International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2020, 10(3), 476-481.

Energy System Structure in Russian Arctic: Coal Production Forecast

Xenia Tabachkova*, Sergey Prosekov, Natalia Sokolinskaya

Financial University Under the Government of the Russian Federation, Moscow, Russia. *Email: xenia.tabachkova@yandex.ru

Received: 19 November 2019 **Accepted:** 18 February 2020 **DOI:** https://doi.org/10.32479/ijeep.9000

ABSTRACT

The article characterizes the electric power industry in the Arctic regions of Russia. The regions of the eastern zone of the Russian Arctic differ significantly in terms of centralization of power supply. Centralized electricity supply in this territory is represented by only a few isolated functioning energy centers: Norilsk in the north of Krasnoyarsk Territory, Chaun-Bilibinsky, Anadyrsky and Egvekinotsky in the Chukotka Autonomous Region. The Arctic and northern regions of the Republic of Sakha (Yakutia) are completely located in the decentralized power supply zone. The paper provides a comparative study of energy system structure. The summary of results obtained the key areas of power generation diversification.

Keywords: Isolated Energy Systems, Generated Power Supplies, Cogeneration, Nuclear Energy Plants, Wind Energy Plants, Solar Energy Plants
JEL Classifications: C30, D12, Q41, Q48

1. INTRODUCTION

While in the Taimyr and Turukhansky districts of the Krasnoyarsk Territory, almost 88% of the capacity structure is accounted for by the power plants of the Norilsk energy center, in Chukotsky Autonomous Okrug - 64% by the power plants of the Chaun-Bilibino, Anadyr and Egvekinotsky power centers, then in the territory of 13 districts of the Republic of Sakha (Yakutia) power plants are classified as autonomous.

The Taimyr and Turukhansky districts of the Krasnoyarsk Territory clearly stand out in terms of the total capacity of power plants in the eastern Arctic sector - 2597 MW, of which five power plants of Norilsk-Taimyr Energy Company JSC account for 2276 MW. In the capacity structure of functioning autonomous departmental power plants, the main part is occupied by gas turbine units of RN-Vankor LLC (252 MW), and municipal ones by Turukhanskenergo (28 MW). In the territory of the Chukotka Autonomous Region, the total capacity of five power plants of Chukotenergo and a branch of Rosenergoatom Concern JSC consisting of three power units is 201 MW. Among autonomous departmental power plants, the main share of the power is accounted for by Chukotka Mining and Geological Company (29 MW), and municipal - by Chukotkommunkhoz (33 MW). The total capacity of autonomous municipal power plants in the eastern zone of the Arctic over the past 5 years has remained virtually unchanged at 253-267 MW. More than half of the capacity of these power plants operates in the Republic of Sakha (Yakutia) (156 MW) and is managed by Sakhaenergo.

The analysis of ownership forms and management structure in electric power generation systems in the eastern zone of the Arctic led to the following conclusions:

- Enterprises with state participation predominate in energy supply systems, organized mainly in the form of joint-stock companies;
- Local energy companies engaged in the production, distribution, transmission and sale of electricity in centralized energy centers are Norilsk-Taimyr Energy Company, as well as Chukotenergo (a subsidiary of Magadanenergo), Sakhaenergo (Yakutskenergo);
- Electric grid enterprises are part of local energy companies, being their branches;

- In the coverage area of local energy centers, along with power plants of local energy companies, power plants of various departmental subordination are operated;
- In the decentralized electricity supply zone, there are energy sources belonging to subsidiaries of local energy companies, municipal unitary enterprises of housing and communal services, as well as various companies and organizations engaged in economic activities in these territories (Alwaelya et al., 2020; An and Dorofeev, 2020; An et al., 2020).

The technological isolation of most of the energy sources in the eastern zone of the Arctic leads to the absence of a competitive electricity market and the emergence of problems of reliable electricity supply and energy security of consumers. Most often, the following scheme operates - the locality, or their group, is provided with electricity from a single energy source. The most acute problems of reliability and energy efficiency are manifested in the decentralized power supply zone. Providing electricity to consumers from autonomous municipal power plants in the Arctic territories is highly costly. The reason for this, on the one hand, is the unsatisfactory condition of the equipment, on the other hand, complicated logistic schemes due to the underdeveloped transport infrastructure. Seasonal functioning of transport routes, long distances and isolation from developed areas due to the lack of year-round roads are the main problem of fuel supply in the eastern zone of the Arctic. So, in the Taimyr district of the Krasnoyarsk Territory, out of 2246 km of roads, 2228 km of seasonal roads. Dirt roads and winters prevail there (Meynkhard, 2020; An et al., 2019d).

2. LITERATURE REVIEW

The main transport routes of the eastern territories of the Arctic are the Northern Sea Route in sections from the mouth of the Yenisei and Lena rivers to the mouths of the Arctic rivers Khatanga, Kotuy, Pyasina, Anabar, Olenek, Yana, Indigirka, Kolyma, Anadyr, the navigable part of these rivers, as well as numerous winters that connect remote settlements with places of accumulation and storage of fuel and cargo (Meynkhard, 2019a; Wustenhagen and Bilharz, 2006).

For the most distant consumers of the northern and Arctic regions, diesel fuel is delivered according to a complex transport scheme "river - sea - river - winter winder" with three overloads and not in one season.

Diesel fuel delivery distances reach 4-7 thousand km (Morris and Barlaz, 2011).

Under the same transport scheme, coal, crude oil and gas condensate are imported for boiler rooms in the Arctic regions (Mikhaylov, 2019; Mikhaylov et al., 2019).

A complex coal transportation scheme leads to significant quantitative losses and a decrease in quality characteristics (Lopatin, 2019a; Lopatin, 2019b).

Given the limited time of sea and river navigation, such a logistic scheme poses one of the main threats from the point of view of the energy security of consumers in the Arctic territories, and the more links in transportation, the longer distances, the more risks and the less reliable the supply of fuel to consumers (Morgan and Yang, 2001).

The problem of fuel supply is becoming especially acute and urgent due to the constant tendency to increase the cost of fuel and the cost of transporting it to consumers in the Arctic (An et al, 2019b; Moiseev, 2017a,b).

A significant increase in the cost of fuel due to the complexity of logistics leads to the high cost of electricity production - up to 50-60 rubles/kWh (Mikhaylov, 2018a,b).

Due to the need to limit the growth of tariffs for the population no higher than the established standards, significant subsidies are allocated from the federal and local budgets for cross-subsidization for tariff equalization and maintenance of energy sources (for example, in the Republic of Sakha (Yakutia) more than 7 billion rubles) (Moiseev, 2017c; Moiseev and Akhmadeev, 2017).

In the State program "Socio-economic development of the Arctic zone of the Russian Federation" in the Arctic territories of the eastern regions, three support zones are formed: Taimyr-Turukhanskaya, Severo-Yakutskaya and Chukotskaya (Mikhaylov et al., 2018; Nyangarika et al., 2018).

The development of these zones involves the implementation of major projects for the development of mineral resources and, as a result, the emergence of new production consumers in hard-to-reach areas (Denisova, 2019; Denisova et al., 2019).

Subsoil users of promising deposits, in the absence of the ability to connect to a centralized power supply, are most often oriented towards traditional power supply schemes, which include a diesel power station and a boiler room. At the same time, other alternative options for autonomous energy supply deserve attention term (Nyangarika et al., 2019a,b).

3. METHODS

In the territory of the eastern Arctic, prerequisites for the expansion of the zone of centralized power supply in the future are available only in the Taimyr-Turukhansk and Chukotka support zones. In the north of the Krasnoyarsk Territory, the expansion of the Norilsk energy center during the development of rare-earth metals deposits Chernogorskoye and Norilsk-1 is possible, as well as the formation of a new energy center for the development of the Vankor group of hydrocarbon deposits (Moiseev and Sorokin, 2018; An et al., 2019a; An et al., 2019c).

The development of the electric grid infrastructure in the Chaun-Bilibino energy center of the Chukotka Autonomous Region is due to the predicted increase in loads during the implementation of new projects for the development of mineral resources. According to the results of the studies, of all prospective consumers in the zone of the energy center, it is economically justified to connect enterprises to the centralized electricity supply during the development of the fields: Elveneyskoye, Pyrkakayskoye, Kekura (Figures 1 and 2).

The limiting factors are the upcoming changes in the structure of the generating capacities of the Chaun-Bilibino energy center in connection with the planned decommissioning, starting in 2019 from the unit, from the operation of the Bilibino, and subsequently the spent resource of the Chaun and the deployment of a floating nuclear power plant in Pevek "Academic Lomonosov" (Zubakin et al., 2015; Tryndina et al., 2020).

A rational option for power supply to the Baimsky with a load of 205 MW at the Peschanka deposit, the development of which is one of the key projects for accelerated industrial development of the Chukotka support zone, depends on many factors. The most acceptable option is the construction of a nuclear plant in the city of Bilibino in order to replace the retiring capacities of the energy center, given the availability of energy infrastructure and human potential. The main barrier to this option is the lack of a ready-made nuclear power unit of the required capacity in ground-based design.

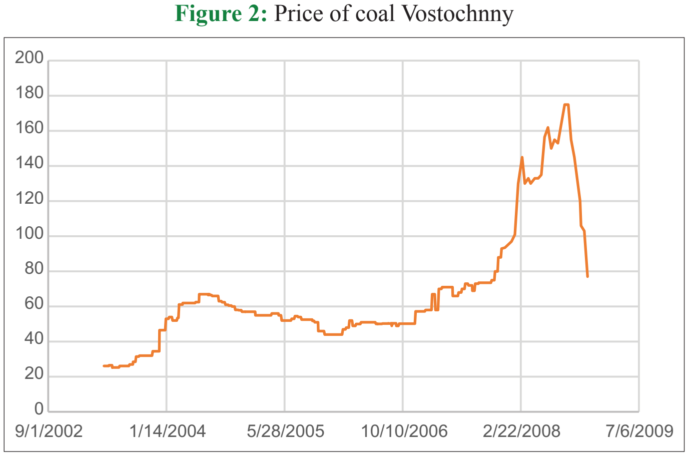
4. RESULTS

As an alternative to the nuclear plant in Bilibino, one can consider the organization of coal generation as part of the Chaun-Bilibino power center on the basis of the Long-awaited field or external power supply from the Magadan power system. Each of these options has its own limitations, due to the mining and economic capabilities of the coal field, as well as the availability of free capacity in the Magadan energy system (Table 1).

Figure 1: Price of coal baltic

Source: Thomson Reuters

Figure 2: Price of coal Vostochnny



Source: Thomson Reuters

Currently, the design of an energy center on Zyryansk coal in the city of Bilibino and a double-circuit 220 kV overhead line from the Magadan region along the route Omsukchan - Peschanka - Kekura - Bilibino is underway.

The combination of the Anadyr and Egvekinotsky energy centers of the Chukotka Autonomous Region is advisable when justifying the increase in the considered prospect of electric loads in the zone of their operation.

Power supply to existing and future consumers in the Republic of Sakha (Yakutia) will be provided only from autonomous energy sources. The main issue is the rational transition to local fuels based on cogeneration plants in order to reduce the transport component in the structure of fuel costs.

Currently, about 500 thousand tons of coal is mined in the eastern zone of the Arctic (Table 1). In recent years, production has been discontinued at the Kotuy mine (Kayakskoye field, Taimyr district of the Krasnoyarsk Territory) in connection with the development of reserves and at the Nagornaya mine (Ugolnaya Bay deposit of the Bering Basin, Chukotka Autonomous Region) due to the inability of the enterprise to realize the volume of production that provides a break-even level functioning.

Prospects for the development of the coal industry in the eastern zone of the Russian Arctic are primarily associated with the development of the Malaya Lemberova River section of the Syradaysky coal-bearing area of the Taimyr coal basin. By 2030, it is planned to increase coking coal production at this site to 30 million tons/year.

In the Chukotka Autonomous Region, when developing the Amaam and Upper Alkatvaam areas of the Bering coal basin, the development of which is carried out as part of the development of the Beringovskaya advanced development area, it is planned to increase the volume of coal production for export to the Asia-Pacific countries by 2030 to 12 million tons/year.

In this connection, it seems expedient to build a mini-CHP on coal near deposits: in the settlement of Dikson in the Taimyr district of

Table 1: Forecast of coal production in the eastern zone of the Arctic, mln t/year

Subject of the Russian Federation	Year		
	2015	2020	2030
Zyryansk	0,12	0,3	0,6
Chukotsky Autonomous Okrug	0,23	1,7	12,45
Anadyrskoe	0,23	0,3	0,45
Bering coal basin	1,2	1,4	12
Krasnoyarsk Territory, total	3,1	5,15	30,15
Syradaysky area	3,7	5	30
Kayerkan	0,15	0,15	0,15
Total	8,73	14	85,8

Source: Author calculation.

the Krasnoyarsk Territory and in the settlement of Beringovsky in the Anadyrsky District of the Chukotka Autonomous Region.

In addition, in the Chukotka Autonomous Region, the Dolgozdannoye coal deposit (Chaunsky District) is considered as promising, where in 2014 exploration was carried out to confirm reserves and forecast resources. In general, the coal in the field is rated as high-quality energy fuel. The development of the field for own needs is planned by Mayskoye.

When implementing coal generation projects in nearby areas, it is expected that production will increase at the Zyryansky open pit in the Republic of Sakha (Yakutia). For energy supply of settlements located on the river. Kolyma in the Verkhnekolymsky, Srednekolymsky, Nizhnekolymsky districts of the Republic of Sakha (Yakutia), it is advisable to build a mini-CHP on Zyryansk coal, including the completion of a mini-CHP in the village of Zyryanka. In addition, during the construction of the "Arktika" highway, it is possible to switch to a similar option for energy supply in the Momsky region using the Jabariqi-Khaisky or Arkagalinsky coal. The cost of electricity production using local types of coal, according to preliminary estimates of the authors, is reduced by almost half compared with diesel power plants.

As alternative options for fuel supply to consumers in the Arctic regions of the republic, it is necessary to pay attention to the validity of involving small coal deposits in the development, such as Taimylyrskoye (Bulunsky district), Krasnorechenskoye (Abyisky district), Buolkalaakhskoye (Anabarsky district).

For the wider use of local fuels in the decentralized zone of the eastern Arctic, it is necessary to provide for the construction of small-tonnage plants for the production of petroleum products and liquefied natural gas (LNG) in hydrocarbon production areas (in the Lena district of Yakutia and the Anadyr region of the Chukotka Autonomous Region). According to the authors, the cost of LNG production at small-capacity plants in the western regions of the Republic of Sakha (Yakutia) is estimated at 15-16 thousand rubles per ton, the cost at the place of consumption depends on the complexity of logistics.

The study of the efficiency of LNG use for energy supply to consumers in the decentralized zone of the northern and arctic regions of the Far East becomes relevant in connection with the intention of NOVATEK to build a terminal for the transshipment of liquefied gas in the deep water bay Mokhovaya near Petropavlovsk-Kamchatsky, which the company plans to deliver via the Northern Sea routes from the Yamal-Nenets Autonomous Okrug to the ports of the countries of the Asia-Pacific region. The terminal will be able to handle the transshipment and storage of up to 20 million tons of LNG per year. The construction of the terminal is planned simultaneously with the implementation of the Arctic LNG-2 project in order to optimize transportation costs by reducing the number of expensive ice-class tankers.

5. DISCUSSION

When organizing the domestic production of power units for small nuclear power plants, it is advisable in the Republic of Sakha (Yakutia) to focus on their use for powering promising enterprises for the development of the Tomtor deposits (Anabarsky district), Verkhnyaya Muna (Oleneksky district), Tirechtyakh Stream, and Kucus (Ust-Yansky district). In addition, this option of energy supply can be recommended in the village of Tiksi (Bulunsky district) with increased loads associated with the expansion of the seaport to ensure the functioning and development of the Northern Sea Route.

In addition, in the eastern zone of the Arctic, as an alternative to traditional diesel generation, AFMM-based energy nodes can be formed from existing consumers with a total load of 3-6 MW in the Verkhoyansk, Ust-Yansky, Bulunsky, Nizhnekolymsky districts of the Republic of Sakha (Yakutia), as well as in the Chukotka and Provideniya districts of the Chukotka Autonomous Region.

Boundary values of the cost of electricity production by low-power nuclear power plants as an autonomous energy source to achieve their competitiveness compared to diesel power plants, according to the authors, are in the range of 18-22 rubles/kWh depending on the price of diesel fuel.

The priority projects of renewable energy in the eastern zone of the Arctic is the construction of wind farms. High values of wind potential indicators and prevailing conditions of energy supply create the prerequisites for the expedient use of wind-diesel complexes for power supply to household consumers of a decentralized zone located on the coast of the northern seas.

In addition, the construction of photovoltaic stations for seasonal power supply of hard-to-reach consumers in Zhigansky, Verkhoyansk, Momsky, Eveno-Bytantaysky, Srednekolymsky districts of the Republic of Sakha (Yakutia) and Turukhansky district of the Krasnoyarsk Territory is economically justified.

Currently, in the Republic of Sakha (Yakutia) there are 19 autonomous solar power plants with a total capacity of 1614 kW, power - 1 MW in Batagay settlement.

Analysis of the functioning of solar power plants in the republic showed that the payback period does not depend on the latitudinal location of the stations and averages about 10 years. At the same time, the installation of additional equipment (drives, trackers), which allows to increase the generation of electricity, significantly increases the capital intensity of the project, which affects the payback period. However, a short observation period does not make it possible to state how much the rise in price is offset by an increase in electricity generation in subsequent years.

The actual indicators of electricity generation and the price of diesel fuel determined the estimated payback periods for the considered period of the year.

The given actual indicators and their analysis allow us to conclude about the positive experience in operating solar power plants for decentralized consumers in the republic even at the highest latitudes and the prerequisites for further expansion of the use of solar potential for energy. High payback periods for SES in the aftermaths of Batamay and Yuchegy are associated with their consistent expansion and installation of additional equipment.

6. CONCLUSION

The analysis showed that the latitudinal location of solar power plants does not affect the payback periods of their construction and operation. However, the dependence of this indicator on the price of diesel fuel is traced. So, in Kudu-Kuel, the value of specific investments is one of the lowest under consideration, while the station is located south of the others, that is, the values of solar radiation are one of the best, but the price of diesel fuel is also the lowest, which led to a comparable payback period with the Arctic stations (Dayong et al., 2020; Meynkhard, 2019b).

Based on multivariate analysis, a list of promising locations for wind and photovoltaic stations has been compiled in addition to municipal diesel power stations in order to displace long-distance fuel. The rational scale of the use of wind power stations in the decentralized zone of the eastern Arctic for the period until 2035 is estimated at 20-30 MW, photovoltaic stations - at 5-10 MW.

According to the results of the research, it estimates the necessary capacity for prospective until 2035 for cogeneration plants using local coal at 45-57 MW; low power nuclear power plants - 66-108 MW; renewable energy sources - 25-40 MW (Lisin, 2020);

The formed list of innovative equipment in some energy sectors necessary for the development of energy supply systems in the eastern zone of the Russian Arctic includes:
- Modular refineries with a capacity of 0.5-1 million tons;
- Power units for nuclear power plants with a unit capacity of 6-12 and 50-100 MW;
- Wind turbines with a unit power of 50-100 kW, which do not require special equipment for installation;
- PV modules.

The proposed list can be considered as requirements for domestic power engineering for the production of equipment in the Arctic:
- Cogeneration plants on coal and gas with a capacity of 3-6 MW;
- Small capacity tanks for storage and installation for LNG regasification.

REFERENCES

Alwaelya, S.A., Yousif, N.B.A., Mikhaylov, A. (2020), Emotional development in preschoolers and socialization. Early Child Development and Care, 190, 3.

An, J., Dorofeev, M. (2019), Short-term FX forecasting: Decision making on the base of expert polls. Investment Management and Financial Innovations, 16(4), 72-85.

An, J., Dorofeev, M., Zhu, S. (2020), Development of energy cooperation between Russia and China. International Journal of Energy Economics and Policy, 10(1), 134-139.

An, J., Mikhaylov, A., Lopatin, E., Moiseev, N., Richter, U.H., Varyash, I., Dooyum, Y.D., Oganov, A., Bertelsen, R.G. (2019c), Bioenergy potential of Russia: Method of evaluating costs. International Journal of Energy Economics and Policy, 9(5), 244-251.

An, J., Mikhaylov, A., Moiseev, N. (2019d), Oil price predictors: Machine learning approach. International Journal of Energy Economics and Policy, 9(5), 1-6.

An, J., Mikhaylov, A., Sokolinskaya, N. (2019a), Machine learning in economic planning: Ensembles of algorithms. Journal of Physics: Conference Series, 1353, 12126.

An, J., Mikhaylov, A., Sokolinskaya, N. (2019b), Oil incomes spending in sovereign fund of Norway (GPFG). Investment Management and Financial Innovations, 16(3), 10-17.

Dayong, N., Mikhaylov, A., Bratanovsky, S., Shaikh, Z.A., Stepanova, D. (2020), Mathematical modeling of the technological processes of catering products production. Journal of Food Process Engineering, 43, 2.

Denisova, V. (2019), Energy efficiency as a way to ecological safety: Evidence from Russia. International Journal of Energy Economics and Policy, 9(5), 32-37.

Denisova, V., Mikhaylov, A., Lopatin, E. (2019), Blockchain infrastructure and growth of global power consumption. International Journal of Energy Economics and Policy, 9(4), 22-29.

Lisin, A. (2020), Biofuel energy in the post-oil era. International Journal of Energy Economics and Policy, 10(2), 194-199.

Lopatin, E. (2019a), Assessment of Russian banking system performance and sustainability. Banks and Bank Systems, 14(3), 202-211.

Lopatin, E. (2019b), Methodological approaches to research resource saving industrial enterprises. International Journal of Energy Economics and Policy, 9(4), 181-187.

Meynkhard, A. (2019a), Energy efficient development model for regions of the Russian federation: Evidence of crypto mining. International Journal of Energy Economics and Policy, 9(4), 16-21.

Meynkhard, A. (2019b), Fair market value of bitcoin: Halving effect. Investment Management and Financial Innovations, 16(4), 72-85.

Meynkhard, A. (2020), Priorities of Russian energy policy in Russian-Chinese relations. International Journal of Energy Economics and Policy, 10(1), 65-71.

Mikhaylov, A. (2018a), Pricing in oil market and using probit model for analysis of stock market effects. International Journal of Energy Economics and Policy, 8(2), 69-73.

Mikhaylov, A. (2018b), Volatility spillover effect between stock and exchange rate in oil exporting countries. International Journal of Energy Economics and Policy, 8(3), 321-326.

Mikhaylov, A. (2019), Oil and gas budget revenues in Russia after crisis in 2015. International Journal of Energy Economics and Policy, 9(2), 375-380.

Mikhaylov, A., Sokolinskaya, N., Lopatin, E. (2019), Asset allocation in equity, fixed-income and cryptocurrency on the base of individual risk sentiment. Investment Management and Financial Innovations, 16(2), 171-181.

Mikhaylov, A., Sokolinskaya, N., Nyangarika, A. (2018), Optimal carry trade strategy based on currencies of energy and developed economies. Journal of Reviews on Global Economics, 7, 582-592.

Moiseev, N. (2017a), Forecasting time series of economic processes by model averaging across data frames of various lengths. Journal of Statistical Computation and Simulation, 87(17), 3111-3131.

Moiseev, N. (2017b), p-Value adjustment to control Type I errors in linear regression models. Journal of Statistical Computation and Simulation, 87(9), 1701-1711.

Moiseev, N. (2017c), Linear model averaging by minimizing mean-squared forecast error unbiased estimator. Model Assisted Statistics and Applications, 11(4), 325-338.

Moiseev, N., Akhmadeev, B. (2017), Agent-based simulation of wealth, capital and asset distribution on stock markets. Journal of Interdisciplinary Economics, 29(2), 176-196.

Moiseev, N., Sorokin, A. (2018), Interval forecast for model averaging methods. Model Assisted Statistics and Applications, 18(2), 125-138.

Morgan, S.M., Yang, Q. (2001), Use of landfill Gas for electricity generation. Practice Periodical of Hazardous, Toxic, and Radio Waste Management, 5(1), 14-24.

Morris, J.W., Barlaz, M.A. (2011), A performance-based system for the long-term management of municipal waste landfills. Waste Management, 31(4), 649-662.

Nyangarika, A., Mikhaylov, A. Richter, U. (2019b), Oil price factors: Forecasting on the base of modified auto-regressive integrated moving average model. International Journal of Energy Economics and Policy, 9(1), 149-160.

Nyangarika, A., Mikhaylov, A., Richter, U. (2019a), Influence oil price towards economic indicators in Russia. International Journal of Energy Economics and Policy, 9(1), 123-130.

Nyangarika, A., Mikhaylov, A., Tang, B.J. (2018), Correlation of oil prices and gross domestic product in oil producing countries. International Journal of Energy Economics and Policy, 8(5), 42-48.

Tryndina, N., Moiseev, N., Lopatin, E., Prosekov, S., Kejun, J. (2020), Trends in corporate energy strategy of Russian companies. International Journal of Energy Economics and Policy, 10(1), 202-207.

Wustenhagen, R., Bilharz, M. (2006), Green energy market development in Germany: Effective public policy and emerging customer demand. Energy Policy, 34, 1681-1696.

Zubakin, V.A., Kosorukov, O.A., Moiseev, N.A. (2015), Improvement of regression forecasting models. Modern Applied Science, 9(6), 344-353.