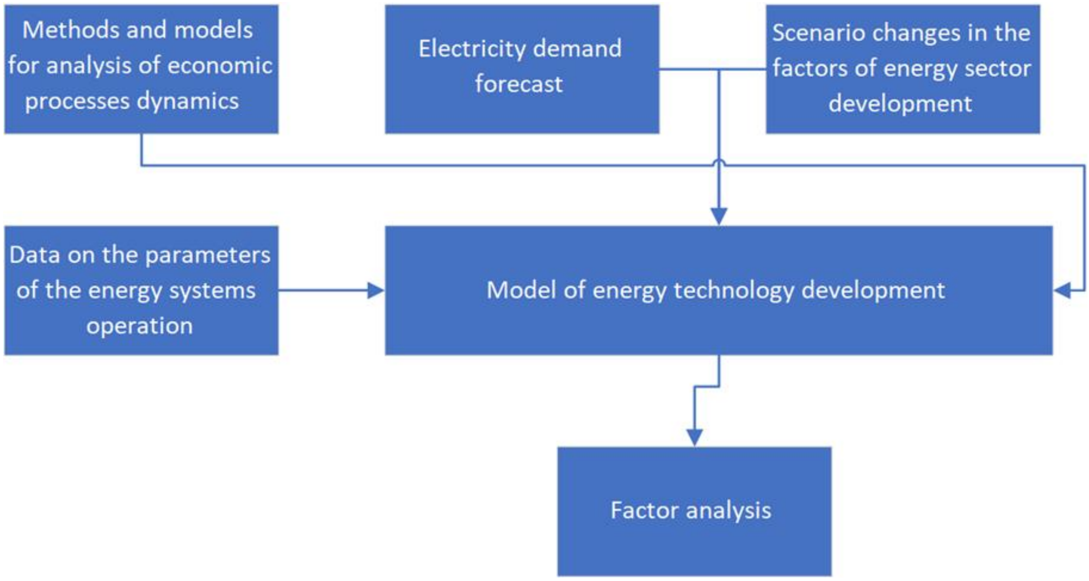

Figure 3. Components of the process of model-scenario analysis of the development of energy technologies

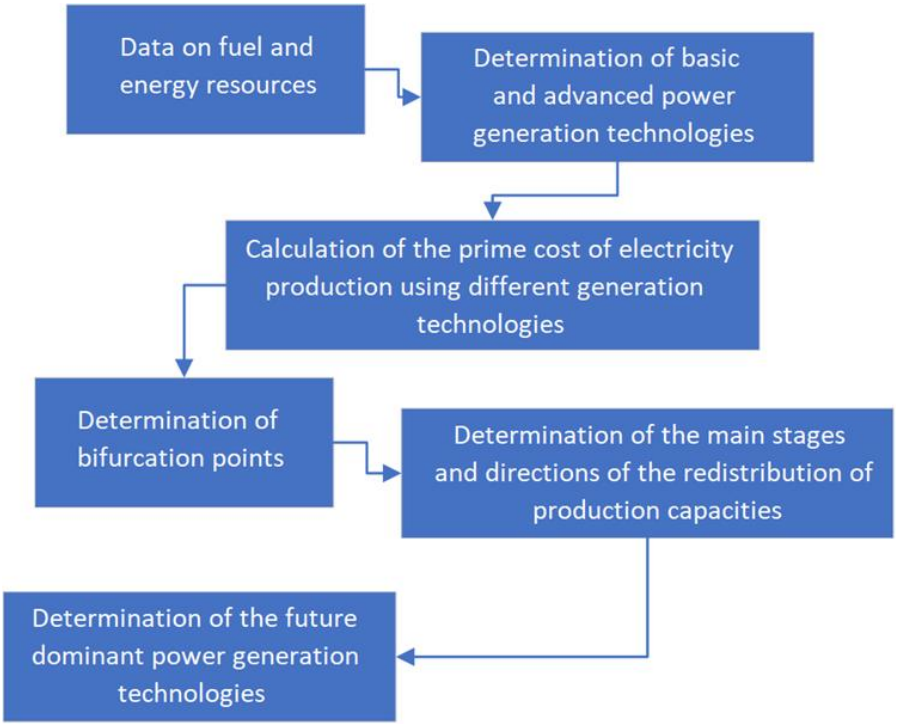

Figure 4. Conceptual diagram of the model

A number of assumptions were made to construct an economic and mathematical parametric model. Namely: we have a set (vector) of technologies $F_i(\eta_i; P_{ck}; q_i; \omega_i; v_i)$, where η_i – coefficient of utilisation; P_{ck} – primary fuel price; q_i – installed capacity; ω_i – unit cost; v_i – CO_2 emissions. The following technologies were chosen for the calculations: $F_1(\eta_1; P_{ck}; q_1; \omega_1; v_1)$ Steam turbine TPP with subcritical steam parameters; $F_2(\eta_2; P_{ck}; q_2; \omega_2; v_2)$ Steam turbine TPP with supercritical steam parameters; $F_3(\eta_3; P_{ck}; q_3; \omega_3; v_3)$ NPP; $F_4(\eta_4; P_{ck}; q_4; \omega_4; v_4)$ HPP; $F_5(\eta_5; P_{ck}; q_5; \omega_5; v_5)$ solar power plants (silicon); $F_6(\eta_6; P_{ck}; q_6; \omega_6; v_6)$ solar power plants (thin-film); $F_7(\eta_7; P_{ck}; q_7; \omega_7; v_7)$ solar power plants (concentrator); $F_8(\eta_8; P_{ck}; q_8; \omega_8; v_8)$ wind power plants. The objective function has the following form (Eq. 1):

$$Z = \sum_{i=1}^{l}\left(C_i \sum_j X_{ij}\right) \rightarrow min \qquad (1)$$

where C_i – the prime cost of electricity production using the *i*-th technology, USD / kWh, which in turn is calculated by the formula (Eq. 2-6):

$$C_{ij} = A_e + OM_e + C_f + W_e + C_{CO2e} \qquad (2)$$

$$A_e = \frac{I_p}{30Q*8750h_i} \qquad (3)$$

$$C_f = f_e P_c \qquad (4)$$

$$We = 0.05OM_e \qquad (5)$$

$$C_{CO2e} = f_e \varepsilon P_{CO2} \qquad (6)$$

The limitations of the model are as follows (Eq. 7-8):

$$\sum_i \sum_j X_{ij} \geq D_j, \quad (7)$$

$$E_n \sum_k \sum_i X_{ik} \leq T_n \quad (8)$$

where X_{ij}, – volume of electricity generated by the *i*-th technology at the *j*-th station; A_e – specific capital costs, USD/kWh; OM_e – operating expenses and management, USD/kWh; C_f – fuel costs, USD/tonne of oil equivalent; We – cost of waste disposal, USD/kWh; C_{CO2e} – emission permitting costs, USD/kWh; f_e – specific fuel consumption, TOE/kWh; P_c – fuel (coal) price, USD/TOE; D – demand for electrical energy, kWh; E_n – greenhouse gas emissions, t/kWh; T_n – target level of greenhouse gas emissions, t.

Scenario conditions for the development of electricity production provide for the accounting of prices for the following types of fuel: oil, natural gas, coal. Natural gas will undoubtedly play a central role in meeting the global energy needs for at least the next two and a half decades. Global demand for natural gas, diminished in 2009 due to the economic downturn, has been recovering its long-term growth trajectory since 2010. It is the only fossil fuel for which demand in all scenarios is higher in 2035 than in 2008, although growth rates are very different [13].

With the long-term rise in oil and gas prices, interest in coal as an alternative energy source in the world is only growing. According to forecasts of the US Department of Energy, after 2020, coal will generally become the fastest growing fuel for power plants, significantly overtaking gas. In Western European countries, where costs and consumer properties of fuel are taken into account, the ratio of prices for gas/coal/fuel oil is at the level of 2/1/ 2.8. Market-based pricing mechanisms should eliminate serious distortions in domestic gas prices and gradually bring energy price ratios to levels that have emerged elsewhere in the world.

The key criteria for choosing the future structure of generating elements are the efficiency of capital investments in various types of generation, which determines the minimum cost of electricity for the consumer (taking into account the reimbursement of capital and all other types of costs in the generation and transmission of electricity), as well as the factors of energy security, general economic efficiency, existing time limits for commissioning and environmental consequences. At the same time, a comparative analysis of the economic efficiency of various types of generation will primarily be determined by specific capital investments for the construction of various types of stations and fuel costs. This ratio is as follows (Table 2) [11].

Table 2. The main parameters of energy technologies (calculations for 2020)

Parameter	Value
Coal power plants	
Discount coefficient, %	8
Efficiency, %	36.7
Annual duration of work, hours	7446
Specific capital investments per kW of installed capacity, USD	1300
Service life, years	40
Project launch period, months	48
Fuel price, USD/mmb	1.2-1.5
Electricity production price, MW, USD	42
Discount coefficient, %	8
Efficiency, %	53
Annual duration of work, hours	7446
Specific capital investments per kW of installed capacity, USD	500
Service life, years	40
Project launch period, months	24
Fuel price, USD/mmb	4.42
Electricity production price, MW, USD	41
Coal power plants	
Discount coefficient, %	8

Efficiency, %	32.8
Annual duration of work, hours	7446
Specific capital investments per kW of installed capacity, USD	2000
Service life, years	40
Project launch period, months	60
Fuel price, USD/mmb	-
Electricity production price, MW, USD	67

Let us compare the cost characteristics of power generating technologies (Table 3). The expected decline in the cost of alternative energy sources is fundamentally dependent not on time, but on the cumulative effect of mass production, which in turn requires the development of the market for these technologies. Most technologies can reduce investment costs by 30-60% from the actual level by 2020 and by 20-50% in the period after 2040, reaching their peak development.

Particular attention should be paid to the bifurcation points. We can assume that after 2025 the cost of electricity generated using renewable energy sources, especially solar, will significantly decrease. Globally, in 2035, coal is the leading energy source used to generate electricity, although its share in electricity production is declining from the current 41% to 32%. Significant growth in coal-based electricity production in non-OECD countries will be partially offset by lower production in OECD countries.

Table 3. Estimated cost of new capacities and cost of electricity (calculations for 2020)

Technology	Investments, USD/kW	Investments, USD/kW year
Coal-fired TPPs		
steam turbine with chemical gas absorption	1850	6.79
steam turbine with supercritical steam parameters	1675	5.70
steam and gas with intracycle coal gasification	2100	6.73
hybrid steam-gas with in-cycle coal gasification and high-temperature solid oxide fuel cells	2100	6.00
with internal gasification on a water-coal mixture	1620	3.35
steam-gas plants with circulating fluidised bed (fluidised bed under pressure) and desulphurisation	1400	5.26
TPPs on gas		
Combined Cycle Plants with Chemical Absorption of Off-Gases	800	5.73
Combined cycle plants with chemical absorption of off-gases and combustion in oxygen	800	5.41
Hybrid TPPs based on a combination of high-temperature solid oxide fuel cells	1200	5.39
Modernisation of steam turbine TPPs based on a gas turbine superstructure	300-550	5.00
NPP (including decommissioning)	1200-2500	2.50-6.00
NPP (life extension)	250-390	2.50-6.00
Large hydropower	1000-2500	1.00-8.00
Small hydropower	800	6.00
Power plants on renewable sources:		
Biomass power plants	226	7.60
Geothermal power plants	2500-5084	6.50-30.80
Solar power plants (photo)	5000	15.00-50.00
Wind power plants	1370	3.60

Globally, the transition to nuclear energy, renewable energy and other low-carbon technologies is expected to reduce CO2 emissions per unit of electricity generated by one third by 2035. According to the scenarios for the development of the electric power industry, the total electrical capacity of the power units of nuclear power plants in the world can significantly increase by 2050. While coal and uranium compete for the leading place in basic electricity production, some developed countries see their progress in the same role. Solar and wind power

will become the main competitor of nuclear power by 2030. The rate of reduction in the cost of solar generation and the development of energy storage technologies allow us to assert that in 20 years, capital costs for solar generation, even in the basic mode, will be lower than for nuclear [4].
Table 4 shows some results of scenario modelling with respect to the movement of bifurcation points, and as a result, a decrease in generation volumes for certain technologies and replacement of one technology with another.

Table 4. Results of scenario modelling with respect to the movement of bifurcation points

	TPP with supercritical steam parameters	WPP	SPP	SPP	NPP
Basic scenario	2012	2014	2011	2025	2029
+ 10% of the fuel cost		2011		2023	2024
+10 % of the cost of quotas					2028
Quota cost up to $ 50/t				2024	2029
Specific fuel consumption + 5%				2022	2022
Capital costs of TPP1 +10%		2013		2024	2027
Capital costs for SPP+10%					

Based on the simulation results, we can see that an increase in the cost of fuel affects the development of technologies for alternative sources of electricity, especially solar energy. The factor of increasing specific fuel consumption is also influential. This is especially true for outdated technologies at thermal power plants. Based on the simulation results, it is possible to trace the stability or insignificant growth of electricity generation from traditional sources and a significant increase in the volume of electricity generation using technologies based on alternative sources. Thus, an economic and mathematical model has been calculated, which allows performing scenario modelling of energy technologies development, both in the world as a whole and for an individual country. On the basis of the simulation results, bifurcation points were determined, which make it possible to determine the directions and stages of the development of macrotechnologies in the field of energy and draw a sketch of further transformations in the field of energy and energy efficiency (Fig. 5).

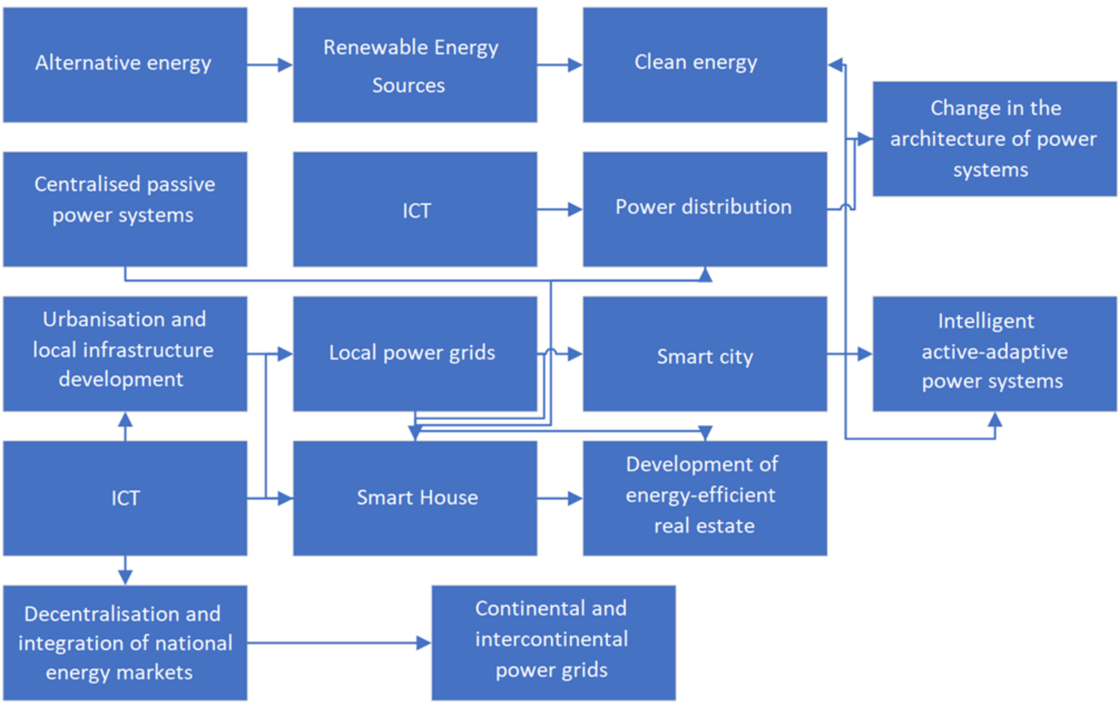

Figure 5. Development in the field of energy and energy efficiency based on digital technologies

On the basis of the energy foresight, a technological roadmap for the formation and development of an intelligent power system is being created. The experience of leading countries has shown that the introduction

of smart energy technologies into existing power systems takes place in three stages. The first stage involves the introduction of digital technologies of existing power systems. The second stage involves the development of a decentralized power system that works in conjunction with the centralized power system. The leading countries of the world are already going through this stage. Distributed generation and the power system become equal in the process of providing the consumer with electricity. There is an interaction between the main power system and the distributed generation system in the management of the energy network. Competition is starting to operate in the retail electricity market. The third stage is the creation of a hybrid power system, in which a significant amount of electricity is generated by decentralized power plants together with centralized generation. Therefore, it is advisable to develop a program for the introduction of new technologies in the electric power industry and the development of industries important in this area [1]. The following possible approaches to the choice of scenarios for the development of an intelligent energy system can be proposed:
1) scenario for monitoring and targeted implementation of certain convergent technologies;
2) scenario for the improvement of existing and creation of new technologies in the energy sector;
3) scenario for the development and implementation of a comprehensive national program for the innovative development of the electric power industry based on convergent technologies.
1. Scenario for monitoring and targeted implementation of individual smart energy system technologies. Monitoring various aspects of the Smart Grid implementation, and based on the results – implementation of proven foreign solutions and projects (not excluding their domestic development) according to the “follow the leader” scheme. Let us define the potential advantages of the scenario: the presence of an understanding of the movement of the Smart Grid development process abroad and the possibilities of using individual results in domestic practice; the ability to influence leaders by virtue of their needs; reducing the cost of financing the development of innovative and disruptive technologies. Disadvantages of this scenario: further loss of key positions in the field of innovative development of the electric power industry; the state remains on the side-lines of technical progress in a field that is extremely important for ensuring the country's energy security; consolidation of the technological gap and import dependence [13].
The necessary conditions for the implementation of this scenario are the creation of a technological monitoring system and development of an appropriate information and analytical base. The necessity and significance of this element is also conditioned by the fact that, as the results of the study have shown, to date, more than 200 technologies that are promising for use within the framework of the Smart Grid concept have been identified and developed abroad. At present, the first steps have been taken towards the implementation of this scenario – we can state the launch of the monitoring process. However, the ongoing monitoring of the implementation of the concept abroad is carried out by individual companies and research organizations and is not of a systemic nature. There is no industry-level center that would analyze the monitoring results and determine its main goals and objectives.
2. A scenario for the improvement of existing and creation of new technologies in the field of intelligent energetics. It assumes the country's inclusion in the global technology development processes in those areas where it can have potential competitive advantages, the use and development of the existing potential in those areas where its competencies are still unique and have no analogues. The advantages of the scenario are as follows: national and energy security; promotion of our own developments and technologies to the global level; growth of import substitution in the industry; development of scientific, technical and innovation potential. Implementation flaws are manifested in the fact that:
1) in 10-15 years, the country, developing individual areas in science and technology that are not united by a systemic concept like Smart Grid, may possess a certain set of modern technologies that will successfully solve individual local problems, but will not allow solving systemic problems of energy development complex at the global level;
2) the country remains technologically dependent on the development of foreign technological areas that are in the interests of the Russian Federation.
3. Scenario for the development and implementation of a comprehensive national program for the innovative development of the electric power industry. The country develops a national concept of an intelligent power system, coordinates it with the priorities of the country's innovative development, key areas and critical technologies, as well as with adopted national programs and projects.
The main driving forces behind the implementation of this strategy can be: energy efficiency; reliability and safety of power supply; advanced power transmission technologies, storage devices, nanomaterials; methods of managing large energy systems; information systems and technologies; supercomputers, parallel computing systems and algorithms. The advantages of this scenario include:

1. Technological: the state develops competencies in science and technology within the framework of the Smart Grid concept; ensure the uniformity of standards and compatibility of technologies; a balanced approach to the development of the power grid complex is being implemented (intensively, through the introduction of new management technologies, and extensively, through the construction of new capacities where it is appropriate and efficient); construction of new networks is carried out taking into account modern standards and requirements of Smart Grid and the experience of introducing domestic and foreign pilot projects.
2. Political: Russian energy companies are successfully integrating into the global electricity market; the prestige of the state as one of the leaders of scientific and technological progress is increasing; the innovative development of the country's energy economy is ensured.
3. Social: investments are directed to the development of the industry and science; creation of new jobs; new markets for sale and export of technologies and goods are being created; in the future, resources are freed up for the development of other sectors of the economy.

The last scenario is the most comprehensive and the best, integrating the previous ones, includes and develops their main advantages. In the process of modernizing the domestic electric power industry, it is necessary to coordinate the issues of interaction between various ministries, committees, agencies whose activities are aimed at regulating and developing infrastructure, electricity, housing and utilities infrastructure and informatization in various sectors of the economy. It is necessary to provide for the creation of an interdepartmental commission to agree and develop a joint action plan, provide for a multi-level system for the development and implementation of projects to modernize the existing system, create an effective mechanism for cooperation between domestic and foreign companies working in the field of informatization of energy systems. Therefore, there is a need to develop a concept of an intelligent energy system of the state and a corresponding comprehensive state program for the modernization of the existing energy system.

5. Conclusions

The rapid development of technology and changes in world's major economies affect the increase in electricity consumption. Under such conditions, the question arises of increasing the efficiency of generation, supply, distribution and use of energy. Today, the energy industry is undergoing a transformation that is gaining a global character, which should lead to significant changes in the energy sector. There are two main answers to the question about the development of energy supply in the future. The first option is known as "energy efficiency plus". It provides for the modernization of existing power systems, which are based on centralized power supply networks, large-scale generation and "carbon energy". The second option is a new concept that relies on the creation of new energy based on renewable energy sources, on the architecture of the power system based on a decentralized smart grid and "smart" urban infrastructure. In the new energy supply system, information acts as the main means of effective management. Management and informational communications are becoming a factor that will turn the existing system into an energy-informational one.

Regarding the problems in government regulation and legislation, these aspects have not yet taken a leading role in the modernization of the energy complex. Government officials lack a clear understanding of the necessary regulatory and legislative initiatives to ensure the implementation of the concept of smart energy systems. There is no necessary mechanism to stimulate investment in programs to improve the quality of electricity, including programs that take into account the relationship between the price and quality of electricity. To overcome the above barriers, it is necessary to take appropriate measures from both the state and energy companies. It is necessary to develop a state strategy to attract investment for the development of the energy sector. The state should stimulate the development of smart energy systems. This can be both a significant reduction in the tax burden and the provision of tax holidays during the introduction of new technologies, depending on the territories or industries where radically new technologies for the production, transmission and use of energy are located. At the same time, traditional energy should not receive benefits from the state. It is necessary to constantly engage in the creation of a new institutional field for the production, use, economy and environmental friendliness of energy resources in the country. Therefore, radical political and economic solutions are necessary for this extremely important issue.

It should be noted the need for the state to take radical measures to implement a new modern strategy for the development of the electric power industry, which would take into account not only economic, but also political, environmental and territorial features of the state. The renewal of the energy strategy should be based on new technologies and consider the possibility of creating a new architecture for the smart energy system. The development of new convergent technologies and their use requires deepening cooperation between the scientific community, business and the state. The Russian Federation needs to take into account the experience of European countries, which indicates that one of the effective organizational and economic mechanisms for the implementation of large-scale technological projects is the creation of technological platforms.

References

[1] Y. -H. Liang, S. -T. Tan, Y. Zhang, X. -G. Xiong, Z. -Y. Liu and Z. -G. Guo, "Application of security techniques to electric energy metering and billing system in regional power network", *Power System Technology*, vol. 28, no. 20, pp. 72-75, 2004.

[2] Q. Zhang, H. Cheng, H. Li and W. Wei, "Multi-parameter degradation model and error evaluation method for digital electrical power metering system", *Dianwang Jishu*, vol. 39, no. 11, pp. 3202-3207, 2015.

[3] E. I. Khabarova, S. V. Nikitina and L. L. Budaeva, "Formation of ecological thinking among the university graduates, namely future professionals and leaders", *Russian Technological Journal*, vol. 5, no. 4, pp. 77-84, 2017.

[4] M. M. Haque, M. K. Hossain, M. M. Ali and M. R. I. Sheikh, "Microcontroller based single phase digital prepaid energy meter for improved metering and billing system", *International Journal of Power Electronics and Drive Systems*, vol. 1, no. 2, pp. 139-147, 2011.

[5] F. Gottschling, "Smart meter operator as a service provider for energy suppliers", *Gas – Erdgas*, vol. 151, no. 5, pp. 312-315, 2010.

[6] C. -P. Young and M. J. Devaney, "Digital power metering manifold", *IEEE Transactions on Instrumentation and Measurement*, vol. 47, no. 1, pp. 224-228, 1998.

[7] S. Luckhardt, "Ready for business with smart communication", *Gas – Erdgas*, vol. 152, no. 5, pp. 314-316, 2011.

[8] B. Wu and N. Tan, "An energy metering and measurement SoC with a novel low-power DSP architecture", *IEEE Internet of Things Journal*, vol. 6, no. 2, pp. 3298-3308, 2019.

[9] L. K. Osika, "Modern requirements on the measuring instruments for commercial electricity metering purposes", *Elektrichestvo*, vol. 3, pp. 2-9, 2005.

[10] H. Hu, W. Wu, M. Lei, Y. Xu, Q. Xiong, X. Xiao and S. Zhang, "Discussion on standardization of merging unit for metering and electronic transformer metering interface", *Dianwang Jishu*, vol. 38, no. 5, pp. 1414-1419, 2014.

[11] Y. -S. Lee, J. Seo, J. Wee, M. Kang and D. K. Kim, "Single-phase energy metering chip with built-in calibration function", *KSII Transactions on Internet and Information Systems*, vol. 9, no. 8, pp. 3112-3129, 2015.

[12] Y. Tang, B. Jiang, H. Li and X. Chen, "Survey on the verification methods for digital electrical energy metering", *Diangong Jishu Xuebao*, vol. 28, no. 2, pp. 372-377, 2013.

[13] Z. Fu, X. Xiong, X. Hou, H. Zhang and S. Li, "Real-time simulation system for electric energy metering based on dSPACE", *Chinese Journal of Scientific Instrument*, vol. 32, no. 8, pp. 1763-1770, 2011.

[14] C. Men and N. Tan, "A harmonic energy metering algorithm suitable for VLSI implementations", *Diangong Jishu Xuebao*, vol. 24, no. 11, pp. 178-183, 2009.

[15] I. Gribust, "Environmental elements for revitalization of entomophages in the forest plantations of the arid zone", *World Ecology Journal*, vol. 9, no. 1, pp. 55-69, 2019.

[16] J. Li, Y. -H. Yang, W. -B. Yu, G. -Q. Zhang and W. -H. Ning, "Review of electric energy metering system", *Dianli Xitong Baohu Yu Kongzhi*, vol. 37, no. 11, pp. 130-134, 2009.

[17] R. A. Stewart, K. Nguyen, C. Beal, H. Zhang, O. Sahin, E. Bertone and P. Kossieris, "Integrated intelligent water-energy metering systems and informatics: Visioning a digital multi-utility service provider", *Environmental Modelling and Software*, vol. 105, pp. 94-117, 2018.

[18] Y. Xiao, R. Luo, W. Zhao, B. Jiang, S. Huang and X. Zhang, "Fast quasi-synchronous harmonic algorithm for IEC61850 based digital energy metering devices", *Dianwang Jishu*, vol. 42, no. 2, pp. 621-627, 2018.

[19] D. Suh, I. Kim and J. Kim, "A knowledge-based energy management model that supports smart metering networks for Korean residential energy grids", *Wireless Personal Communications,* vol. 94, no. 3, pp. 431-444, 2017.

[20] W. L. Stebbins, "New concepts in electrical metering for energy management", *IEEE Transactions on Industry Applications*, vol. 22, no. 2, pp. 382-388, 1986.

[21] P. Kumar, A. Gurtov, M. Sain, A. Martin and P. H. Ha, "Lightweight authentication and key agreement for smart metering in smart energy networks", *IEEE Transactions on Smart Grid*, vol. 10, no. 4, pp. 4349-4359, 2019.
[22] 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.
[23] 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.
[24] 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.
[25] 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.
[26] 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.
[27] 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.
[28] 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.
[29] 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.
[30] 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.
[31] 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.
[32] 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.
[33] 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.
[34] 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.
[35] 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.
[36] 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.
[37] M. N. Krasil'shchikov, D. A. Kozorez, K. I. Sypalo, O. F. Samarin, V. Y. Savost'yanov, "High accuracy positioning of phase center of multifunction airborne radar antenna," *Gyroscopy and Navigation,* vol. 4, no. 3, pp. 164-173, 2013.
[38] A. E. Sorokin, S. V. Novikov, "Formation of the national economy of Russia in the context of state support of innovation actions," *Espacios,* vol. 40, no. 38, pp. 1-9, 2019.
[39] 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.
[40] E. E. Galkina, A. E. Sorokin, "Quality management and sustainable economic development," *Russian Engineering Research,* vol. 40, no. 7, pp. 577-578, 2020.
[41] 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.

[42] 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.

[43] 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.

[44] 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.

[45] 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.

[46] 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.

[47] 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.

[48] 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.

[49] 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.

[50] 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.

[51] 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.

[52] 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.

[53] 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.

[54] 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.

[55] 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.

[56] 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.

[57] 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.

[58] 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.

[59] 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.

[60] 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.

[61] 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.

[62] 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.

[63] 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.

[64] M. M. Sevryukova, Y. P. Piryatinski, S. V. Vasylyuk, V. M. Yashchuk, O. O. Viniychuk, A. O. Gerasov, Y. L. Slominskii, O. D. Kachkovsky, “Cyanine-like and polyenic relaxation paths of merocyanine derivatives ofmalonodinitrile in the excited state detecting by low temperature time-resolved fluorescence,” *Ukrainian Journal of Physics,* vol. 57, no. 8, pp. 812-823, 2012.

[65] S. V. Vasylyuk, A. D. Suprun, L. V. Shmeleva, O. D. Kachkovsky, “Configuration of charge waves in polymethine linear dye systems,” *Springer Proceedings in Physics,* vol. 246, pp. 189-201, 2021.

[66] I. A. Kapitonov, “Low-carbon economy as the main factor of sustainable development of energy security,” *Industrial Engineering and Management Systems,* vol. 19, no. 1, pp. 3-13, 2020.

[67] I. A. Kapitonov, “Transformation of social environment in the application of alternative energy sources,” *Environment, Development and Sustainability,* vol. 22, no. 8, pp. 7683-7700, 2020.

[68] S. Kukharets, G. Golub, O. Skydan, Y. Yarosh, M. Kukharets, “Justification of air flow speed in the oxidation area of a gasifier in case of straw pellets using,” *INMATEH – Agricultural Engineering,* vol. 60, no. 1, pp. 37-44, 2020.

[69] G. Golub, O. Skydan, V. Kukharets, Y. Yarosh, S. Kukharets, “The estimation of energetically self-sufficient agroecosystem’s model,” *Journal of Central European Agriculture,* vol. 21, no. 1, pp. 168-175, 2020.

[70] G. Golub, S. Kukharets, O. Skydan, Y. Yarosh, V. Chuba, V. Golub, “The optimization of the gasifier recovery zone height when working on straw pellets,” *International Journal of Renewable Energy Research,* vol. 10, no. 2, pp. 529-536, 2020.

[71] G. Golub, S. Kukharets, J. Česna, O. Skydan, Y. Yarosh, M. Kukharets, “Research on Changes in Biomass During Gasification,” *INMATEH – Agricultural Engineering,* vol. 61, no. 2, pp. 17-24, 2020.

[72] V. P. Privalko, R. V. Dinzhos, E. G. Privalko, “Enthalpy relaxation in the cooling/heating cycles of polypropylene/ organosilica nanocomposites I: Non-isothermal crystallization,” *Thermochimica Acta,* vol. 432, no. 1, pp. 76-82, 2005.

[73] N. M. Fialko, V. G. Prokopov, N. O. Meranova, Yu. S. Borisov, V. N. Korzhik, G. P. Sherenkovskaya, “Heat transport processes in coating-substrate systems under gas-thermal deposition,” *Fizika i Khimiya Obrabotki Materialov,* vol. 2, pp. 68-75, 1994.

[74] D. G. Blinov, V. G. Prokopov, Yu. V. Sherenkovskii, N. M. Fialko, V. L. Yurchuk, “Effective method for construction of low-dimensional models for heat transfer process,” *International Journal of Heat and Mass Transfer,* vol. 47, no. 26, pp. 5823-5828, 2004.

[75] R. V. Dinzhos, N. M. Fialko, E. A. Lysenkov, “Analysis of the thermal conductivity of polymer nanocomposites filled with carbonnanotubes and carbon black,” *Journal of Nano- and Electronic Physics,* vol. 6, no. 1, 01015, 2014.

[76] N. I. Kobasko, N. M. Fialko, N. O. Meranova, “Numerical determination of the duration of the nucleate-boiling phase in the course of steel-plate hardening,” *Heat Transfer. Soviet Research,* vol. 16, no. 2, pp. 130-135, 1984.

[77] V. G. Prokopov, N. M. Fialko, G. P. Sherenkovskaya, V. L. Yurchuk, Yu. S. Borisov, A. P. Murashov, V. N. Korzhik, “Effect of coating porosity on the process of heat transfer with gas-thermal deposition,” *Powder Metallurgy and Metal Ceramics,* vol. 32, no. 2, pp. 118-121, 1993.

[78] A. Zvorykin, S. Aleshko, N. Fialko, N. Maison, N. Meranova, A. Voitenko, I. Pioro, “Computer simulation of flow and heat transfer in bare tubes at supercritical parameters,” *International Conference on Nuclear Engineering, Proceedings, ICONE,* vol. 5, pp. 1-12, 2016.

[79] R. Navrodska, N. Fialko, G. Presich, G. Gnedash, S. Alioshko, S. Shevcuk, “Reducing nitrogen oxide emissions in boilers at moistening of blowing air in heat recovery systems,” *E3S Web of Conferences,* vol. 100, 00055, 2019.

[80] N. M. Fialko, V. G. Prokopov, N. O. Meranova, Yu. S. Borisov, V. N. Korzhik, G. P. Sherenkovskaya, “Single particle-substrate thermal interaction during gas-thermal coatings fabrication,” *Fizika i Khimiya Obrabotki Materialov,* vol. 1, pp. 70-78, 1994.

[81] R. Dinzhos, E. Lysenkov, N. Fialko, “Simulation of thermal conductivuty of polymer composites based on poly (methyl methacrylate) with different types of fillers,” *Eastern-European Journal of Enterprise Technologies,* vol. 6, no. 11, pp. 21-24, 2015.

[82] A. Zvorykin, N. Fialko, S. Julii, S. Aleshko, N. Meranova, M. Hanzha, I. Bashkir, S. Stryzheus, A. Voitenko, I. Pioro, “CFD study on specifics of flow and heat transfer in vertical bare tubes cooled with water at supercritical pressures,” *International Conference on Nuclear Engineering, Proceedings, ICONE,* vol. 9, pp. 1-13, 2017.

[83] N. Fialko, R. Navrodska, M. Ulewicz, G. Gnedash, S. Alioshko, S. Shevcuk, "Environmental aspects of heat recovery systems of boiler plants," *E3S Web of Conferences,* vol. 100, 00015, 2019.

[84] 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.

[85] N. M. Fialko, R. O. Navrodska, G. O. Gnedash, G. O. Presich, S. I. Shevchuk, "Study of heat-recovery systems of or heating and moisturing combustion air of boiler units," *Science and Innovation,* vol. 16, no. 3, pp. 43-49, 2020.

[86] D. V. Topchiy, A. S. Bolotova, "The monolithic buildings complex renovation's organizational and technological model creation," *IOP Conference Series: Materials Science and Engineering,* vol. 913, no. 4, 042016, 2020.

[87] D. Topchiy, A. Bolotova, "Systematization of factors affecting the organizational processes in the conversion of buildings," *IOP Conference Series: Materials Science and Engineering,* vol. 753, no. 3, 032042, 2020.

[88] D. Topchiy, A. Bolotova, "Assessment and inspection of the technical condition of monolithic reinforced structures in transportation infrastructure facilities," *Journal of Physics: Conference Series,* vol. 1425, no. 1, 012005, 2020.

[89] D. Topchiy, A. Bolotova, "Studying specific features of the monolithic construction technology based on systemic analysis," *IOP Conference Series: Materials Science and Engineering,* vol. 603, no. 5, 052004, 2019.

[90] A. Lapidus, D. Topchiy, "Construction supervision at the facilities renovation," *E3S Web of Conferences,* vol. 91, 08044, 2019.

[91] A. Lapidus, A. Makarov, "Automation of roof construction management by means artificial neural network," *Advances in Intelligent Systems and Computing,* vol. 692, pp. 1168-1176, 2018.

[92] A. Lapidus, Y. Shesterikova, "Mathematical model for assessing the high-rise apartment buildings complex quality," *E3S Web of Conferences,* vol. 91, 02025, 2019.

[93] A. Lapidus, A. Khubaev, T. Bidov, "Development of a three-tier system of parameters in the formation of the organizational and technological potential of using non-destructive testing methods," *E3S Web of Conferences,* vol. 97, 06037, 2019.

[94] 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.

[95] V. Z. Kutsova, M. A. Kovzel, P. U. Shvets, A. V. Grebeneva, V. V. Prutchykova, "Structure, phase composition of supercooled austenite, and kinetics of its decomposition in perlite temperature range of chromium-manganese cast iron," *Metallofizika i Noveishie Tekhnologii,* vol. 40, no. 4, pp. 551-560, 2018.

[96] N. Zaurbekov, A. Aidosov, N. Zaurbekova, G. Aidosov, G. Zaurbekova, I. Zaurbekov, "Emission spread from mass and energy exchange in the atmospheric surface layer: Two-dimensional simulation," *Energy Sources, Part A: Recovery, Utilization and Environmental Effects,* vol. 40, no. 23, pp. 2832-2841, 2018.

[97] I. V. Cherunova, S. S. Tashpulatov, S. V. Kurenova, "Treated textile electrostatic properties study," *Materials Science Forum,* vol. 992, pp. 439-444, 2020.

[98] S. S. Tashpulatov, I. V. Cherunova, M. K. Rasulova, D. D. Inogamdjanov, M. Yu. Umarova, A. D. Daminov, U.R. Uzakova, S. G. Jurayeva, "Development of the calculation method of polymer compound mass to be applied onto the textile garment pieces," *IOP Conference Series: Materials Science and Engineering,* vol. 459, no. 1, 012067, 2018.

[99] L. N. Nutfullaeva, A. F. Plekhanov, I. G. Shin, S. S. H. Tashpulatov, I. V. Cherunova, S. H. N. Nutfullaeva, E. A. Bogomolov, "Research of conditions of formation package and ensure the safety of the pillows from composite nonwoven fibers materials," *Izvestiya Vysshikh Uchebnykh Zavedenii, Seriya Teknologiya Tekstil'noi Promyshlennosti,* vol. 380, no. 2, pp. 95-101, 2019.

[100] I. Cherunova, S. Tashpulatov, Y. Davydova, "Geometric conditions of mathematical modeling of human heat exchange processes with the environment for CAD systems creating heat-shielding clothing," *IOP Conference Series: Materials Science and Engineering,* vol. 680, no. 1, 012039, 2019.

[101] A. B. Baibatsha, A. Muszyński, T. K. Shaiyakhmet, G. S. Shakirova, "3D modeling for estimation of engineering-geological conditions of operating mineral deposits," *News of the National Academy of*

Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences, vol. 4, no. 442, pp. 19-27, 2020.
[102] 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.
[103] A. Jurgaitis, D. Topchiy, A. Kravchuk, D. Shevchuk, "Controlling methods of buildings' energy performance characteristics," *E3S Web of Conferences,* vol. 91, 02026, 2019.
[104] D. V. Topchiy, A. S. Bolotova, A. A. Zelentsov, A. S. Vorobev, A. V. Atamanenko, "Technical rationing of the construction technology of reinforced concrete floor slabs using non-removable empitness-liners," *International Journal of Civil Engineering and Technology*, vol. 10, no. 2, pp. 2160-2166, 2019.
[105] 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.
[106] V. Z. Kutsova, M. A. Kovzel, A. V. Grebeneva, I. V. Ratnikova, O. A. Velichko, "The influence of alloying elements on structure formation, phase composition and properties of chromium-manganese iron in the cast state," *Metallurgical and Mining Industry,* vol. 7, no. 9, pp. 1090-1095, 2015.
[107] B. Sinchev, S. E. Sibanbayeva, A. M. Mukhanova, A. N. Nurgulzhanova, N. S. Zaurbekov, K. S. Imanbayev, N. L. Gagarina, L. K. Baibolova, "Some methods of training radial basis neural networks in solving the Navier-Stokes equations," *International Journal for Numerical Methods in Fluids,* vol. 86, no. 10, pp. 625-636, 2018.
[108] A. A. Talaspayeva, R. O. Zhilisbayeva, S. S. H. Tashpulatov, "Study of strength characteristics of nonwoven samples," *Izvestiya Vysshikh Uchebnykh Zavedenii, Seriya Teknologiya Tekstil'noi Promyshlennosti,* vol. 371, no. 5, pp. 126-128, 2017.
[109] B. H. Baymuratov, S. S. Tashpulatov, R. D. Akbarov, M. Ilhamova, G. A. Yusuphodjaeva, U. T. Uzakov, N. A. Yusuphodjaeva, "Development of special fabrics protecting from electromagnetic radiation," *IOP Conference Series: Materials Science and Engineering,* vol. 459, no. 1, 012031, 2018.
[110] 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.
[111] A. Mustafin, A. Kantarbayeva, "A catalytic model of service as applied to the case of a cyclic queue," *Izvestiya Vysshikh Uchebnykh Zavedeniy. Prikladnaya Nelineynaya Dinamika,* vol. 27, no. 5, pp. 53-71, 2019.
[112] A. Kadyrov, A. Ganyukov, M. Imanov, K. Balabekova, "Calculation of constructive elements of mobile overpass," *Current Science,* vol. 116, no. 9, pp. 1544-1550, 2019.
[113] D. Topchiy, A. Bolotova, "Risk management in monolithic construction," *IOP Conference Series: Materials Science and Engineering,* vol. 962, no. 2, 022078, 2020.
[114] S. A. Montayev, S. M. Zharylgapov, K. A. Bisenov, B. T. Shakeshev, M. Z. Almagambetova, "Investigating oil sludges and their application as energy efficient and modifying component in ceramic pastes", *Research Journal of Pharmaceutical, Biological and Chemical Sciences,* vol. 7, no. 3, pp. 2407-2415, 2016.
[115] A. Kadyrov, K. Balabekova, A. Ganyukov, S. Akhmediyev, "The constructive solution and calculation of elements of the unified module of the mobile bridge overcrossing", *Transport Problems,* vol. 12, no. 3, pp. 59-69, 2017.
[116] K. Sultanov, B. Khusanov, B. Rikhsieva, "Underground pipeline strength under non-one-dimensional motion," *IOP Conference Series: Materials Science and Engineering,* vol. 883, no. 1, 012023, 2020.
[117] K. Sultanov, B. Khusanov, B. Rikhsieva, "Interaction of a rigid underground pipeline with elastic-viscous-plastic soil," *IOP Conference Series: Materials Science and Engineering,* vol. 883, no. 1, 012038, 2020.
[118] S. Z. Mirzaev, U. Kaatze, "Dynamic scaling in the ultrasonic attenuation spectra of critical binary mixtures," *Chemical Physics Letters,* vol. 328, no. 3, pp. 277-282, 2000.
[119] R. A. Maleev, S. M. Zuev, A. M. Fironov, N. A. Volchkov, A. A. Skvortsov, "The starting processes of a car engine using capacitive energy storages," *Periodico Tche Quimica,* vol. 16, no. 33, pp. 877-888, 2019.
[120] N. Khripach, L. Lezhnev, A. Tatarnikov, R. Stukolkin, A. Skvortsov, "Turbo-generators in energy recovery systems," *International Journal of Mechanical Engineering and Technology,* vol. 9, no. 6, pp. 1009-1018. 2018.