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Management of Arctic Field Development Based on a Multi-Criteria Approach

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***Abstract*—The article provides recommendations for improving the methodological basis for the selection of priority projects for the development of Arctic shelf deposits. The emphasis is on the use of a multi-criteria approach at the stage of selection of the most effective projects, which will directly lead to a faster strengthening of positions in the world market of companies implementing these projects. It will also ensure that oil companies achieve their strategic goals and increase their production capacity. The authors propose to use the technology of program-target planning to increase the efficiency of the production potential of oil companies due to the optimal sequence of commissioning of Arctic fields. Complementing and developing the existing methodological framework for a comprehensive, systematic assessment of Arctic shelf deposits, the authors propose a basic version of the system of evaluation indicators. When reducing the procedure for selecting priority deposits to a multi-criteria problem, the authors conduct approbation calculations using two methods for obtaining an integral evaluation indicator: the first is the methods by V. Pluta and the second one is the additive convolution of criteria. The work also focuses on the study and consideration of risks associated with Arctic shelf deposits. The Conclusions and the results can be interesting for representatives of the oil business, as well as researchers studying the scientific and methodological foundations of planning and development of the production potential of oil and gas companies.**

***Keywords*—oil and gas complex, Arctic deposits, field development, risks, multi-criteria approach, Arctic shelf.**

I. INTRODUCTION

For the last decade, due to oil and gas fields, the Arctic has become the world's center of attention. First of all, this is connected with its huge resource wealth, not only hydrocarbons, but also other minerals, which have been accumulated and stored in the subsoil during all these years.

At present, in the conditions of increasing international competition for the rights to carry out activities in the Arctic zone, Russia faces an important task of maintaining and strengthening its economic and geopolitical presence in the Arctic. This issue is particularly relevant in the study of forecasts for the development of the hydrocarbon resource base.

In the picture 1, it shows the consumption of primary energy in the world by fuel type in the framework of the basis, which assumes the development of world energy and fuel markets-mainly on the basis of already mastered energy technologies. In the long term, the absolute dominance of fossil fuels will remain, and the share of oil and gas in global primary energy consumption will remain virtually unchanged (53.6% in 2010 and 51.4% by 2040) [1].

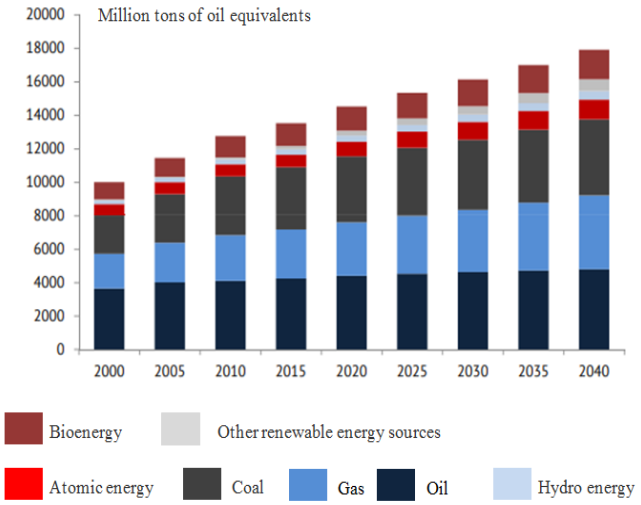


Fig. 1. World primary energy consumption by fuel type, base case

Viral The analysis of officially published analytical materials allows us to identify the following threats to the balanced and progressive development of the oil and gas complex [2-3]:

- annual production in most oil and gas producing regions is not offset by reserves gains;
- production of hydrocarbons is decreasing in traditional production centers of Western Siberia;
- there are almost no hydrocarbon reserves on the land that could provide an increase in reserves;
- the number of new developed fields has decreased;
- the number of hard-to-recover hydrocarbon reserves and the others are increasing

The above-mentioned threats, the growth of competition and increased risks in the market of fuel and energy resources, determine the priority of the search for new guidelines aimed at the development of the oil and gas complex of Russia. One of such landmarks is the development of offshore oil and gas fields of the Arctic shelf. Currently, Arctic and marine projects are of national importance, and their development will make a significant contribution to the replenishment of the resource base, as well

as the development of the Russian economy. According to the forecasts of the Ministry of energy, it is expected to increase offshore oil production to 26 million. tons (17% compared to 2016). By 2035, Russia is expected to produce about 80 million tons on the shelf [4].

It should be noted that, despite the fact that a certain model and management structure have already been formed in the oil and gas industry, new projects require improvement of the methodological basis for planning and selection of priority projects, the implementation of which will increase the efficiency of using the production potential of the Arctic shelf fields and directly of oil companies engaged in their development.

II. Literature review

Currently, there is an increased interest on the part of both representatives of academic science and representatives of oil and gas companies, the business environment, government officials and scientists to address issues of strategic management of the oil and gas complex, and in particular the development of the Arctic shelf. General issues of strategic management of the oil and gas complex are disclosed in the works of such authors as Fadeev A.M., Mikhalenko V. K., Rybakov A. G., Shelepov G. I., Nikov A.V., Mochalov R. M., Malikov U. M., Kamenskov V. D., Ilyinsky A. A., Eremeev O. Zh., Frakhtin O. D., Borodin K.A., Bogoyavlensky V. I., Belozertseva O. V., Bakhtina O. S., etc. Practical aspects are presented in a number of industry magazines, for example, such as “Siberian oil”, “Oil and gas vertical”, “Oil and gas” and others.

III. Research methodology

The program-targeted management of the development of the Arctic shelf metro fields involves the selection of priority programs and projects that will primarily ensure the achievement of medium-term and long-term goals of oil companies. The selection of priority programs and projects is advisable to be carried out on the basis of a system of evaluation criteria, which allows evaluating in a complex the various aspects of field development. Moreover, the assessment system may include more than a dozen criteria, which allows us to talk about the need to reduce the selection procedure to a multicriteria problem and to search for the most optimal methods for solving it.

According to the authors, the most important task at the initial stage of the formation of the program and target plan for the development of Arctic shelf deposits is the selection of those deposits that, on the one hand, are in the zone of acceptable risk, and on the other are attractive from a technical and economic point of view.

Considering the risk component at the initial stage of the assessment and selection process, it should be noted that the development of Arctic shelf deposits is accompanied by a high level of uncertainty and risk due to insufficient exploration of the region, lack of experience in the development of Arctic deposits, a large amount of information, including probabilistic in nature, and with severe climatic and geographical conditions. To include programs and projects for the development of these fields in the general program and target plan, it is necessary to identify the main risk groups, assess their impact on the economic activity of the enterprise and the oil and gas industry, and also develop measures to minimize such risks [5-6]. Table I presents the main risk groups and possible measures to reduce the threat (this list is open and can be supplemented).

It should be noted that each type of risk can be assessed by some minimal set of indicators (quantitative or qualitative) in order to further compare various alternative options and projects. Fragmentally estimated criteria for the identified types of risks are presented in table 1. The evaluation criteria for the block of environmental risks can be expanded based on the adaptation of the material described in the work that reveals environmental and economic problems in the oil industry of the northern territories [6].

TABLE I. Main risks arising in the development of Arctic shelf deposits

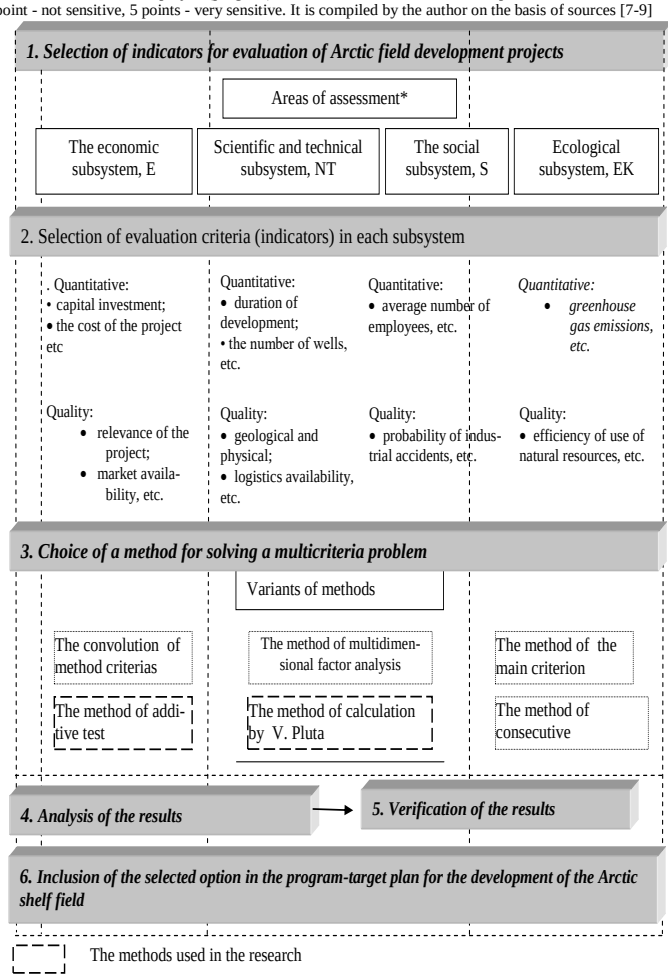
Type of risk	Causes of occurrence	Evaluation Criterion	Ways to minimize risks
Economic	- high capital intensity of projects; - the need to attract investment; - duration of the project, etc.	- capital intensity of the project (program), million rubles; - the duration of the project (program), years; - * the sensitivity of the project (program) to changes in the starting conditions laid down during the economic evaluation of the project (program) (for example, the price of oil on the world market, etc.), score - and others	- improvement of tax legislation (differentiation of taxes at different stages of project implementation); - regulation of export and import issues (e.g. technologies); - regulation of relations between investors and the state (for example, also in the field of tax legislation, reducing the tax burden, etc.).
Geological	- insufficient knowledge of the Arctic shelf; - the Cenomanian tier (the place where the main oil-bearing layer lies) has a complex tectonics; -feature of geological structure of oil deposits, etc.	- the probability of confirmation of stocks, dolly; - the resource intensity of the study and development of the shelf per company, million rubles per 1 company; - the probability of obtaining positive results from ongoing research work within 3 years; - and others	- state financing of expeditions, research works on the shelf; - allocation of costs for exploration and development of the shelf between companies; - redistribution of costs between different activities, etc.
Transport-technological	- lack of technology; - failure of equipment due to the influence of harsh climatic conditions; - logistic lack of knowledge and lack of transport routes for transportation and performance of works; - difficult ice conditions; - lack of specialized icebreakers and other types of transport;	- availability of technology for development of the field; - the probability of equipment failure in harsh climatic conditions; - the degree of development of transport logistics; - degree of infrastructure development - and others. In this and subsequent blocks, risks are mainly assessed by quality indicators, based on the expert assessment method on a 5-point scale.	- innovation, implementation and development of innovative technologies; - equipment insurance; -co-financing of construction of vehicles; - creation and distribution of activities in different economic zones, etc.

	- isolation and remoteness of deposits, etc.		
Ecological	- difficult ice conditions and permafrost; - vulnerable ecosystem incapable of self-healing; - the remoteness of the coastline, the inability to eliminate accidents, etc.	- the likelihood of damage to the environmental situation; - the possibility of implementing measures to restore the ecological background of the territory; - and etc.	- creation of insurance system; - introduction of innovations (waste-free production, etc.); - funding research to identify areas for activities; - state support for the establishment of monitoring centers and safe production in the Arctic, etc.
Geopolitical	- the interest of other countries to own the Arctic space; - sanctions on technology or specialized equipment.	- the need to use domestic equipment; - the need to use foreign equipment; - interest of other countries in the developed territory; - and etc.	is the establishment of relations between neighbouring States, and States having in possession of the Arctic zone, etc.
Personnel	- the lack of qualified human resources; - lack of specialized scientific centers and educational institutions, etc.	- the degree of provision of qualified labor resources; - the need for staff training; - the availability of educational programs to obtain the required competencies; - and etc.	- personnel training, specialized courses; - to resort to the help of experts, the creation of a scientific research group; - creation of personnel reserve; - opening of classrooms, universities, research centers of special orientation, etc.

* - the sensitivity of the project to changing the starting conditions laid down in the calculation of the economic assessment of the project (program) is carried out on the basis of the expert assessment method on a 5-point scale: 1 point - not sensitive, 5 points - very sensitive. It is compiled by the author on the basis of sources [7-9]

A comprehensive assessment of the effectiveness of the development of Arctic shelf deposits includes not only an assessment of the risk component, but also an assessment of various aspects of the development of Arctic shelf deposits: technical, technological, economic, environmental, innovative, social aspects, etc. This approach involves the possibility of evaluating a variety of alternatives, creation of program-target planning and activities at the oil company, which fit into industry-wide program-oriented plan for development of the Arctic deposits. Taking into account all the features of the oil and gas industry, and in particular, the Arctic deposits, the multi-criteria approach allows the choice of numerous criteria, which is an undoubted advantage of this approach, as well as the possibility of qualitative assessment and analysis. Figure 2 presents a diagram of the stages of applying a multi-criteria approach to the development of hydrocarbon fields in the Arctic. This scheme fits quite well with the model of strategic management of oil companies and managerial decision-making, which allows taking into account the industry specifics of oil companies. This model is described in detail in [9].

Quantitative methods for solving multicriteria problems are based on the introduction of a single complex criterion of optimality (value function), which allows to uniquely evaluate the compared options. The problem of multi-criteria optimization is reduced to a single-purpose one [10-11]. The most commonly used linear value function (additive criterion), which is calculated as follows [12]:



* Areas of evaluation can be expanded depending on the objectives of the evaluation

Fig. 2. Stages of application of multi-criteria approach in the development of hydrocarbon fields in the Arctic

$$V = \sum_{i=1}^{N} w_i k_i \tag{1}$$

where i - is the index of the optimality criterion; w_i - weight (importance) of the i -th criterion. Usually relative weights are used, i.e. $\sum_{i=1}^{N} w_i = 1$; k_i – the value of the i-th criterion, if ki are integers, then the method is a point.

The fields of the Western Arctic shelf, namely the waters of the Pechersk and Kara seas, were chosen as objects of research, as they are the most promising and investment-attractive.

The approximation calculations presented in this paper are based on the use of the integral analysis method and the additive method.

The method of multivariate analysis described in the work of V. Dodges involves performing calculations in three stages:

- A preparatory block includes a grouping of parameters of the technical and economic potential (x_n).
- Calculation block-calculation of the integral index.
- Analytical block - determination of cause-and-effect relationships.

The calculation begins with the formation of observation matrices whose dimension is m (number of deposits) = n (number of describing criteria). The elements of the matrix will be the values of the input criteria x_n, which are inhomogeneous, which causes the fact that the use of ordinary arithmetic addition is impossible. Therefore it is necessary to make preliminary transformations of indicators (standardization on Z_{ix}), for the subsequent Association them in one integral indicator according to V. Pluta's technique.

In the context of the large amount of information that companies' reports contain, it is difficult to find the most significant relationships. The method of multicriteria optimization allows to allocate the most generalizing (aggregate) factors, and also dominating tendencies from set of the versatile characteristics describing objects of research. A significant advantage of this method is the ability to compare heterogeneous indicators by combining them into such quantities that satisfy and combine all the characteristics.

IV. Results

The use of methods of multicriteria optimization, namely multivariate V. Pluta's analysis and the method of additive criterion, allowed to obtain the following results. Table III presents the results of calculations obtained using the method by V. Pluta.

TABLE II. Rating of the level of development of deposits in the Arctic

The name of the field	Convention	Indicator of the result	Position in the aggregate rating
Field 7 (CF)	A7	0.91	1
Field 6 (OF)	A6	0.87	2
Field 4 (OF)	A4	0.79	3
Field 8 (CF)	A8	0.79	4
Field 3 (OF)	A3	0.59	5
Field 5 (OF)	A5	0.57	6
Field 9 (GF)	A9	0.50	7
Field 1 (CF)	A1	0.46	8
Field 10 (GF)	A10	0.44	9
Field 2 (GF)	A2	0.43	10

CF - condensate field; GF - gas field; OF - oil field

Thus, in this paper we propose a multi-criteria assessment of the development of deposits on the Arctic shelf, which allows to obtain an integral assessment by aggregating a set of measured characteristics into one parameter, the result of which is the ranking of deposits with the determination of their leading or lagging positions.

To compare and to refine the results obtained by the integral analysis method, it was decided to apply another common method for solving multicriteria problems – the additive method. The results are presented in table III.

TABLE III. Rating of the level of development of deposits in the Arctic

The name of the field	Convention	Calculated values of indicators			Position in the aggregate rating
		Technical potential	*Economic potential*	*The result*	
Field 7 (CF)	A7	-18.88	8395.55	8376.67	1
Field 6 (OF)	A6	-5.35	8376.41	8371.05	2
Field 8 (CF)	A8	-19.23	7602.89	7583.66	3
Field 4 (OF)	A4	-0.39	6872.79	6872.40	4
Field 3 (OF)	A3	-3.07	5567.10	5564.03	5
Field 5 (OF)	A5	-1.54	4482.60	4481.06	6
Field 9 (GF)	A9	-0.47	3631.98	3631.51	7
Field 1 (CF)	A1	-0.79	3228.67	3227.88	8
Field 10 (GF)	A10	-0.52	3138.09	3137.58	9
Field 2 (GF)	A2	-3.36	2226.41	223.05	10

CF - condensate field; GF - gas field; OF - oil field

Thus, these methods, and the calculations made on the basis of them, allow to make strategic management decisions about the beginning of development of offshore oil and gas fields of the Arctic and the sequence of their commissioning, while taking into account the integral indicator that combines the technical, financial, climatic, social and other types of characteristics of the fields.

V. Practical significance

In practice, the method of multi-criteria optimization can be presented in determining the sequence of development of Arctic shelf deposits. The optimization mechanism inherent in the methods for solving multi-criteria problems will allow for a gradual increase in the production potential of oil companies engaged in the development of Arctic deposits. Calculations by this technique, will identify the most appropriate sequence of field development, to conduct a comprehensive analysis of the research objects, which together contribute to choice-making on the beginning of the development of offshore oil and gas fields. It is important to note that this approach involves the inclusion of both qualitative and quantitative indicators in the multi-criteria model, which makes it possible to comprehensively substantiate managerial decisions regarding the sequence of commissioning of Arctic shelf deposits.

VI. Discussion

Active discussion of various aspects of the development of Arctic shelf deposits can be traced in the publication activity in this direction. At the same time, the activity of scientific and practical conferences on this topic is observed in almost all Universities of Russia. The search for the optimal implementation of projects for the development of Arctic shelf deposits is quite a difficult task, including the formation of multi-level program and target plans to achieve strategic goals, both at the state level and at the level of individual oil and gas producing structures. The use of multi-criteria optimization methods is associated with a number of difficulties in the formation of the evaluation system of criteria (indicators), determining the degree of its detail, the included activities and a number of other issues. The question noted in Osinovskaya I. V. and Lenkova O. V. concerning the determination of weight coefficients of the criteria included in the evaluation system remains unresolved [12].

In multi-criteria optimization problems, the case when an optimal solution is achieved for all criteria at once is unlikely. It is typical for such problems that alternatives or admissible solutions with the best values of one group of criteria, as a rule, lead to deterioration of the values of the criteria of the other group [4].

VII. Conclusion

Summing up, we can say that this sequence of actions allowed us to identify the most promising regions of the Western Arctic shelf in terms of estimated hydrocarbon reserves and resources. The proposed approach will optimize the tasks of modernizing traditional industries, increasing the efficiency of managerial decisions, which together will contribute to addressing the strategic development of the oil and gas complex. In the future, it is possible to assess the overall impact of the oil and gas complex on the sustainable development of the regions of our country in the development of hydrocarbon fields in the Arctic, which will allow to identify different spheres of influence.

In the current conditions, in order to ensure reliable and efficient development of Arctic shelf deposits, it is necessary to choose the right approach to management. In this case, we mean a set of targeted impacts, both on the oil and gas industry and other industries in Russia, aimed at the creation and development of high-tech production and strategic development of Russian industry. To ensure this, it is advisable to talk about the use of a program-target approach at the planning stage of achieving goals both at the level of the oil and gas industry as a whole and at the level of individual oil companies.

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