Advances in Social Science, Education and Humanities Research, Volume 489
Proceedings of the International Conference Digital Age: Traditions, Modernity and Innovations (ICDATMI 2020)

Management of the Regional Energy Systems Development Based on the Economic Assessment of Energy Security

Evgeny Lisin
dept. of Economics in Power Engineering and Industry
National Research University "Moscow Power Engineering Institute"
Moscow, Russia
lisinym@mpei.ru

Oksana Konovalova
dept. of Economics in Power Engineering and Industry
National Research University "Moscow Power Engineering Institute"
Moscow, Russia
konovaog@mpei.ru

***Abstract*—The paper examines the problem of managing the development of regional energy systems from the standpoint of ensuring energy security. The economic and managerial threats of disruption of reliable power supply to consumers, arisen in the process of introducing market relations in the energy industry, are considered. A model for assessing the economically justified level of energy security on the basis of the criterion for ensuring a balance of interests of territorial government bodies and regional generating companies when forming a strategy for the development of regional energy systems has been developed. On the basis of the developed model, conclusions about the effectiveness of the energy policy for the development of energy systems in the Far Eastern region of Russia are made.**

Keywords—regional power systems, management methods, territorial public administration, regional energy companies, economic accessibility

I. INTRODUCTION

Economic and financial instruments, such as taxes, fees, tEnsuring energy security is one of the priorities of the state's economic activity. At the same time, the state's activity in the energy sector is traditionally included in its economic functions and is understood rather narrowly as the regulation of natural monopolies in the energy sector, which is a clear underestimation of the role that energy plays in the economy [1, 2, 3, 4, 5].

The state's activity in the energy sector, first of all, should be aimed at ensuring reliable and continuous energy systems operation at various organizational levels, the sustainable development of which in the face of energy security modern problems and challenges will be a guarantee of energy security of the country and its regions. In this case, the economic relations regulation arising in the process of regional energy systems functioning and development will be the key mechanism of state management at the territorial level in market conditions. This representation of the state's activity allows us to distinguish its energy function as a set of economic activity directions aimed at ensuring the reliable operation and sustainable development of the energy system of the country and its regions, the formation of energy resources and products markets, and the regulation of legal relations between their participants.

The market model of energy sector management adopted in Russia requires coordination of development strategies for its facilities from the energy companies that manage them and territorial government bodies, in order to ensure the necessary level of energy security of the regions to respond to external and internal challenges to the reliability and efficiency of local consumers integrated energy supply.

The conflict of interests generated by the market, which is shown in the difference in ideas about the efficiency of the energy sector at different levels of management of its facilities (region and energy enterprises), leads to a mismatch of the territorial energy management system. While the state's criterion for the efficiency of the energy sector is effective operation of power systems while ensuring a given level of reliability, the criterion for energy enterprises is profitability, that is, the compliance of economic facilities with a competitive technological infrastructure that allows to earn profits in the various trading sectors of energy markets [5, 6, 7].

Failure to take this factor into account in the formation of regional energy policy leads to conditions under which energy enterprises are not able to meet the state requirements for the energy sector. Thus, the energy strategy of the region is deprived of the ability to carry out managerial functions, turning into a framework document. Preconditions are created not only for deviating the development of the energy economy from the science-based directions laid down in the strategy, but also for the formation of completely different vectors of its

evolution, caused by unexplored causal relationships, which increases the uncertainty and, consequently, the probability of realization of threats to energy security.

II. LITARATURE REVIEW

The key documents defining the conceptual apparatus and the main indicators of energy security of Russian regions are [8, 9, 10, 11, 12, 13, 14]:

- Energy Strategies of Russia until 2030 and 2035 (2009, 2014);
- General layout of power facilities until 2030 and 2035 (2010, 2017);
- Federal Laws "On the Electric Power Industry" (2010), "On Heat Supply" (2010), "On the Safety of Fuel and Energy Complex" (2011);
- Energy Security Doctrine (2012).

According to these documents, energy security, expressing the energy aspects of national security, determines the state of the country's defense against threats to reliable fuel and energy supply, the provision of which is one of the priority tasks of the state.

The conceptual apparatus of energy security is based on the concepts of national security and reliability [5, 14, 15].

From the standpoint of the concept of national security, energy security expresses its energy aspects and reflects the contribution of energy to its provision. In fact, energy security is a part of economic security that characterizes the security of economic relations. It is implemented through economic mechanisms and stands out in a separate category due to the decisive influence of energy on the development of the national economy [5, 14, 16].

From the standpoint of reliability concept, energy security characterizes the continuity of the process of energy supply to consumers. At the same time, if reliability is a property of the regional power system, then energy security characterizes the state of the power system, achieved by ensuring [14, 17, 18]:

- a deficit-free supply of resources in the region,
- the economic availability of energy products for local consumers,
- the availability of technologies that make it possible to organize reliable and efficient operation of the power system under existing environmental restrictions.

Hence, energy security is characterized by such categories as resource sufficiency, economic accessibility and technological feasibility.

III. BACKGROUND

The main sources and nature of modern threats to energy security are enshrined in the Energy Security Doctrine of Russia. It identifies the following types of threats to energy security:

- internal economic threats,
- socio-political threats,
- technogenic threats,
- natural threats,
- foreign economic and foreign policy threats.

Economic and managerial are the key threats at the present stage of economic and energy development. Among them are the following main threats [19, 20, 21, 22]:

- Investment deficiency that can lead to uncompensated disposal of production facilities and energy complex,
- low innovative activity in the energy sector, which leads to a decrease in the technical level of energy complex facilities due to insufficient R&D funding,
- complication of the energy complex management system and the growth of uncertainty in the results of its operation caused by the processes of globalization and the energy sector liberalization,
- structural changes in the economy that lead to an increase in the unevenness of energy products demand due to an increase in the share in energy consumption of the population and the non-production sphere,
- slowdown in the diversification of the energy balance and the dominance of natural gas in the European regions of the country.

According to the Federal State Statistics Service of Russia, the depreciation of the main production assets of the electric power industry is about 40%. At the same time, the assets of the backbone grid complex are the least worn out, followed by the generation segment, and the closing one is the distribution grid complex with wear up to 70%. It should be noted that more than 90% of the capacities of existing power plants, 70% of boiler houses, 70% of electric and 66% of heating networks were put into operation before 1990. This suggests that the main strategy to combat the wear and tear of energy enterprises is to extend the service life of production assets through capital repairs [23, 24].

Fuel efficiency at thermal power plants has been decreasing over the past decades and is about 54%. This is caused by a decrease in the heat load of power plants due to the transition to heat supply mainly from boiler houses, which is caused by the low competitiveness of CHPs when operating in the energy market, and an incorrect pricing policy on the heat market (in particular, cross-subsidization), which led to a number of large heat consumers leaving of a from district heating systems. In general, the average efficiency of Russian power plants is 36.6% (38% - coal-fired, 41% - gas) (for comparison, in the world - 39-41.5%). At the same time, the International Energy Agency recommends the efficiency indicators of coal-fired stations at 43% and gas-fired stations at 55% as the lower technological limit of efficiency [23, 24, 25]. The discrepancy between efficiency indicators suggests low innovation activity and technological lag in the country's energy sector.

The level of energy efficiency in the country and its regions is characterized by the energy intensity indicator of the gross domestic product. Russia takes the last place in the world ranking of 44 countries in terms of energy consumption per unit of GDP, its energy intensity index is 5 times higher than the world's best values. High energy intensity is due to climate conditions (75% of energy consumed by the population is heat), low efficiency of energy and energy-intensive industries, as well as insufficient attention to energy conservation problems at the territorial level [5, 6, 23]. In the regions of the country there is a shortage of heat capacity, estimated at 20% of the total heat demand, which leads to fuel overconsumption due to the use of other energy sources by 2-2.5 times (when replacing heat with electricity - by 3.5-4 times). For comparison, the energy intensity of the GDP of Canada with a similar climate and developed industry is 1.8 times lower than that of Russia.

The gradual transition to a post-industrial economy leads to a reduction in the share of energy-intensive industrial production and an increase in the share of household consumers in the structure of energy consumption. This is due to the growth of urban population and an increase in energy consumption per capita due to an increase in the number of household appliances that consume electricity. This circumstance has a strong impact on the production efficiency of the power system.

In turn, the slowdown in the diversification of the country's energy balance is caused by the existing difference in the cost of coal and gas, which does not correspond to their differences in the quality of energy sources. Today, the ratio of gas and coal prices is 1.3 and does not even reach the world indicator of 1.5 [25, 26]. At the same time, coal is a competitive fuel in comparison with gas with a price ratio of at least 1.6 at the present stage of energy conversion technologies development.

IV. METHODS

According to the clarification of the conceptual apparatus of energy security, we will characterize it as the state of protection of the country's region from threats to reliable fuel and energy supply, achieved by ensuring the functioning of its energy system in market conditions in accordance with the principles of consumer availability of energy products and economic profitability of its production.

Thus, energy security, on the one hand, is determined by the economic profitability of energy production, on the other by its availability to the consumer. In general, an assessment of the energy security level can be obtained from the analysis of the energy products cost for the consumer and its structure:

$$\begin{cases} P = PC + MP \le LP \\ MP \ge PC \cdot RR \end{cases} \quad (1)$$

where P is the price of energy products, PC - production costs, MP - marginal profit, LP - limit price, RR - the required rate of profit.

The price of energy products should not exceed the limit price, which guarantees the state economic availability of products for the final consumer in accordance with the level of socio-economic development of the region. In turn, the marginal profit of energy enterprises should correspond to the profitability that allows the enterprise to attract investments in order to reproduce fixed assets, improve the quality and ensure the competitiveness of products.

It can be said that the interests of the state and the energy business are contradictory. If a particular criterion of the state is the fulfillment of the condition of consumer availability of energy products, then for energy enterprises it is the production profitability.

This contradiction is overcome by coordinating the economic criteria of the state and business through the compilation of a generalized efficiency criterion that includes particular criteria. Finding the extreme value of the generalized criterion function makes it possible to determine the cost of energy products, at which a balance of interests is achieved. The higher the value of the generalized criterion, the higher the level of energy security. Thus, we assume that an economically justified level of energy security will be achieved at the cost of energy products that maximizes the function of the generalized criterion.

We represent the generalized criterion, which reflects the level of energy security as a multiplicative function of two particular criteria:

$$J_{ES}(P) = J_G(P) \cdot J_B(P) = (LP - P) \cdot (MP - PC \cdot RR) = (LP - P) \cdot (P - PC - PC \cdot RR) \quad (2)$$

where J_G is a private criterion of the state characterizing the remoteness of the energy products cost from the limit value; J_B is a particular criterion for the energy business, characterizing the excess of the marginal profit over the required level of profitability from the energy products sales.

The economically justified level of energy security will be determined by the cost of energy products, at which, taking into account the restrictions, the generalized criterion will take the highest value:

$$J_{ES}^0(P^0) = \max_P \left\{ J_{ES}^0(P) \right\} \quad (3)$$

$$\begin{cases} P \le LP \\ P \ge PC(1 + RR) \\ PC > 0,\ 0 < RR < 1 \end{cases} \quad (4)$$

To analyze the relationships between the economic parameters of energy security and their impact on the cost of energy products for the consumer, a model of relationships between the parameters was developed, presented in Fig. 1.

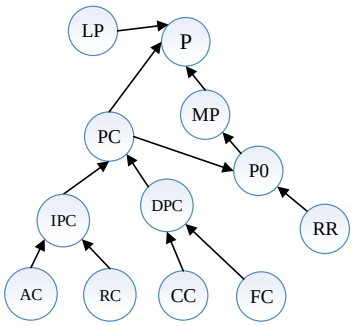

Fig. 1. The model of relations of economic parameters of energy security

The cost of energy products for the *P* in market conditions is determined by the marginal profit *MP* and production costs PC of the generating enterprise, the transport tariff *T*, the established price limit *LP*, operating within the borders of the region. In turn, in the case of market pricing, the marginal profit *MP* depends on the established equilibrium market price P_0, which, under conditions of prevailing demand, is determined by the production costs of the generating company *PC* and its profit rate. Production costs are divide into direct production costs *DPC* (determined by the cost of fuel *FC* and the cost of converting it to energy products *CC*) and general production costs *IPC* (includes depreciation *AC* and *RC* reliability maintenance costs).The transport tariff *T* largely depends on the actual costs of transmission *TC* (determined by the material costs *MTC* and the cost of losses *WTC*) and tax deductions *D* from the profits of generating enterprises, which compensate for part of these costs.

V. Results and Discussion

The Far Eastern economic region was selected as the region for testing the proposed energy security assessment model. It unites 9 territorially related subjects of the country by economic relations. It includes: the Republic of Sakha, Primorsky, Khabarovsk and Kamchatka regions, Amur, Magadan and Sakhalin regions, Jewish Autonomous Region, Chukotka Autonomous Region. The territory of the Far Eastern economic region is 36% of the country's territory. At the same time, the population is only 6.2 million people (4.2% of the total population of the country), which is decreasing by about 0.3% per year) [5].

The industrial specializations of the region are non-ferrous metallurgy, mining and food industries. main production of the region is concentrated in the Khabarovsk and Primorsky regions, Yakutia and the Sakhalin Region, where about 80% of the gross regional product is produced.

The power system of the Far Eastern economic region is represented by a fuel supply system and production systems of heat and power supply.

The fuel supply system is focused on the use of local fuels (primarily coals). At the same time, the export of natural gas and oil products from Western Siberia is also carried out. The structure of consumption of primary fuel and energy resources in comparison with the structure of consumption in the country is shown in Fig. 2.

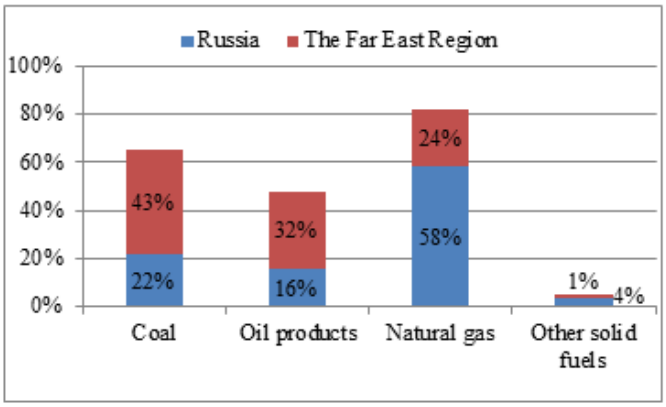

Fig. 2. Comparison of the consumption of fuel and energy resources of the Far Eastern region with the national average

As can be seen, in contrast to the structure of fuel consumption in the country, in which natural gas prevails, the main energy resource of the Far East region is steam coal. At the same time, due to the development of oil and gas condensate fields, the share of gas in the energy balance of the region has increased significantly over the past ten years. In the future, a rational decrease in the share of coal and oil products towards the use of natural gas will help to increase the level of energy security of the economic region and to solve environmental problems.

Own gross production of fuel resources in the Far Eastern region is almost 3 times higher than their consumption and is excessive for each energy resource. However, due to the uneven distribution of fuel sources across regions, only the Republic of Sakha, Khabarovsk Region and Sakhalin Region are surplus for coal, and Sakhalin Region for gas (more than 90% of the region's gas is produced). The demand for natural gas in the Sakha Republic, Kamchatka Territory and Chukotka Autonomous Region is provided by its own production, while the Khabarovsk and Primorsky Regions are fully provided by external supplies.

The distribution and type of available energy resources determined the location and type of power facilities in the economic region

The Amur Region and the Republic of Sakha (South) are surplus in terms of electricity generation, the surplus of which is mainly sold in the Khabarovsk and Primorsky Regions and the Jewish Autonomous Region. The energy systems of these territorial entities form the united energy system (UES) of the East, operating in parallel with the UES of Siberia and being part of the unified energy system (UES) of the country, operating in the conditions of the wholesale electricity market. The Republic of Sakha (North), Kamchatka Territory, Sakhalin and Magadan Regions, Chukotka Autonomous Region are autonomous in terms of energy supply.

The following main threats to the energy security of the Far Eastern economic region can be identified [5, 8]:

- increasing moral and physical deterioration of fixed assets for the production and distribution of energy (on

average 41.6% for the regions, while in a number of regions it exceeds 60%);

- a significant share of coal in the fuel balances of a number of subjects of the economic region (especially in Yakutia and the Primorsky Region), which significantly affects the environment, production and technological efficiency of the industry and energy security;
- rather low indicators of the efficiency of energy resources use by the subjects of the economic region in comparison with the national average (despite the availability of their own energy resources, significant supplies of oil and gas are carried out from Western Siberia);
- focal industrial development of the economic region, due to the extremely uneven distribution of fuel and energy resources, the largest of which are concentrated in remote areas;
- high tariffs for energy resources (gas, oil) and services of infrastructure companies for industrial enterprises, exceeding the national average by 2.3 and 1.5 times, respectively.

Low energy efficiency of the region's energy system (Table 1) and high depreciation of its main production assets pose a significant threat to energy security [5, 27].

TABLE I. SPECIFIC FUEL CONSUMPTION AND LOSSES IN THE NETWORKS OF THE FAR EAST REGION

Indicator	Far East region	Russia
Specific fuel consumption for electricity generation at TPPs, g.c.e / kWh	392,8	334,3
Specific fuel consumption for heat generation at TPPs, kg.c.e / Gcal	159,3	152
Power losses in the networks, %	11,4	10

Poor implementation of energy efficiency programs in the region's energy systems is largely due to the lack of coordination in the management of the energy complex development at various organizational levels. The reason for this is the liberalization of economic relations in the industry in 2007 and the emergence of many local energy management entities that represent conflicting interests of the state and the energy business. These conflicting interests have a significant impact on the formation of electricity prices in the region.

Table 3 presents the assessment of the energy security level according to the developed model based on the analysis of the prevailing average prices for electricity in the territorial entities of the Far Eastern region.

TABLE II. RESULTS OF THE ANALYSIS OF THE FAR EASTERN REGION TERRITORIAL ENTITIES ENERGY SECURITY LEVEL

Region territorial entities	Current price for energy, RUB / kWh	Energy price limits that ensure energy security, RUB / kWh		Optimization results	
				Energy price, RUB / kWh	Reasonable level of energy security
Amur region	2,2	3,0	3,4	3,2	1,13
Jewish Autonomous Region	2,1	3,2	3,6	3,5	1,05
Kamchatka Territory	4,9	5,7	6,2	5,8	1,14
Magadan Region	4,0	6,0	6,5	6,5	1,00
Primorsky Region	2,7	2,9	3,2	2,9	1,15
Sakha Republic	6,2	4,4	5,1	5,1	0,67
Sakhalin Region	4,2	3,0	3,3	3,3	0,62
Khabarovsk region	2,9	3,6	3,9	3,6	1,17
Chukotka Autonomous Region	10,8	7,2	7,8	7,8	0,52

The lower limit of electricity prices is determined by the production costs of generating companies. In the considered territorial entities, they are quite high due to high fuel prices, that is associated with climatic conditions, insufficient development of local deposits and the pricing model used. Also, significant production costs are explained by the high level of depreciation of generating equipment, which increases the share of fuel costs in the structure of production costs.

The upper limit of electricity prices is determined by the level of socio-economic development of the territorial entity, reflecting the economic availability of energy products for the consumer. The significant economic potential of the Far Eastern region is currently rather poorly realized, which determines the need for significant containment of electricity prices to ensure its availability for the consumer.

High values of the lower limits of electricity prices at low upper limits lead to rather narrow price corridors, within which the energy security of territorial entities is ensured without subsidizing energy enterprises and consumers from the state. In turn, the current electricity prices for end consumers of territorial entities go beyond the borders of the corridor, which is a threat to energy security. For most of the territorial entities of the economic region, they are artificially lowered for political reasons and the need to provide conditions for the advanced development of industrial zones, which leads to unprofitable energy business. In this case, a decrease in the value of the lower limit of the interval is required. This can be achieved by optimizing the production structure of generating companies in order to reduce fuel costs and intensify the development and diversification of local fuel sources. At the same time, the electricity prices in a number of territorial entities of the economic region go beyond the upper

limit due to the level of socio-economic development. This situation is caused by the significant role of generation in the structure of the gross regional product and its significant influence on the formation of the territorial entity budget. In this case, a policy of regional production diversification is required.

VI. Conclusion

The result of the study is the proposal of a model for assessing the economically justified level of energy security of the country's region. The method is based on a refined concept of energy security, according to which it is assumed to achieve the protection of a country's territorial unit from threats to reliable energy supply if the conditions for consumer availability of energy products and economic profitability of its production are met.

The fulfillment of these conditions is associated with overcoming the contradiction in the criteria for the efficiency of the energy system development on the part of the state and energy enterprises. If a particular criterion of the state is the fulfillment of the condition of consumer availability of energy products, then the economic profitability of production is important for energy enterprises.

To coordinate the private criteria of the state and business, a generalized efficiency criterion was developed, based on the multiplicative principle that combines private criteria. The investigated indicator is the cost of energy products for the consumer, at which the maximum of the generalized criterion (indicating an economically justified level of energy security) is reached.

The Far Eastern economic region of Russia, whose economic development is a national priority, was chosen as a region for testing the proposed model for assessing the energy security level.

It is shown that the existing policy of equalizing prices in the territorial entities of the Far Eastern region without taking into account the state and features of the functioning of regional energy systems, and their level of socio-economic development, not only cannot purposefully contribute to increasing the level of energy security.

Acknowledgment

This work was performed under the grant of RF President for governmental support of young scientists PhD and DSc (MD-914.2020.6).

References

[1] Bompard, E., Carpignano, A., Erriquez, M., Grosso, D., Pession, M., & Profumo, F. (2017). National energy security assessment in a geopolitical perspective. Energy, 130, 144-154.

[2] Chernyaev, M. V., & Kreydenko, T. F. (2018). Enhancing the efficiency of oil and gas complex as a basis for ensuring energy safety. European Research Studies Journal, 21(3), 516-529.

[3] Isaeva, O. M., & Vasić, B. (2018). Ensuring Global Energy Security: The Role of Russian Energy Policy. Current Politics and Economics of Russia, Eastern and Central Europe, 33(1/2), 1-31.

[4] García-Gusano, D., Iribarren, D., & Garraín, D. (2017). Prospective analysis of energy security: A practical life-cycle approach focused on renewable power generation and oriented towards policy-makers. Applied energy, 190, 891-901.

[5] Lisin, E., Strielkowski, W., Chernova, V., & Fomina, A. (2018). Assessment of the territorial energy security in the context of energy systems integration. Energies, 11(12), 3284.

[6] Lisin, E., Kurdiukova, G., Ketoeva, N., & Katina, J. (2018). Sustainability issues of territorial power systems in market conditions. Entrepreneurship and Sustainability Issues, 6(2), 1041-1052.

[7] Melas, V., Lisin, E., Tvaronavičienė, M., Peresadko, G., & Radwański, R. (2017). Energy security and economic development: renewables and the integration of energy systems. Journal of Security & Sustainability Issues, 7(1), 133-139.

[8] Senderov, S. M., & Edelev, A. V. (2018). Technology to Ensure Energy Security in Development of Russia's Energy Strategy. Energy Systems Research, 1(1), 35-43.

[9] Proskuryakova, L. (2017). Russia's energy in 2030: Future trends and technology priorities. foresight.

[10] Alekseev, A. N., Bogoviz, A. V., Goncharenko, L. P., & Sybachin, S. A. (2019). A Critical Review of Russia's Energy Strategy in the Period until 2035. International Journal of Energy Economics and Policy, 9(6), 95-102.

[11] Federal Law of the Russian Federation No. 35-FZ "On the Electric Power Industry" http://extwprlegs1.fao.org/docs/pdf/rus41857E.pdf (accessed 01/09/2020)

[12] Federal Law of the Russian Federation No. 190-FZ "On Heat Supply" https://policy.asiapacificenergy.org/node/201 (accessed 01/09/2020)

[13] Federal Law of the Russian Federation No. 256-FZ "On the Safety of Fuel and Energy Complex" http://base.garant.ru/12188188/ (accessed 01/09/2020)

[14] Bogoviz, A. V., Lobova, S. V., Ragulina, Y. V., & Alekseev, A. N. (2018). Russia's energy security doctrine: Addressing emerging challenges and opportunities. International Journal of Energy Economics and Policy, 8(5), 1-6.

[15] Proskuryakova, L. (2018). Updating energy security and environmental policy: Energy security theories revisited. Journal of environmental management, 223, 203-214.

[16] Khrushcheva, O., & Maltby, T. (2016). The future of EU-Russia energy relations in the context of decarbonisation. Geopolitics, 21(4), 799-830.

[17] Khorol'skii, V. Y., Ershov, A. B., & Efanov, A. V. (2017). Quantitative and comparative analyses of the reliability of energy arrays. Russian Electrical Engineering, 88(8), 490-493.

[18] Postnikov, I. V., Stennikov, V. A., Mednikova, E. E., & Penkovskii, A. V. (2017). A methodology for optimziation of component reliability of heat supply systems. Energy Procedia, 105, 3083-3088.

[19] Dudin, M. N., Lyasnikov, N. V. E., Sekerin, V. D., Gorokhova, A. E. E., Danko, T. P., & Bank, O. A. E. (2017). Technological changes as the development factor of the global and Russian energy sector. International journal of energy economics and policy, 7(1), 209-215.

[20] Lakhno, Y. V. (2015). Russian coal industry: Threats and possibilities. Studies on Russian Economic Development, 26(5), 476-482.

[21] Lisin, E., Rogalev, A., Strielkowski, W., & Komarov, I. (2015). Sustainable modernization of the Russian power utilities industry. Sustainability, 7(9), 11378-11400.

[22] Lisin, E., Shuvalova, D., Volkova, I., & Strielkowski, W. (2018). Sustainable development of regional power systems and the consumption of electric energy. Sustainability, 10(4), 1111.

[23] Lisin, E., Kindra, V., Strielkowski, W., Zlyvko, O., & Bartkute, R. (2017). Economic analysis of heat and electricity production in the decentralisation of the Russian energy sector. Transformations in Business & Economics, 16(2), 75-88.

[24] Lisin, E., Sobolev, A., Strielkowski, W., & Garanin, I. (2016). Thermal efficiency of cogeneration units with multi-stage reheating for Russian municipal heating systems. Energies, 9(4), 269.

[25] Lisin, E., Strielkowski, W., & Krivokora, E. (2016). Economic Analysis of Industrial Development: a Case of Russian Coal Industry. Montenegrin Journal of Economics, 12(4), 129-139.

[26] Takaishvili, L. N., & Sokolov, A. D. (2019). Modeling the Development Prospects of the Coal Industry of Russia and its Regions. Energy Systems Research, 2(4), 59-66.

[27] Kalashnikov, V., Gulidov, R., & Ognev, A. (2011). Energy sector of the Russian Far East: Current status and scenarios for the future. Energy Policy, 39(11), 6760-6780.