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Spatial Organization of Economic Development of Energy Resources in the Arctic Region of the Russian Federation

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Abstract:

In the conditions of price reduction in the world energy market, the issue of determining the priorities of the economic development of hydrocarbons in the Arctic Region of the Russian Federation (RF) becomes highly relevant. The article is aimed at developing an optimal model for the spatial organization of energy resources in the Arctic Region. The expert elicitation procedure was used to determine the efficiency indicators for the economic development of the oil-and-gas-bearing areas in the Arctic Region and clusterization of these areas was carried out in terms of economic efficiency. Based on the factor analysis, the degree of influence of efficiency indicators on the economic development of the oil and gas bearing areas of the region was determined and, an integrated performance indicator of economic development for oil-and-gas-bearing areas for each cluster was calculated with regard to the factor loadings. A 3-D model was developed for the organization of economic development of oil and gas in the Arctic Region. The 3-D model became the basis for determining the priorities for territorial exploration, development and production of hydrocarbons in terms of their economic efficiency, taking into account the trends in the development of the world energy market and break-even fields. A set of recommendations was developed to improve the efficiency of the spatial organization of economic development of oil and gas in the Arctic Region. The implementation of the proposed measures can contribute to the development of the oil and gas industry in the region, its socio-economic development and the long-term sustainability of Russia's energy security.

Keywords: spatial organization; economic development of the Arctic Region; energy market; efficiency of economic development of hydrocarbons; the Arctic energy resources; oil; gas; oil-and-gas-bearing areas (OGA)

JEL Classification: L23; L71; Q35; R11; R12.

Introduction

The Arctic is one of the richest mineral resources base in the world. According to the US Geological Survey, the Arctic contains about 412 billion barrels of oil equivalent, or 22% of the world's undiscovered hydrocarbon reserves: 90 billion barrels of oil (13% of the world's undiscovered reserves), 48.3 trillion cubic meters of natural gas (30% of the world's undiscovered reserves) and 44 billion barrels of gas condensate (20% of the world's undiscovered reserves) (Andreassen 2016; Hintsala *et al.* 2016; Lindholt and Glomsrød 2018). Russia has a leading role in the development of the Arctic. It should be noted that, according to the forecasts of the Ministry of Energy of the Russian Federation (MERF), in the conditions of depletion of old fields, oil production in the country may drop from 1.2% to 46% by 2035 (Cheng 2014; Nazarova 2016; Novak 2015). It is possible to compensate for a significant decline in the budget-forming industry only by developing the deposits in the Arctic Region.

To boost the economic development of energy resources in the Arctic Region, the Russian Federation needs substantial investment for geological exploration and production of specialized equipment. But, taking into account the fact that the world price for oil fell by half over the recent 5 years and today it makes 70.1 dollars per barrel (Investing.com 2018), and the breakeven production of oil in the Arctic is in the corridor of 65-110 dollars per barrel, as estimated by the MERF (2018), while the economic development of Arctic hydrocarbons can be calculated in decades (Bucelli *et al.* 2018), in these conditions it is feasible to focus on less expensive projects with faster returns in the Arctic Region. In this regard, it seems relevant to determine the priorities in the spatial organization of energy resources development in the Arctic Region of the Russian Federation in terms of economic efficiency, taking into account the current trends in the development of the world energy market.

The purpose of the research was to develop the 3-D model of an effective organization for the economic development of hydrocarbons in the Arctic Region of the Russian Federation. In the course of the study, the following tasks of scientific search were solved:

- to determine the main trends of the economic development of energy resources in the Arctic Region of Russia;
- to assess economic efficiency of oil-and-gas-bearing areas of the Arctic Region;
- to identify the priorities for the economic development of oil and gas in the Arctic Region of the Russian Federation, taking into account the trends in the development of the world energy market;
- to develop conceptual recommendations for increasing economic efficiency of the hydrocarbon exploration, development and production in the region with the purpose of ensuring the sustainability of the country's energy security in the long term.

1. Materials and Methods

Methodological procedures of the research included the following methods of scientific cognition: the expert elicitation, cluster analysis, integrated assessment and principal components analysis (factor analysis).

The expert method was used within the framework of the study to confirm the representativeness of the system of indicators for assessing the performance of economic development of energy resources.

The degree of representativeness was estimated by formula 1 (Astfalck *et al.* 2018):

$$R = \frac{b_1 + b_2 + \ldots + b_n}{b_1^{max} + b_2^{max} + \ldots + b_n^{max}} * 100\%, \quad (1)$$

where R is the degree of representativeness of the indicators system, %;

$b_{1,\ldots,n}$ – score of the 1st, 2nd, nth expert;

$b_{1,\ldots,n}^{max}$ – maximum possible score of the 1st, 2nd, nth expert;

n – the number of experts.

Adequacy of the expert elicitation results is ensured by a high degree of consistency of experts' opinions, which is estimated by the variation index if there is one factor in the study (formula 2) (Rousseau *et al.* 2018):

$$v = \frac{\sigma}{\bar{x}} * 100\%, \quad (2)$$

where v is the coefficient of variation of experts' estimates;

σ – root-mean-square deviation of experts' estimates;

$\bar{x}$ – arithmetic mean deviation of experts' estimates.

When $v \leq 10\%$, experts' estimates are slightly variable, that is, there is a high degree of opinion consistency; when $10 < v \leq 20\%$ the estimates are medium variable; when $v > 20\%$ they are highly variable, the degree of experts' opinion consistency is low.

Cluster analysis is used to break up the multitude of oil-and-gas-bearing areas of the Arctic zone of the Russian Federation into clusters according to the level of economic development efficiency. The Euclidean distance between objects is a classification criterion for clusters (formula 3), which should be minimized within the cluster and maximized between the clusters (Ramon-Gonen and Gelbard 2017):

$$d_{jk} = \sqrt{\sum_i^n (x_{ij} - x_{ik})^2}, \tag{3}$$

Where: d_{jk} is the distance from the j-th object to the center of the k-th cluster;

x_{ij} – the value of the i-th indicator of the j-th object;

x_{ik} – the value of the i-th indicator of the k-th cluster center.

The ANOVA parameters are the indicators of the clusterization quality: the coefficient of intra-group (formula 4) and intergroup (formula 5) variance, the Fisher F-criterion (formula 6) (Ramon-Gonen and Gelbard 2017):

$$(\text{Within SS})_k^2 = \frac{\sum_i^n (x_{ij} - \overline{x_{ik}})^2}{n_k}, \tag{4}$$

$$(\text{Between SS})^2 = \frac{\sum_i^n (\overline{x_{ik}} - \tilde{X}_i)^2 \cdot n_k}{N}, \tag{5}$$

$$F_e = \frac{(\text{Within SS})_k^2}{(\text{Within SS})_{k'}^2} \tag{6}$$

where: $(\text{Within SS})_k^2$ is the intra-group variance of the k-th cluster;

$(\text{Within SS})_{k'}^2$ – the intra-group variance of the k'-th cluster ($k' \in [1; k]$);

$(\text{Between SS})^2$ – the intergroup variance;

x_{ij} – the value of the i-th indicator of the j-th object;

$\overline{x_{ik}}$ –the mean value of the i-th indicator of the k-th cluster;

$\tilde{X}_i$ – the mean value of the i-th indicator of the sample;

n_k – the number of objects of the j-th cluster;

N – sample size; F_e – the empirical (calculated) value of the Fisher criterion.

The results of clustering are statistically significant if the following conditions are met (formula 7) (Ramon-Gonen and Gelbard 2017):

$$\begin{cases} (\text{Between SS})^2 > (\text{Within SS})_k^2; \\ F_e > F_t; \\ (\text{signif. p}) < 0.05 \rightarrow 0 \end{cases} \tag{7}$$

where: F_t is a tabular value of the Fisher criterion, which is determined by statistical tables depending on the number of degrees of freedom and the level of significance;

(signif. p) – the error level.

Using the integrated assessment method by calculating the integral efficiency score, the priority evaluation was made for economic development of the oil-and-gas-bearing areas in the Arctic Region of the Russian Federation (formula 8) (Menke 2018, 207–222):

$$I_j = \sum_i^k d_{Fi} * F_{ij}, \tag{8}$$

where: I_j is the value of the integrated performance indicator of economic development of the j-th oil-and-gas-bearing area;

d_{Fi} – the value of the i-th factor variance;

F_{ij} – the value of the i-th factor for the j-th oil-and-gas-bearing area;

k – the number of factors.

The higher the level of the integrated indicator, the higher the level of economic development efficiency of the oil-and-gas-bearing region.

The principal components analysis (factor analysis) was used in the Statistika 10 software product to determine the degree of influence of the performance indicators of the economic development of the energy resources of the Arctic Region. The mathematical model of factor analysis has the following form (formula 9) (Menke 2018, 207–222):

$$V_i = A_{i,1}F_1 + A_{i,2}F_2 + ... + A_{i,k}F_k + U \quad (9),$$

where: V_i is the value of the *i*-th variable which is expressed as a linear combination of k common factors;
$A_{i,k}$– regression coefficients showing the contribution of each of the k factors to a given variable;
$F_{1..k}$ – factors that are common to all variables;
U – residue specific factor (residues).

The minimum of the discrepancy between the covariance matrix of the original characteristics and the one obtained after estimating the factor loads is used as an optimality criterion to find the values of the coefficients $A_{i,k}$.

Each of the k factors is expressed as a linear combination of the observed variables (formula 10) (Menke 2018, 207–222):

$$F_j = W_{j,1}V_1 + W_{j,2}V_2 + ... + W_{j,p}V_p \quad (10),$$

where: Wj.1 are the loads of the j-th factor on the i-th variable of the factor loads;
p – the number of the variables.

2. Results

2.1. The analysis of the current state of economic development of hydrocarbons in the Arctic Region of the Russian Federation

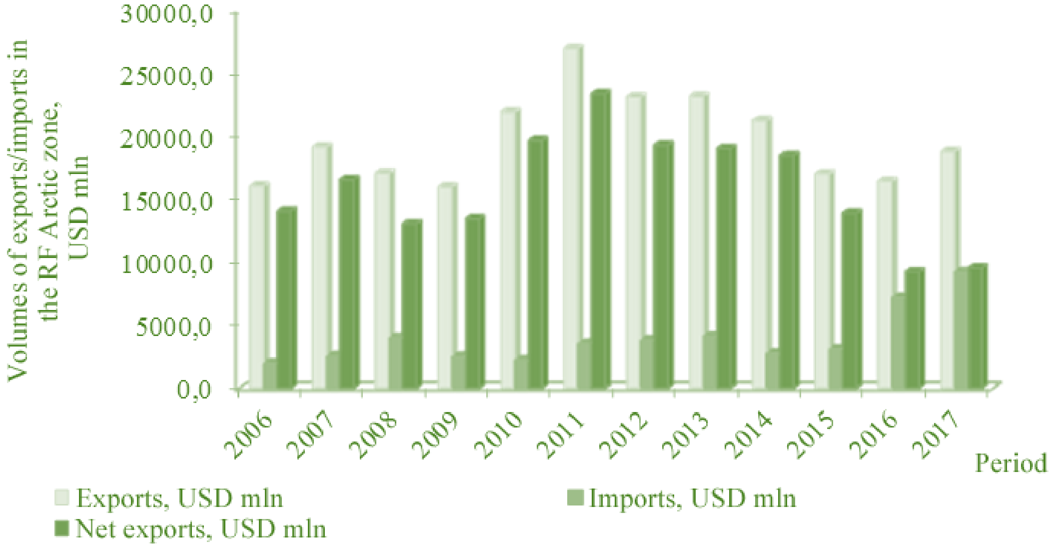
Nowadays in the territory of the Arctic zone of the Russian Federation having about 10.5 million square kilometers and a population of 7 million people (4.9% of the Russian population as of 2017) (Federal State Statistics Service 2018) about 9% of the country's Gross Domestic Product (GDP) is produced. The total volume of GRP of the RF territorial entities in the Arctic zone has increased 4-fold over the recent 12 years (Figure 1) and is characterized by a steady growing dynamics (Federal State Statistics Service 2018).

Figure 1. Indicators of the GDP Dynamics in the Arctic Region of the Russian Federation

Source: Federal State Statistics Service 2018

Territorial entities of the Arctic zone of the Russian Federation are cumulatively characterized by a trade surplus. Over 2006-2017 net exports increased by 68% (Figure 2) (Federal State Statistics Service 2018), which indicates the growth of foreign capital in the region, and exceeds 5% of Russia's total exports (Figure 4) (Federal State Statistics Service 2018).

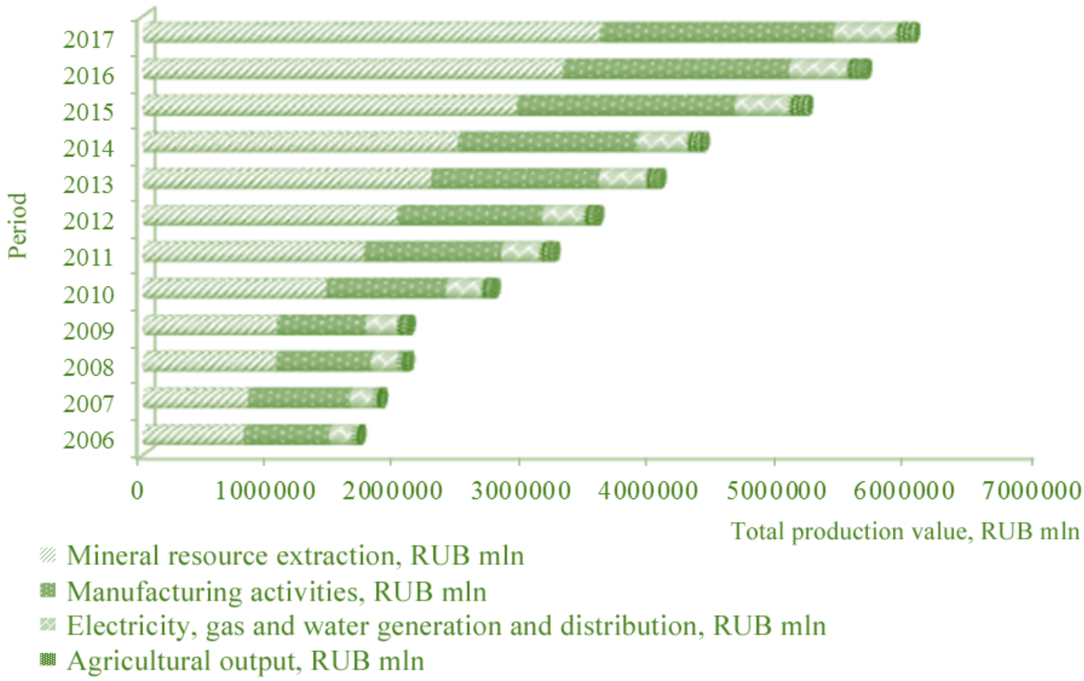
Figure 2. Trade Balance Dynamics in the Arctic Region of the Russian Federation



Source: Federal State Statistics Service 2018

Since the main volume of production in the Arctic falls on the extraction of minerals (making more than 70%, as of 2017), the main share of exports is the export of products of the fuel and energy complex (FEC) of the region. The extraction of minerals in the region increased by 4.5 times during the period under review (Figure 3), the share of exports of fuel and energy products doubled (Figure 4) (Federal State Statistics Service 2018).

Figure 3. Production Dynamics in the Arctic Region of the Russian Federation



Source: Federal State Statistics Service 2018

Figure 4. Export Ratio Dynamics of the Arctic Region Products in the Russia's Exports

Source: Federal State Statistics Service 2018

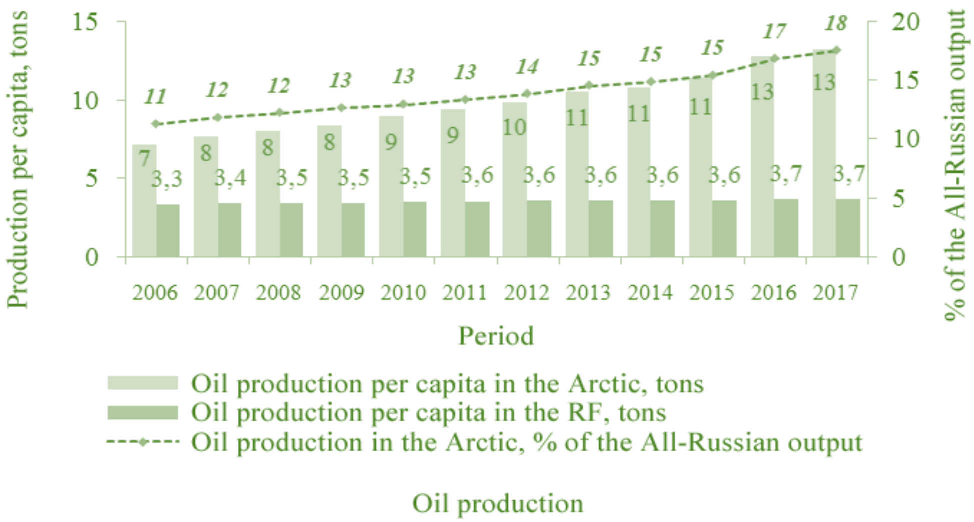
The main extracted and processed products of the fuel and energy complex in the Arctic Region of the Russian Federation are oil, gas and coal.

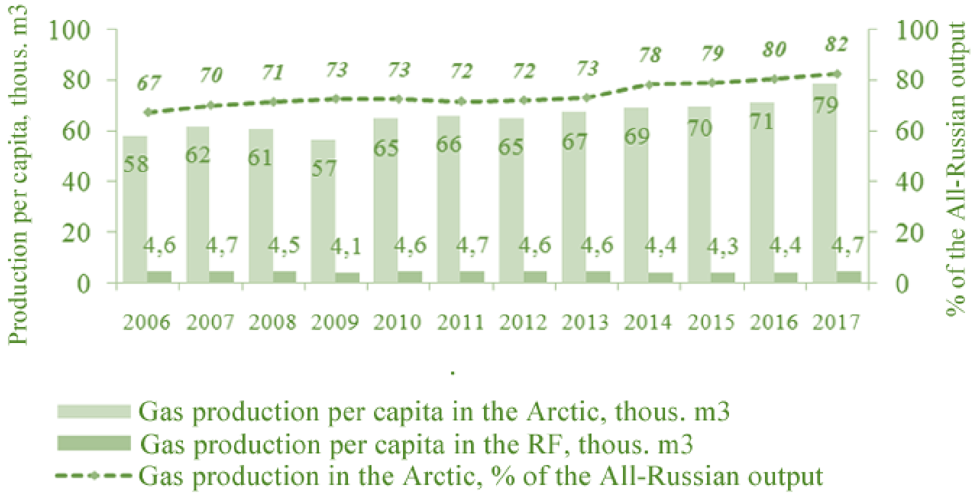
According to the official data, the production of hydrocarbons in the Arctic Region of the Russian Federation is constantly increasing in absolute terms; the share of the Arctic in the total extraction of energy resources in Russia also tends to increase. The volume of oil production in the Arctic Region increased by 77% in 2006-2017 and amounted to 13 tons per capita, while the total oil production in the Russian Federation is 3.7 tons per capita. The ratio of Arctic oil in the all-Russian production increased by 63% making 18% in 2017, compared to 11% in 2006 (Figure 5) (Ministry of Energy of the Russian Federation 2018).

The ratio of gas production in the Arctic Region of the Russian Federation makes the lion's share of the total volume of Russian gas production – 82% (over 2006-2017 the increase amounted to 22%). Gas production in the region is also characterized by stable positive dynamics, during the period under study, gas production increased by 29% and amounted to 79 thousand cubic meters per capita (in 2017 this indicator for Russia was 4.7% per capita) (Figure 5) (Ministry of Energy of the Russian Federation 2018).

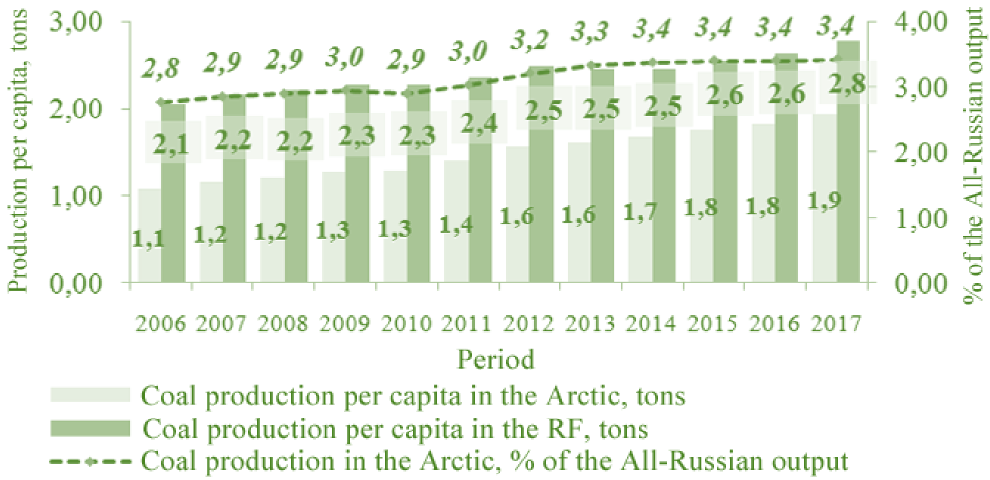
Coal production in the Arctic regions increased significantly (+ 72%) and amounted to 2.8 tons per capita. The ratio in the total volume of coal production in Russia was recorded at 3.4% in 2017. (the increment was 21% for 2006-2017) (Figure 5) (Ministry of Energy of the Russian Federation 2018).

Figure 5. Dynamic Indicators of Hydrocarbon Production in the Arctic Region of the Russian Federation





Gas production

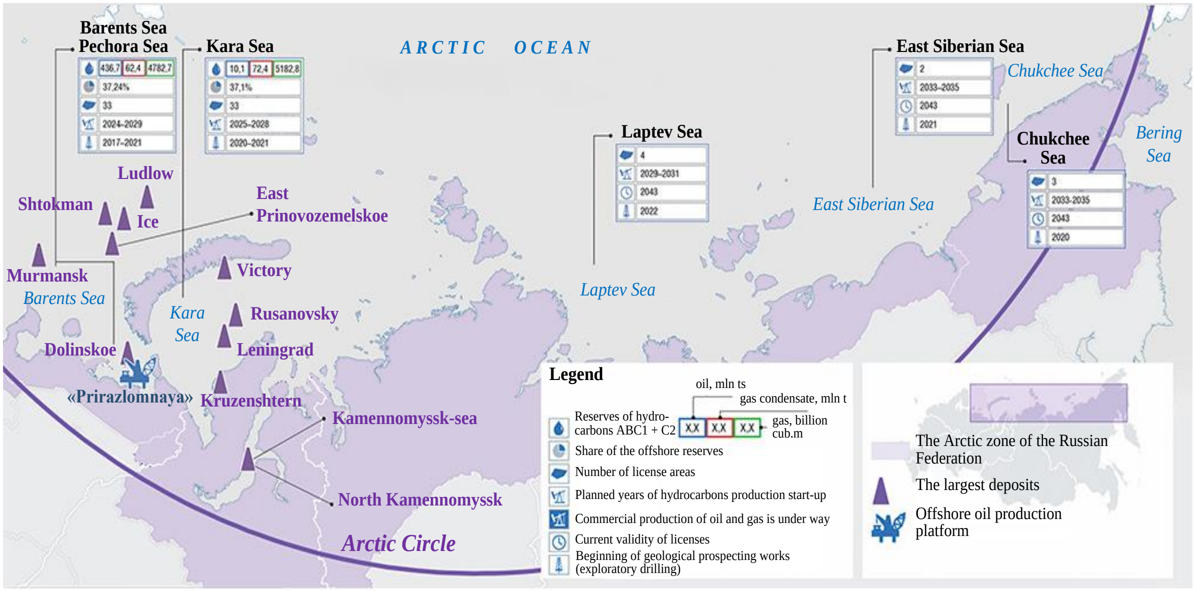


Coal production

Source: Ministry of Energy of the Russian Federation 2018

The major part of Arctic hydrocarbons (up to 60%) is concentrated in the oil-and-gas-bearing areas of the continental shelf (Figure 6) (Kolpakov 2016). And the largest marginal continental West Siberian oil and gas province contains up to 32% of the region's resource base. The State Program "Socio-Economic Development of the Arctic Zone of the Russian Federation for the period until 2020" (Ministry of Economic Development of the Russian Federation 2014) states that oil and gas production will have a wide multiplicative effect and will affect positively the social and economic development of the region. In addition, in the official energy documents of Russia the need to increase oil and gas production in the Arctic is spelled out (including on the shelf) to ensure the stable operation of the country's oil and gas industry in the long term. Nevertheless, it should be noted that according to experts, the volume of geological exploration in the Russian Federation today is ten times lower than in the American shelf of the Chukchi Sea and 20 times lower than in the Norwegian shelf (Ermida 2014; Wood-Donnelly 2016). This lag from the competitors in the investigation of oil fields leads to a lag in their development.

Figure 6. The Largest Deposits of Hydrocarbons in the Arctic Shelf Zone of the Russian Federation



Source: Kolpakov 2016

It is possible to give just one example of the hydrocarbon production in the Arctic shelf of the Russian Federation – this is the Prirazlomnoye oilfield development project of PAO Gazprom Neft in the Pechora Sea. The recoverable reserves of this oilfield are estimated by experts to exceed 70 million tons of oil (Cheng 2014). The portfolio of Gazprom Neft's offshore assets also comprises the Dolginskoye oil field (recoverable reserves exceed 200 million tons of oil), the North-Western (105 million tons of oil, 60 billion cubic meters of gas, the site is located in the southeast (140 million tons of oil and condensate, 2 trillion cubic meters of gas, the site is located in the northern part of the Barents Sea, to the west of the Novaya Zemlya Archipelago, at a distance of about 1 thousand km from the mainland) and North Wrangel (projected geological resources are estimated at over 2 billion tons of oil and gas condensate, about 1 trillion of cubic meters of natural gas) license areas. Geological exploration is carried out on these sites (Kolpakov 2016).

Currently, gas is produced by Russian companies in the Arctic Region only in the mainland of the Arctic, while the offshore part remains undeveloped. However, in the context of the fall in the world prices for energy resources, the development of hard-to-recover and offshore energy resources is seen to be unprofitable, therefore, in modern conditions it seems expedient and promising to develop already functioning and less capital intensive hydrocarbon fields with quick economic returns by increasing economic efficiency of extraction and transportation.

2.2. Prioritization of the spatial organization of the economic development of the energy resources of the Arctic Region of the Russian Federation

Within the framework of the study, a cluster analysis of the Arctic continental and oceanic (offshore) oil and gas provinces and regions was carried out in terms of economic development efficiency to determine and substantiate the priorities of the economic development of energy resources in the Arctic Region of the Russian Federation.

Using the expert elicitation method, a system of key performance indicators of economic development of hydrocarbons in the oil and gas provinces is determined as of 2017:

- the density of allocating total resources of hydrocarbons – an indicator that characterizes the presence and territorial concentration of energy resources in the region;
- the availability of a pipeline system for energy resources transportation. The availability of operating pipelines was estimated at 2 points, with 1 point assigned to the projected pipelines and "0" in case of their absence;
- the availability of sea port infrastructure. This indicator was estimated by the availability of ports within the oil-and-gas-bearing area or in the adjacent area. The point "1" is indicative of the sea port availability, "0" indicates the sea port absence ;
- the extent of exploration maturity. This indicator was estimated by the level of development of energy resources within the oil-and-gas-bearing area: extraction at licensed areas (blocks) and transportation (2 points); preparation for development of a deposit ready for exploitation, extraction did not reach the commercial scale (1point); search, exploration (0);

- a qualitative characteristic of the space containing hydrocarbons. According to the exploration status and production conditions, 3 zones were identified: "operating" zone – the space of the Arctic zone of the Russian Federation (the territory and subsoil), "medium" zone – the space of the continental shelf of the Arctic seas, and "extreme" zone – the Arctic space covered with ice, the latter zone was not considered due to the lack of reliable data on the availability of reserves and potential resources of hydrocarbons in these areas. "Operating zone" is estimated at 1 point, "medium zone" is assigned 0 points;
- the availability of oil and gas refinery plants, oil pumping stations. This indicator characterizes the development of the territorial infrastructure: the availability of an ORP or a GRP contributes to the increase in production output and is estimated at 1 point, the ORP/GRP absence is estimated at 0 points;
- the potential manpower in the region. This indicator characterizes labor resources, average per capita cash income – the level of labor costs, since oil and gas production is the main source of income in the Arctic Region (Federal State Statistics Service 2018). The labor headcount and per capita monetary incomes of that territorial entity of the Russian Federation, whose territory coincides with the OGA or where the facilities for hydrocarbons processing are located, were used for estimation.

The representativeness of the system of indicators for performance assessment of the economic development of energy resources in the Arctic Region of the Russian Federation is confirmed by the results of an expert survey conducted by the Delphi method (Astfalck *et al.* 2018). This method allows minimizing the influence of subjective psychological factors inherent in a collective discussion, as it provides anonymity of experts and the absence of a direct communication between them.

Ten specialists of the "All-Russia Scientific Research Institute of Geology and Mineral Resources of the World Ocean named after Academician I.S. Gramberg "(FSBI "VNIIOkeangeologia") engaged in the study of geology and petroleum issues were the experts to assess the representativeness of the indicators (FSBI "VNIIOkeangeologia" 2018). FSBI "VNII Oceangeologia" is the basic scientific organization of the Russian Federation in the field of geological study of the continental shelf, the World Ocean, the Arctic and the Antarctic, which ensures a high level of competence of experts in the subject matter. The experts were offered by email to assess the representativeness of a system of indicators, consisting of an indicator of the total hydrocarbon resources density, the availability of oil pipelines, the availability of gas pipelines, the exploration maturity, the availability of marine infrastructure, the availability of oil and gas refineries, extraction conditions, labor headcount in the region, average per capita monetary incomes for the performance assessment of economic development of energy resources. Based on the results of the expert elicitation, it is determined that the representativeness of the proposed indicators makes 87%, that is, these indicators determine the efficiency of economic development of energy resources in the Arctic Region by 87%. The deviation in expert estimates does not exceed 10%, which is indicative of a high degree of opinion consistency (Rousseau *et al.* 2018).

The quantitative data of the system of economic performance indicators for the development of oil-and-gas-bearing provinces and areas of the Russian Federation are given in Table 1. The different dimensions of the performance indicators necessitated the standardization of data, in this connection, further calculations and simulations were carried out on the basis of the standardized data for 2017.

Table 1. Performance indicators of economic development of energy resources in the Arctic Region of the Russian Federation for 2017

Oil-and-gas-bearing province, area	Density of total HC resources, thous.t, km2	Availability of oil pipelines (points)	Availability of gas pipelines (points)	Exploration maturity (points)	Availability of sea routes (points)	Availability of ORP, GRP (points)	Extraction conditions (points)	Region's manpower, thous. people	Average per capita monetary incomes (per month), RUB.
Eastern Arctic POGP	3	0	0	0	0	0	0	522	52589.2
Shtokman-Luninskaya OGA	65	0	1	2	1	0	0	1015	40499.5
South-Barents OGA	65	0	1	1	1	0	0	1015	40499.5
Finnmarken OGA	40	0	0	0	1	0	0	445	48986.0
Yamalskaya OGA	250	0	2	2	0	0	1	321	73384.4
Gydanskaya OGA	250	0	1	2	0	0	1	321	73384.4
Nadym-Purskaya OGA	300	0	2	2	0	0	1	321	73384.4

Oil-and-gas-bearing province, area	Density of total HC resources, thous.t, km2	Availability of oil pipelines (points)	Availability of gas pipelines (points)	Exploration maturity (points)	Availability of sea routes (points)	Availability of ORP, GRP (points)	Extraction conditions (points)	Region's manpower, thous. people	Average per capita monetary incomes (per month), RUB.
Pur-Tazovskaya OGA	250	0	0	2	0	0	1	321	73384.4
Frolovskaya OGA	250	2	2	2	0	0	1	321	73384.4
Sredneobskaya OGA	300	2	2	2	0	1	1	321	73384.4
Yenisei-Khatanga OGA	40	0	0	2	1	0	1	1482	27976.8
Predyeniseiskaya OGA	40	0	0	0	1	0	1	1482	27976.8
Yeloguy-Turukhanskaya OGA	40	0	0	0	1	1	1	1482	27976.8
West-Siberian OGP – the sea	65	0	0	2	0	0	0	321	73384.4
Laptevskaya POGP	20	0	0	0	0	0	0	490	39765.0
Vilyuiskaya OGA	20	0	2	2	0	1	1	490	39765.0
Predverkhoyanskaya OGA	7.5	0	0	2	0	0	1	490	39765.0
Nepsko-Botuobinskaya OGA	75	2	2	2	0	1	1	490	39765.0
Baykitskaya OGA	75	1	0	2	1	1	1	1482	27976.8
Predpatomskaya OGA	40	0	0	2	0	0	1	490	39765.0
Anabarskaya POGA	4	0	2	0	1	0	1	1972	33870.9
North-Tungusskaya OGA	40	0	0	0	1	0	1	1482	27976.8
Turukhano-Norilsk OGR	40	0	0	0	1	0	1	1482	27976.8
South-Tungusskaya OGA	75	0	0	0	1	0	1	1482	27976.8
Syudzherskaya POGA	8	0	2	0	0	0	1	490	39765.0
Anabaro-Khatangskaya OGA	30	0	0	0	1	0	1	1482	27976.8
Leno-Anabarskaya OGA	30	0	0	0	0	0	1	490	39765.0
West-Vilyuiskaya OGA	20	0	0	0	0	0	1	490	39765.0
North-Aldanskaya OGA	3	0	0	0	0	0	1	490	39765.0
Novosibirsk-Chukotka POGP	4	0	0	0	0	0	0	522	52589.3
Timano-Pechorskaya OGP	125	0	2	2	0	1	1	489	50174.0

Source: compiled based on: Russian Geological Portal 2018; Federal State Statistics Service 2018; Saxinger 2016; Vatansever 2017; Kontorovich *et al.* 2017; Kus *et al.* 2015; Sobolev *et al.* 2016

The oil-and-gas-bearing areas of the Arctic zone of the Russian Federation were classified using cluster analysis according to the level of economic efficiency of development, as a result of which 3 clusters were identified (Table 2), which include the developed oil and gas provinces and regions (OGPs and OGAs), promising OGPs and OGAs (POGPs and POGA) and the Turukhano-Norilsk Independent Oil and Gas Region.

Table 2. Cluster composition of the oil-and-gas-bearing provinces and areas in the Arctic Region of the Russian Federation according to the level of economic development efficiency

Cluster	Cluster composition (oil-and-gas-bearing areas)
Cluster 1	Eastern Arctic POGP, Finnmarken OGA, West-Siberian OGP – the sea, Laptevskaya POGP, Predverkhoyanskaya OGA, Predpatomskaya OGA, Syudzherskaya POGA, Leno-Anabarskaya OGA, West-Vilyuiskaya OGA, North-Aldanskaya OGA, Novosibirsk-Chukotka POGP
Cluster 2	Shtokman-Luninskaya OGA, South-Barents OGA, Yenisei-Khatangskaya OGA, Predyeniseiskaya OGA, Yeloguy-Turukhanskaya OGA, Baykitskaya OGA, Anabarskaya POGA, North-Tungusskaya OGA, Turukhano-Norilsk OGR, South-Tungusskaya OGA, Anabaro-Khatangskaya OGA
Cluster 3	Yamalskaya OGA, Gydanskaya OGA, Nadym-Purskaya OGA, Pur-Tazovskaya OGA, Frolovskaya OGA, Sredneobskaya OGA, Vilyuiskaya OGA, Nepsko-Botuobinskaya OGA, Timano-Pechorskaya OGP

Source: compiled by the authors

To justify the adequacy and accuracy of cluster analysis findings within the research framework, the ANOVA results of clustering of oil-and-gas-bearing provinces and areas of the Russian Federation are given in Table 3.

Table 3. ANOVA results of clustering oil-and-gas-bearing provinces and areas of the Russian Federation according to the level of economic development efficiency

Indicator	Between - SS	df	Within - SS	df	F	signif. - p
Density of total HC resources (X_1)	20.90	2	10.10	29	29.99	0.00
Availability of oil pipelines (X_2)	16.92	2	14.08	29	4.17	0.03
Availability of gas pipelines (X_3)	18.99	2	15.01	29	15.44	0.00
Exploration maturity (X_4)	19.68	2	16.32	29	13.04	0.00
Availability of maritime infrastructure (X_5)	27.21	2	3.79	29	104.14	0.00
Availability of ORP, GRP (X_6)	26.46	2	14.54	29	3.82	0.03
Extraction conditions (X_7)	15.19	2	5.81	29	3.92	0.03
Region's manpower (X_8)	28.11	2	2.89	29	140.89	0.00
Average per capita monetary incomes (per month) (X_9)	18.70	2	12.30	29	22.06	0.00

Source: compiled by the authors

According to the Fisher criterion, with a probability of 95%, the statistical significance of clustering can be stated, since the calculated values of the F-test (Table 3) are greater than the tabulated value of 3.33 (with the significance level $p = 0.05$ and the number of degrees of freedom 2, 29). The probability of an erroneous reference of a research object (oil and gas bearing region) to a definite "cluster" by each indicator does not exceed 3% (signif. – $p \leq 0.03$) (Ramon-Gonen and Gelbard 2017).

Thus, based on the cluster analysis (Table 2), it can be concluded that the oil-and-gas-bearing areas included in cluster 3 have the highest values of the performance indicators of economic development. Except for the X5 (availability of the maritime port infrastructure) and X8 (region's manpower) indicators, whose values are significantly higher than for the regions of cluster 2.

The low values of the region's labor force headcount are conditioned by the fact that oil-and-gas-bearing areas of cluster 3 are located within the territory of the Nenets Autonomous District, which has the smallest population among the territorial entities of the Russian Federation in the Arctic zone, and the Yamalo-Nenets Autonomous District, the Republic of Komi and the Republic of Sakha (Yakutia), the economically active population of which amounts to 50-58% of those registered in the territorial entities of the Russian Federation (Federal State Statistics Service 2018). There are no large seaports in these the territorial entities of the Russian Federation, which are of strategic importance for the efficiency of the economic development of hydrocarbon deposits (Theocharis *et al.* 2018).

The oil-and-gas-bearing areas that had formed cluster 3 have the highest level of energy potential.

Oil-and-gas-bearing areas of cluster 2 have lower level of energy potential compared to cluster 3, but they have a sea port infrastructure (sea routes) and are provided with human resources.

The oil-and-gas-bearing areas of cluster 1 have the lowest level of energy potential. oil-and-gas-bearing areas: There are no oil and gas pipelines, ORPs and GRPs within the space of these OGAs, average density of total HC resources makes 22 thousand tons/km^2, oil and gas are practically not extracted (Russian Geological Portal 2018; Naseri *et al.* 2016). In this regard, further research on the spatial organization of efficiency of the economic development of energy resources of the Arctic will be carried out for clusters 2 and 3.

With regard to the identified clusters in terms of efficiency of energy resources in the Arctic Region of the Russian Federation, the priority of spatial organization of the economic development of oil-and-gas-bearing provinces and areas was determined within the allocated clusters on the basis of the calculation of the integrated performance indicator for the resource development.

The factor analysis (PCA) was used to calculate the integrated performance indicator for economic development of the energy resources of the Arctic Region of the Russian Federation. As indicators, the economic development performance indicators are singled out as the factors (Table 1).

The expediency of using factor analysis is the possibility of identifying key factors that determine the efficiency of extracting energy resources, and calculating the integrated performance indicator, with regard to the priority influence of these factors.

The Kettel's criterion was used to determine the optimal number of factors to maximize the percentage of factorization, which implies selection of the number of factors at which the decline in the factor eigenvalues is slowed down as much as possible (Menke 2018, 207–222). Three factors are singled out by the Kettel's criterion.

Table 4. Qualitative indicators of efficiency factors of economic development of energy resources in the Arctic Region of the Russian Federation

Factor eigenvalues

Factor	Eigenvalue	% Total variance	Cumulative Eigenvalue	Cumulative %
1	3.80	46.95	3.80	46.95
2	1.90	23.41	5.70	70.36
3	0.89	11.02	6.59	81.38

Factor structure

Indicator	Factor loadings (the significant ones are highlighted ≥ |0.65|		
	Factor1	Factor 2	Factor 3
X_1	0.79	-0.42	0.13
X_2	-0.18	0.77	0.21
X_3	-0.29	0.70	0.46
X_4	0.75	-0.43	0.38
X_5	0.84	-0.09	-0.05
X_6	0.09	0.89	0.07
X_7	0.69	0.34	0.18
X_8	-0.05	0.00	0.95
X_9	-0.02	0.40	-0.85

Source: compiled by the authors

Based on the principal components analysis, the following results were obtained for the assessment of the factor impact on the efficiency of the economic development of the energy resources in the Arctic Region of the Russian Federation.

Factor 1 reflects the greatest degree of influence. It explains 46.95% variance and includes indicators that characterize the resource potential of oil-and-gas-bearing areas: the density of total hydrocarbon resources, the exploration maturity, the availability of the sea port infrastructure and the conditions of oil and gas production.

Factor 2 determines the infrastructure of oil and gas production: the availability of oil pipelines, gas pipelines, ORP and GRP in the region. The impact of this factor on the efficiency of economic development of energy resources was 23.41%.

Factor 3, covering of the region's manpower and average per capita monetary income, characterizes the labor potential of the region and the level of labor remuneration. The basis of monetary incomes of the population of the Russian Arctic zone is formed by wages for the extraction and processing of oil and gas, which is an expenditure item for hydrocarbon production and processing enterprises. Therefore, this indicator has a negative impact on the efficiency, which is expressed by a negative value of the factor loading (-0.85). The impact of this factor on the efficiency of energy resources extraction was 11.02%.

In general, the investigated factors determine the efficiency of energy resources extraction by 81.38%, which indicates a high level of factorization, the adequacy of simulation results.

Taking into account the degree of factor impact, the integrated performance indicator of the economic development of energy resources in the Arctic Region of the Russian Federation was calculated by additive convolution of factor values (Table 5) adjusted for their significance and expressed in terms of variance percentage (Table 4) using formula 8. The results are given in Table 6.

Table 5. Factorized values of performance indicators of economic development of energy resources in the Arctic Region of the Russian Federation

OGA	Factor 1	Factor 2	Factor 3
Sredneobskaya OGA	1.44	1.25	1.11
Timano-Pechorskaya OGP	1.23	1.16	0.62
Nadym-Purskaya OGA	1.16	0.92	0.31
Frolovskaya OGA	0.90	0.51	0.34
Yamalskaya OGA	0.84	0.52	0.31
Gydanskaya OGA	0.84	0.51	0.31
Pur-Tazovskaya OGA	0.84	0.51	0.31
Nepsko-Botuobinskaya OGA	0.81	0.57	0.34
Vilyuiskaya OGA	0.80	0.57	0.34
Baykitskaya OGA	0.81	0.51	0.33
Shtokman-Luninskaya OGA	0.44	0.16	0.14
South-Barents OGA	0.35	0.12	0.09
Yenisei-Khatanga OGA	0.30	0.11	0.05
South-Tungusskaya OGA	-0.03	-0.10	-0.10

OGA	Factor 1	Factor 2	Factor 3
Yeloguy-Turukhanskaya OGA	-0.04	-0.11	-0.06
Predyeniseiskaya OGA	-0.17	-0.18	-0.19
North-Tungusskaya OGA	-0.17	-0.18	-0.19
Turukhano-Norilsk OGR	-0.17	-0.18	-0.19
Anabarskaya POGA	-0.33	-0.21	-0.24
Anabaro-Khatangskaya OGA	-0.29	-0.28	-0.29
West-Siberian OGP – sea	-0.31	-0.29	-0.31
Predpatomskaya OGA	-0.32	-0.30	-0.35
Finnmarken OGA	-0.33	-0.30	-0.35
Predverkhoyanskaya OGA	-0.53	-0.49	-0.40
Leno-Anabarskaya OGA	-0.61	-0.49	-0.40
West-Vilyuiskaya OGA	-0.63	-0.49	-0.40
Laptevskaya POGP	-0.74	-0.49	-0.40
Syudzherskaya POGA	-0.88	-0.48	-0.40
North-Aldanskaya OGA	-0.97	-0.58	-0.40
Novosibirsk-Chukotka POGP	-0.99	-0.80	-0.75
Eastern Arctic POGP	-1.00	-0.80	-0.75

Source: compiled by the authors

Table 6. Priority ranking of oil and gas production in the Arctic Region of the Russian Federation in terms of oil-and-gas-bearing areas broken down by their economic development efficiency

Cluster	OGA	Integrated performance indicator of economic development	Priority	Cluster	OGA	Integrated performance indicator of economic development	Priority
Cluster 3	Sredneobskaya OGA	1.09	1	Cluster 1	West-Siberian OGP - sea	-0.25	21
	Timano-Pechorskaya OGP	0.92	2				
	Nadym-Purskaya OGA	0.79	3		Predpatomskaya OGA	-0.26	22
	Frolovskaya OGA	0.58	4				
	Yamalskaya OGA	0.55	5		Finnmarken OGA	-0.26	23
	Gydanskaya OGA	0.55	6				
	Pur-Tazovskaya OGA	0.55	7		Predverkhoyanskaya OGA	-0.41	24
	Nepsko-Botuobinskaya OGA	0.55	8				
	Vilyuiskaya OGA	0.55	9		Leno-Anabarskaya OGA	-0.45	25
Cluster 2	Baykitskaya OGA	0.54	10				
	Shtokman-Luninskaya OGA	0.26	11		West-Vilyuiskaya OGA	-0.46	26
	South-Barents OGA	0.20	12		Laptevskaya POGP	-0.51	27
	Yenisei-Khatanga OGA	0.17	13		Syudzherskaya POGA	-0.57	28
	South-Tungusskaya OGA	-0.05	14		North-Aldanskaya OGA	-0.64	29
	Yeloguy-Turukhanskaya OGA	-0.05	15				
	Predyeniseiskaya OGA	-0.15	16		Novosibirsk-Chukotka POGP	-0.74	30
	North-Tungusskaya OGA	-0.15	17				
	Turukhano-Norilsk OGR	-0.15	18		Eastern Arctic POGP	-0.74	31
	Anabarskaya POGA	-0.23	19				
	Anabaro-Khatangskaya OGA	-0.23	20				

Source: compiled by the authors

Oil-and-gas-bearing areas and provinces with positive integrated indicators (from 1.09 to 0.17) are characterized by a significant (above average) level of economic efficiency of their development and include objects of clusters 3 and 2. These objects are prioritized for economic development in the Arctic in modern conditions.

Spaces of cluster 1 have a low level of the integrated performance indicator of economic development. These are OGAs with a low resource distribution density (only West-Siberian OGP-the sea has a density of 65,000 tons/km^2, all others show less than 40,000 tons/km^2); there are no oil and gas pipelines, ORP, GRP; they lack a system of sea transportation of energy resources; almost half of the OGAs (Eastern Arctic POGP, Finnmarken OGA, West Siberian OGP – the sea, Laptevskaya POGP, Novosibirsk-Chukotka POGP) have complicated conditions of extraction. Therefore, these oil-and-gas-bearing provinces and areas can be developed when extracting the objects of 1-13 priority ranking points upon creation of the appropriate economic and infrastructural conditions, or in the presence of other, for example, political considerations.

3. Discussion

Based on the clustering and priority ranking of oil-and-gas-bearing provinces and areas of the Arctic Region of the Russian Federation, it seems possible to justify recommendations for spatial organization of the economic development of energy resources of the Arctic in the near future. The oil-and-gas-bearing provinces and areas that have positive values of the integrated performance indicator are most promising for economic development of energy resources. That is, the economic efficiency of the development of these objects appears to be above average. However, taking into account the fact that the development and production of oil and gas in the Arctic Region of Russia is a capital-intensive and long-term process, for feasibility of the proposed priorities for the spatial organization of economic development of energy resources, the threshold of minerals extraction profitability should be accounted for together with the world level of energy prices (Novoselov *et al.* 2017). This approach will allow assessing the break-even level of the economic development of hydrocarbon fields in the priority oil-and-gas-bearing provinces and areas, with regard to the global trends in oil and gas prices.

According to the estimates of Rystad Energy (2018), the international energy consulting and business intelligence data firm, the Ministry of Energy of the Russian Federation (Ministry of Energy of the Russian Federation 2018) and the Federal Agency for Subsoil Use (2018), the profitability threshold for oil production within the Arctic zone of the Russian Federation amounts to USD 65-110 per barrel, depending on the complexity of production: according to the official data, the profitability threshold for oil extraction from the Arctic shelf is USD 100-110 per barrel, making USD 65-70 per barrel for difficult oil from the mainland of the Arctic zone of the Russian Federation.

The internal rate of return on oil production from the Arctic shelf is 9%, and 45% for difficult oil; the payback period is 10 and 2 years, respectively (Rystad Energy 2018; Bucelli *et al.* 2018).

In addition, as already noted, it is necessary to take into account trends in world oil prices in modern conditions. For the period of January-May 2018, the average oil price is USD 70.1 per barrel, the minimum price being USD 64.55 and the maximum price being USD 75.37 for this period (Investing.com 2018).

Given the current dynamics and trends in the oil price fluctuations, the extraction of hard-to-recover oil reserves is on the verge of profitability, while oil production in the Arctic continental shelf is unprofitable. Only at the oil price level above USD 100 per barrel, economic development of the continental shelf of the Arctic seas will be efficient for the Russian economy. And since the issue of oil price regulation lies rather in the geopolitical plane, the transition to the development of oil fields of the Arctic continental shelf is difficult to predict in modern conditions. In 2017, the Federal Agency for the Subsurface Use of the Russian Federation agreed to transfer the terms of geological exploration and production for 31 companies, including offshore the Arctic seas due to a collapse in oil prices (Federal Agency for Subsoil Use 2018).

The fact that the Prirazlomnoye oil field development project of the PAO Gazprom Neft in the Pechora Sea is the only example of hydrocarbon production at the Russian Arctic shelf confirms the inefficiency of oil production in the current conditions. The recoverable reserves of this oil field exceed 70 million tons, as estimated by experts. But it should be noted that the exploitation of this field began in 2013, that is, before the use of international economic sanctions against the Russian Federation. In the future, it is planned to reach the volume of oil production of 5 million tons by 2020 (Kolpakov 2016).

Offshore assets of PAO Gazprom, the above mentioned Dolginskoye oil field, as well as North-Western, Heiss and North Wrangel license areas are only at the stage of geological exploration. Expansion and prospective launch of these deposits is possible only with significant investments and use of the advanced technological equipment, which contributes to reducing the cost of oil exploration and production (Kolpakov 2016; Novikov 2017).

Thus, based on the conducted calculations, the integrated performance indicator of economic development of oil in the Arctic Region of the Russian Federation and regarding the level of the world oil prices, a conclusion can be drawn that in modern conditions it is economically profitable to extract oil from the fields that have been developed before the sanction period.

The profitability threshold for natural gas production is USD 40-45 per 1,000 cubic meters in the Arctic shelf and USD 30-35 in the continental part (Ministry of Energy of the Russian Federation 2018; Rystad Energy 2018).

Since 1990, the level of world prices for natural gas has not fallen below USD 41.93 per 1,000 cubic meters (1992). In January-May 2018, the minimum price for gas was USD 95.49 per 1,000 cubic meters, the maximum price being USD 107.23 and the weighted average – USD 100.69 per 1,000 cubic meters (Investing.com 2018), therefore, increasing production from old and developing new fields is profitable, but only if the current level of demand for gas continues.

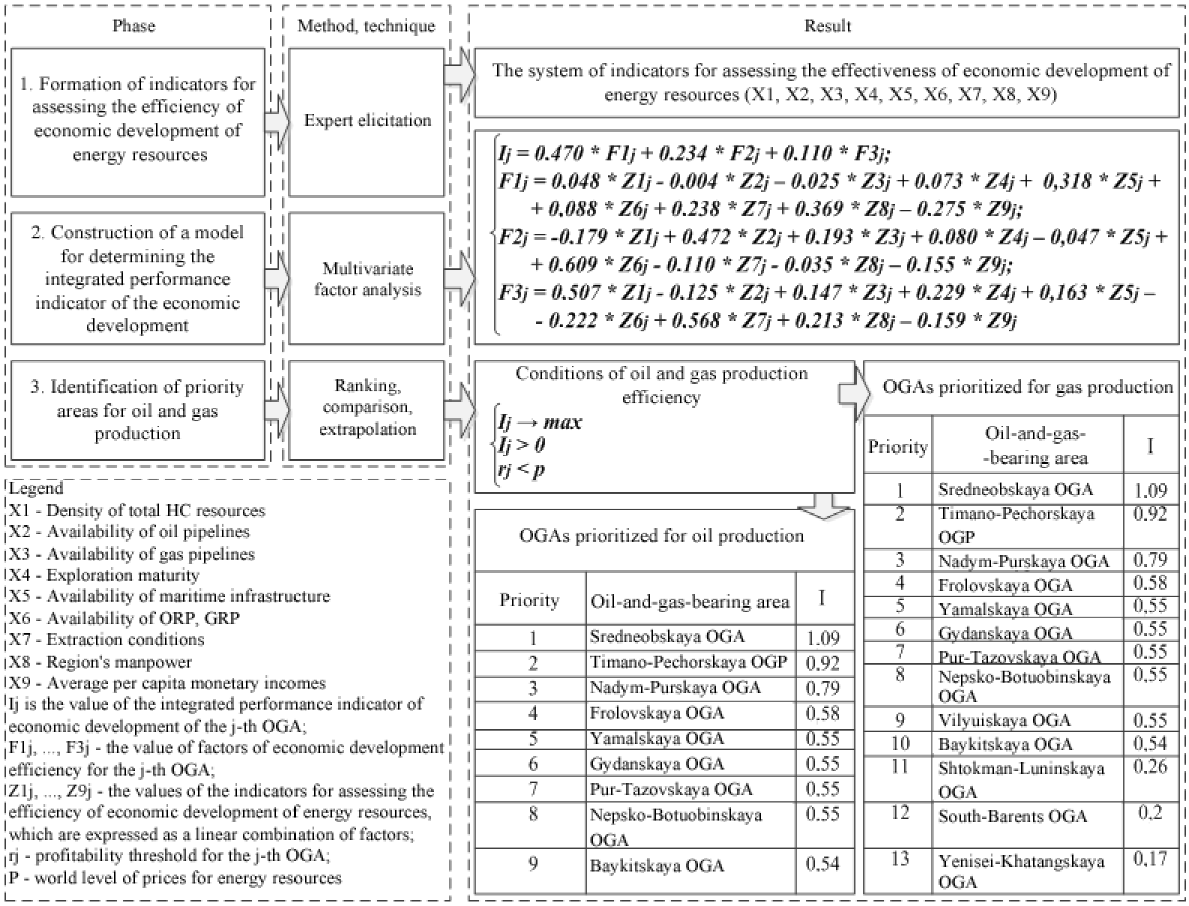
The current price for oil and gas (January-May 2018) was taken to emphasize the relevance of this research. The statistical database of performance indicators of the economic development of energy resources was formed for the purposes of the study in 2017, but given their scale, they are not subject to a rapid quantitative change in time, which does not contradict the adequacy of the results obtained in the study with a certain time lag as to the world oil price.

Nowadays gas production is carried out by Russian companies only in the mainland of the Arctic, while the shelf remains undeveloped. One of the large-scale projects in the region was the development of the Shtokman Gas Condensate Field by the Gazprom, which is considered among the largest in the world (predicted resources contain 3.9 trillion cubic meters of gas and 56.1 million tons of gas condensate) (Shadrina 2016). According to expert estimates, the projected natural gas production in this field exceeds Germany's annual gas consumption. The first stage of the project started in 2008, when a joint venture Shtokman Development AG was established, which is owned by Gazprom (51%), French Total (25%) and Norwegian Statoil ASA (24%) (Kolpakov 2016). However, the imposition of economic sanctions, as well as the shale boom in the United States that provoked a decline in the demand for gas, caused a significant rise in the cost of the project and the repeated postponement of its implementation. According to the recent expert estimates, two sections of the field are expected to be commissioned by 2025, subject to the current level of demand for gas (Kolpakov 2016).

Also, due to the imposed sanctions, which prohibited the US and European business from importing equipment for offshore operations, the prospective projects of economic development of oil by Russian companies in the Kara Sea in cooperation with the US Company ExxonMobil were suspended; in 2018 Rosoil lost its main partner in an oil production project on the Kara Sea shelf (Internet-Newspaper “Znak” 2018).

In view of the above, taking into account the worked out distribution of oil-and-gas-bearing provinces and areas according to the economic efficiency of development (Table 6), a 3-D model of economic development of oil and gas in the Arctic Region of the Russian Federation was developed (Figure 7). This model makes enables to make the following recommendations on the spatial organization of the economic development of energy resources in the Arctic Region of Russia.

Figure 7. 3-D model of efficiency of economic development of energy resources in the Arctic Region of the Russian Federation



Source: compiled by the authors

From the viewpoint of economic expediency, the spatial organization of oil development is represented by nine OGAs and OGPs having positive integrated performance indicators (from 1.09 to 0.54) and characterized by a significant (above average) level of economic development efficiency (Figure 7).

These nine objects should be recognized as economically effective, both in terms of oil extraction, and in terms of natural gas extraction.

Another four objects are added to these nine, which are recognized as economically efficient in terms of gas production only. These are Vilyuiskaya (I = 0.55), Shtokman-Luninskaya (I = 0.26), South-Barents (I = 0.2) and Yenisei-Khatanga (I = 0.17) OGAs.

It should be noted that unlike oil, gas fields with a negative level of the integrated performance indicator are characterized as promising deposits, which even at an unstable level of oil prices, provided they are explored and developed, will be breakeven. Only the level of demand for gas in the world market is the fundamental factor of the efficiency of economic development of these fields today. In the conditions of a growing demand trend, it seems expedient to develop the objects of cluster 2 in the short term in the following priority ranking by economic efficiency: South Tunguskaya (I = -0.05), Predyeniseiskaya (I = -0.15) and Anabaro-Khatangskaya OGAs (I = -0.23).

On the basis of the proposed optimization model of the spatial organization, the following system of practical recommendations is appropriate for improving the efficiency of economic development of the energy resources in the Arctic Region:

- to expand geological exploration in the Arctic Region of the Russian Federation, especially in the study of the Russian shelf. According to expert estimates, Russia is ten times less geologically investigated than the American shelf of the Chukchi Sea and 20 times less than the Norwegian shelf (Tysiachniouk and Petrov 2018; Kolpakov 2016);
- to expand international collaboration and cooperation ties on joint exploration, development and production of hydrocarbons in the region, conducted by the state and private companies;

- to build up international cooperation for access to new advanced technologies for exploration, development and extraction of energy resources;
- to retrofit and work out the process design for the production of own specialized equipment for the exploration, development and production of hydrocarbons, which will significantly reduce the dependence on imports;
- to construct road and transport networks, trunk oil and gas pipelines, seaports, oil transshipment terminals, LNG terminals on a new technical basis, to create belt and scraper conveyors with a digital control system for transporting minerals in the Arctic;
- to develop scientific, engineering and production potential of the economic development of the region on the principle of complementarity;
- to implement systematic analysis and forecasting of trends in the development of global markets for energy resources to make and timely adjust the strategy for the economic development of oil and gas fields, including with regard to the level of the world oil prices, the EU energy saving program and the activation of shale gas production in North America;
- to develop a reliable and efficient system of energy saving in the region;
- to provide active financing of scientific research of the region's climate and so on.

Practical implementation of the proposed set of conceptual recommendations will contribute to the increase in the efficiency of economic development of already functioning oil and gas fields over time and also to the elaboration of promising projects for the development of energy resources of the Arctic shelf.

Conclusions

Based on the empirical study, the following conclusions were drawn:

1. The Arctic zone of the Russian Federation is a powerful potential reserve of energy resources for economic development, but in the context of economic sanctions and a reduction in the level of the world oil prices, currently it is only possible to develop and produce hydrocarbons in the land territories of the region. Economic development of oil of the Arctic shelf of Russia is unprofitable because of the capital intensity of projects and difficult climatic conditions.

2. The developed model of the spatial organization of economic development of energy resources contributed to the identification of oil-and-gas-bearing regions, whose development efficiency is above average in modern conditions – the integrated performance indicator ranged within 1.09-0.17. Hydrocarbon exploration, development and production efficiency is ensured in these regions of the Arctic zone of the Russian Federation even with a significant fluctuation in the level of world demand and prices for energy resources.

3. The following oil-and-gas-bearing areas are break-even and economically profitable for development: Sredneobskaya OGA, Timano-Pechorskaya OGP, Nadym-Purskaya OGA, Frolovskaya OGA, Yamalskaya OGA, Gydanskaya OGA, Pur-Tazovskaya OGA, Nepsko-Botuobinskaya OGA, Vilyuiskaya OGA, Baykitskaya OGA, Shtokman-Luninskaya OGA, South-Barents OGA, and Yenisei-Khatangskaya OGA.

4. The development of gas in the Arctic shelf and land territories is economically viable in conditions of maintaining the level of demand for gas in the global energy market in such OGAs as South-Tungusskaya, Predyeniseiskaya and Anabaro-Khatangskaya.

In conclusion, it should be emphasized that the recommendations on improving the efficiency of the economic development of the energy resources in the Arctic Region of the Russian Federation are based on the modernization of the process design for hydrocarbon exploration, development and production, improvement of the territory infrastructure, cooperation and scientific approach to the development of hydrocarbons.

The practical implementation of the proposed set of optimization measures will promote the fullest unlock of the energy potential of the Arctic Region of the Russian Federation and ensure the sustainability of state energy security in the long term.

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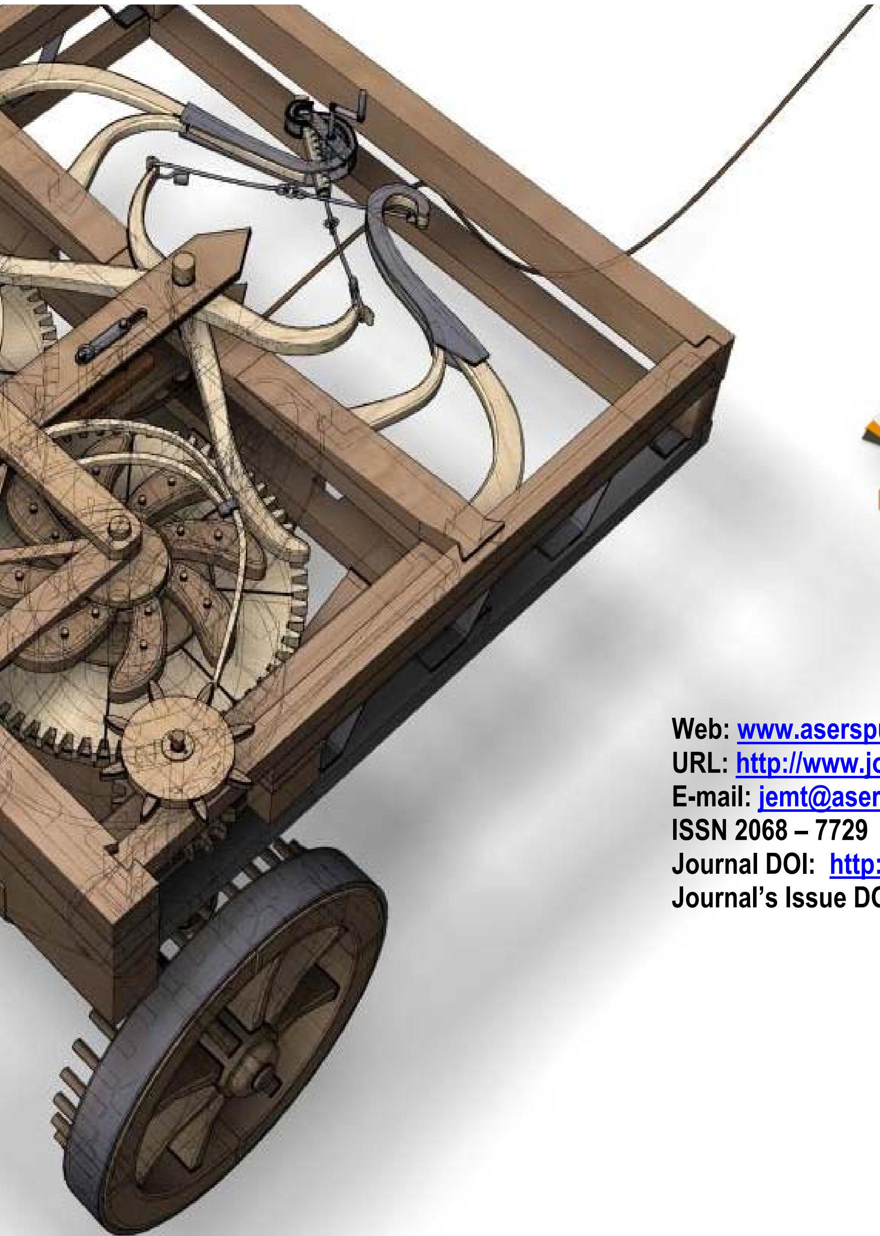

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