Impact of global and regional factors on dynamics of industrial development of hydrocarbons in the Arctic continental shelf and on investment attractiveness of energy projects

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Abstract. The article considers problems and trends in industrial development of hydrocarbons in the continental shelf of the Russian Arctic Zone. We have provided a general description for the dynamics of industrial development of hydrocarbons in the Arctic continental shelf, including the Prirazlomnoye oil field. We have established that the pace of industrial development of the continental shelf depends on two interrelated trends, i.e., the drive for intensified industrial development of hydrocarbons and the current level of socio-economic development of Russia and the Arctic territories. We have systematized the factors that heavily affect the dynamics of development of the Arctic continental shelf and reduce the attractiveness of investment projects in industrial development of hydrocarbons on the shelf. We have confirmed that socio-economic efficiency of shelf deposit development in the Arctic should to be assessed comprehensively, which is impossible without organizing systematic integrated assessment of resources, the state of the environment, the projected technical and economic indicators and environmental consequences of development of shelf deposits. Furthermore, economic assessment has to be carried out for positive and negative externalities arising from industrial development of hydrocarbons in the continental shelf, affecting the socio-economic status of the population of the Arctic regions, health and quality of life.

1. Introduction

Two interconnected trends can be traced in rapid industrial development of the Russian Arctic. On the one hand, the Russian Arctic is a breeding ground for intensified industrial development of the country, including, in particular, exploration and extraction of hydrocarbons and other mineral resources in the waters of the continental shelf. On the other hand, industrial development of the Arctic Zone depends on the pace of social and economic development of the Arctic territories. In turn, development of coastal areas is the key factor affecting the pollution of sea waters and bottom sediments, which means that stringent and costly measures should be introduced in the region to ensure its environmental safety; this, naturally, slows down industrial development in the Arctic and in the continental shelf.

Thus, there is both a direct technological relationship between the rates of development of coastal areas and the continental shelf, and an inverse one, determining the relationship between the rates of economic development of coastal areas and the pollution of the Arctic waters. All factors have to be
taken into account in development of the Arctic, which was discussed in a number of publications [1, 2]. Development of the continental shelf of the Russian Arctic is a unique experience that can lay the foundations for long-term international cooperation [3, 4], improving integration mechanisms for interaction of companies [5], and ultimately contributing to the country’s increased competitiveness [6].

Meanwhile, plans for economic development are not coordinated with measures for ensuring environmental safety, further aggravating the environmental status in the territories where industrial development is particularly aggressive. Growing expenses on environmental protection in recent years do little to combat the problem, particularly, for marginal seas, where the environmental situation remains tense. Therefore, the same as problems of industrial development of territories cannot be solved without taking into account environmental protection measures, environmental protection measures cannot be addressed separately from the economic strategy for development of the Arctic Zone [7, 8].

2. General characteristics of dynamics of industrial development of hydrocarbons in the Arctic continental shelf

According to the BP Statistical Review of World Energy [9], the total production of the top ten oil-producing countries amounted to about 3 billion tons of oil in 2017. Russia’s share amounted to 12.6% of total global production (4.39 billion tons), while the share of Saudi Arabia, the world's leader in oil production, was 12.8% (561.7 million tons). Russia’s proven oil reserves were estimated at 14.5 billion tons in early 2018. It can be seen from Table 1 that production of oil and gas in Russia is steadily increasing, which is why forming hydrocarbon reserves is drastically important for long-term development of the country.

Table 1. Oil and gas production in the Russian Federation, 2010–2017

| Indicator                                      | 2010  | 2011  | 2012  | 2013  | 2014  | 2015  | 2016  | 2017  |
|------------------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| Oil produced, including gas condensate, million tons | 505.6 | 512.4 | 518.7 | 521.7 | 526.1 | 534.7 | 547.8 | 546.4 |
| Growth rate compared to 2010                   | 1     | 1.01  | 1.03  | 1.03  | 1.04  | 1.06  | 1.08  | 1.08  |
| Natural and associated gas, billion cubic meters | 651.3 | 670.8 | 654.7 | 667.6 | 642.2 | 633.6 | 640.8 | 691.5 |
| Growth rate compared to 2010                   | 1     | 1.03  | 1.01  | 1.02  | 0.99  | 0.97  | 0.98  | 1.06  |

According to the US Geological Survey, about 90 billion barrels of oil (13% of all unexplored reserves) are located in the Arctic. The total hydrocarbon reserves in the Arctic are estimated at 400 billion barrels, with 88% of these reserves belonging to three countries: Russia, the United States and Denmark. Russia has the largest hydrocarbon resources (about 25% of global reserves).

Substantial resources are found within offshore oil and gas provinces, distributed rather unevenly. The largest shares of 49% and 35%, respectively, are located in the Barents and Kara seas, 15% in the Sea of Okhotsk, and only about 1% in the Baltic and Caspian seas [10]. Currently, Russia extracts oil and gas in the shelf of the Baltic, Caspian, Okhotsk and Barents Seas. The continental shelf of the Barents Sea, particularly, its south-eastern part, the Pechora Sea, is the most well-studied and developed.

Russia lags far behind other countries such as Norway, Sweden, Greenland and the USA (Alaska) that have been extracting hydrocarbons on the shelves on a regular basis since the 1980s. Meanwhile, regular extraction of offshore oil has only begun in Russia since 2004 [11]. Before 2000, seismic surveys and exploratory drilling revealed 16 fields in the seas of the Western Arctic, the
Shtokmanskoje (1988), Rusanovskoye (1989) and Leningradskoye (1990) gas condensate fields among them. The total gas reserves are about 10 trillion cubic meters.

Even though most of the offshore fields were discovered more than 20 years ago, development is constantly postponed. In fact, the only active project in oil production in the Arctic is the Prirazlomnoye oil field, where an offshore ice-resistant platform was built. The oil reserves of the Prirazlomnoye field are estimated at 54.83 million tons (33.67 million tons proved and 21.16 million tons potential). The field’s development began in December 2013. Production volumes amounted to about 300,000 tons of oil in 2014, more than 750,000 tons in 2015, and 2.2 million tons by 2016. Production volumes exceeded 2.64 million tons in 2017 and 3.58 million tons in 2018. The optimal plan is to reach a production level of 5.5 million tons by 2022.

Analysis in [12] revealed rather low level of economic potential for the Prirazlomnoye field, giving it an aggregate sixth position in the rating of oil and gas fields in the Arctic; nevertheless, the Prirazlomnoye oil field remains the only one on the Western Arctic shelf.

New deposits are clearly not explored on a sufficient scale. Importantly, the number of exploration wells drilled annually, for example, in Norway exceeds this figure for Russia by about 20–30 times on average [11].

3. Factors affecting the dynamics of industrial development of hydrocarbons in the continental shelf

Certain interrelated factors hinder active industrial development of hydrocarbon resources in the Arctic continental shelf. Some of these factors can be mitigated or compensated by appropriate measures in planning integrated industrial development of hydrocarbons in the continental shelf. Other factors are objective, and cannot be changed; in this case, the task is to find the best solution for the current conditions.

The following factors play the greatest role in the dynamics of developing the Arctic continental shelf:

- cyclical price fluctuations in the global and domestic energy markets, accompanied by fluctuations in the prices for hydrocarbons;
- inhomogeneous chemical compositions, entailing additional processing costs due to high concentration of impurities, in particular, sulfur;
- imperfect technologies for ensuring high profitability of deposit development while complying with environmental safety standards;
- severe natural and climatic conditions of the Arctic;
- lack of production and social infrastructure onshore;
- insufficient geological data on the Arctic shelf, lack of comprehensive data on the resource potential;
- lack of domestic experience in development of offshore fields in high Arctic latitudes;
- impact of sanctions on the technological solutions available;
- more profitable projects available on land;
- potential large drop (shortfall) of oil and gas budget revenues in the event of large-scale development of the shelf with tax benefits granted.

Fluctuation of oil prices is one of the most prominent global factors integrally promoting or hindering intensified development of oil fields, particularly in the Arctic. Dynamics of oil prices is one of the most difficult problems; economists consider different factors ultimately shaping the prices for oil on world markets. The policies pursued by oil-exporting countries are particularly noteworthy issues, taking into account the dynamics of consumer demand and negative indicators of this dynamics during periods of economic recession.

For instance, Arctic Oil (ARCO) is extracted at the Prirazlomnoye field. This crude appeared on the world market in early 2014. ARCO has a relatively high density (906 kg/m³), high sulfur content (2.3%) and low paraffin content. ARCO trades at a discount to the price for Urals (density of 860–871 kg/m³; sulfur content of no more than 1.8%) about $3–5 per barrel.
Urals, in turn, trades at a discount to Brent oil (density of 825–828 kg/m³; sulfur content of 0.2–1%), since Russian oil is considered to be of lower quality due to its high content of sulfur as well as of heavy and cyclic hydrocarbons. Sulfur compounds cause serious damage to the environment, in particular, disrupting catalytic converters installed in modern cars to neutralize exhaust gas. Increasingly stringent international requirements are introduced for sulfur content in fuels.

Severe natural and climatic conditions of the Arctic region where development of the continental shelf takes place are another significant factor. The main problem with assessing risks related to shelf development is that hydrocarbon reserves are concentrated in the depths of the Arctic seas with extreme ice conditions and severe climatic conditions [13]. For example, the ice cover on the Pechora Sea lasts from October to late June, and the nights are long from November to January. The maximum water temperature in August is 12 degrees. The average salinity is 35 ppt. Ice starts to form in the Pechora Sea by late November, continuing to grow until April. The average daily tidal range is within 1.1 meters. Other negative factors include floating icebergs, strong wind and seismic activity. All of the above are objective reasons for low rates of industrial development of hydrocarbons in the continental shelf. Notably, all of the above-mentioned factors affect the costs of field development, posing the problem of comprehensively assessing the socio-economic efficiency of shelf deposit development in the Arctic.

4. Economic factors and risks of hydrocarbon development in the continental shelf

Management of marine resources is characterized by high capital intensity (drilling on the shelf is on average 3-5 times more expensive than on land) and, consequently, long payback periods. For this reason, investment projects can only be implemented with complete economic justification, risk analysis and, ultimately, formulating long-term strategies and regional development programs. At the same time, considering the significant impact on the region's environment, and, consequently, on all aspects of life of the population in the Arctic territories, justification for the efficiency of shelf resource development cannot be based on economic criteria alone. Comprehensive analysis should be carried out for the current and forecasted environmental and social situations at the regional level during industrial development of specific zones of the shelf and adjacent land areas [14].

This means that economic and environmental justifications and calculations of social efficiency should be completed as early as at the pre-project stage; additionally, economic and environmental inventories of natural resources should be developed.

Analysis of investment costs for developing offshore Arctic gas fields in [15] established that substantially larger investments are required for implementing these types of projects, compared to development of fields in less severe climatic (ice) conditions. Indicators of net present value (NPV) and internal rate of return (IRR) for such projects are typically lower. Notably, emerging new technologies could improve the indicators of investment efficiency [16] and the risks of projects for development of shelf deposits in the Arctic. However, the ranking of projects by efficiency of field development is likely to remain unchanged.

Aside from high capital intensity, investment projects for development of offshore fields have a considerable R&D intensity. Implementing major energy projects in the Arctic involves not only advanced technologies but also significant scientific developments, as well as adapting existing technologies and equipment to work in specific difficult conditions (ships, drilling platforms, systems for sub-sea/sub-ice drilling, various types of geophysical and navigation equipment) [17]. The technical solutions used for development of the Arctic offshore fields can be so complex they are sometimes compared to space technologies or nano-industry.

The investment attractiveness of projects for development of offshore fields is considerably decreased because the shelf is poorly explored, reducing the reliability of assessment of hydrocarbon reserves and development costs. Geological exploration surveys by government and private organizations need to be carried out on a wider scale compared to the present situation.
The environmental component has to be taken into account and environmental standards are to be observed, which further lowers the commercial attractiveness of investment projects for development of hydrocarbons in the Arctic continental shelf.

At the same time, innovative technologies and substantial investments in research and development are needed to comply with environmental standards. For example, there are presently no technologies for disposal of numerous nuclear waste dumps at the bottom of the northern seas, nor technologies for oil spill response in Arctic conditions. The negative impact of oil spills on the Arctic’s vulnerable ecosystem is profound, while the lack of experience in response to such situations increases the environmental risks. Meanwhile, as positive experience accumulated by a number of countries indicates, environmental risks are assessed together with technical and economic considerations in decision-making [18]: risks and uncertainties penetrate all aspects of oil exploration, and environmental risks are not unique in this sense. A case in point is the experience of the United States in formulating approaches to development of hydrocarbon resources on the coast of Alaska [19].

State support in development of offshore fields could consist in granting a number of benefits, including tax benefits, to companies participating in such projects. However, the budget revenues from oil and gas are likely to considerably drop in the event of large-scale development of the continental shelf, and it is the mineral extraction tax that plays a major role in the total federal budget revenues from general taxes. State participation could be also directed towards study of the shelf and towards restricting potential development of the most controversial areas. This should greatly reduce the environmental and associated risks to the reputation of extracting companies.

Thus, investment attractiveness of development of the shelf’s natural resources (taking into account strategic interests) cannot be ensured without organizing systematic integrated assessment for resources, state of the environment, projected technical and economic indicators and environmental consequences of development as part of regional economic inventories of natural resources (including mineral inventories, non-economic and summary inventories of specific zones of the shelf). The entire system of inventories containing economic data should act as the most important tool for environmental and economic justification of measures for assessing the efficiency of resource development, the efficiency of geological exploration and environmental protection measures. The main factors lowering the attractiveness of investment projects for industrial development of hydrocarbons in the continental shelf are given in Table 2.

Table 2. Key factors of investment attractiveness of energy projects in the Arctic

|                                | Direction of effect                              | Managerial decisions                                      |
|--------------------------------|--------------------------------------------------|----------------------------------------------------------|
| **Increasing risks**           |                                                  |                                                          |
| Cyclical fluctuations of economic activity (crises), accompanied by sharp fluctuations in prices for hydrocarbons | Selecting period when conditions favor implementation of projects |
| Scarce geological data for Arctic shelf, incomplete data on resource potential of shelf | Increased geological exploration by government and private companies |
| Sectoral sanctions affecting available technological solutions | Import substitution; stepped-up research and development |
| Insufficient experience in development of offshore fields in northern latitudes | Study of foreign experience, detailed risk analysis of offshore field development, accumulation of own experience |
| **Increasing investments**     |                                                  |                                                          |
| Harsher climatic conditions compared to other Russian waters | Accepting risks associated with adverse environmental conditions; choosing technologies allowing to act in current circumstances |
| Lack of coastal transport and logistics infrastructure | Constructing road and transport networks, seaports, LNG terminals and so on; constructing warehouses, |

5
Poorly developed legal framework
Improving legal framework

Imperfect technologies for ensuring high profitability of deposit development complying with environmental safety standards;

Developing measures for oil spill response in Arctic conditions; establishing rapid oil spill response services; developing technologies for oil spill mitigation in Arctic conditions; using of foreign technologies and equipment

Notably, implementation of large-scale projects in extraction and processing of raw materials cannot be assessed by solely economic criteria or even a combination of environmental and economic criteria or based on estimates for commercial or budgetary efficiency. Implementation of large-scale projects generates large-scale externalities, both positive and negative, which have a significant impact on socio-economic development of the region, and, in case of the Arctic, on socio-economic development of the country. For this reason, externalities arising from intensified industrial development of hydrocarbons in the continental shelf should be identified, estimated and taken into account in assessing field development projects in terms of social efficiency.

Potential externalities for the region are given in Table 3. Achieving a positive socio-economic effect for regional industries in a strategic perspective and reconciling conflicting interests are the main goals for the state and for the regional authorities.

| Positive externalities                                                                 | Negative externalities                                                                 |
|---------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|
| Stepped-up research and development, effective technologies emerging in related sectors | Aggravated environmental situation, growing pollution of environment                    |
| Growing regional industry, related sectors, services                                  | Potential dependence on reserves, negative consequences for economy if extraction volumes drop |
| Better developed coastal transport and logistics infrastructures                       | Possible environmental and man-made disasters                                           |
| Logistics                                                                             |                                                                                        |
| Growing tax base, improved living standards for population                            | Potentially reduced budget revenues from mineral extraction tax                        |
| Increased profitability of business in basic and service sectors                      | Risk of extensive development of regional economy, orientation to raw materials and single-product industry (extraction and export of raw materials) |
| Increased population incomes                                                          | Population stratification by income                                                    |
| Developed social infrastructure of territories                                        | Negative consequences for indigenous peoples (i.e., disruption to traditional lifestyles) |

5. Conclusions and discussion

There are currently several negative trends concerning the extended industrial development of hydrocarbons in the Russian Arctic shelf; these are sanctions, large-scale development of unconventional hydrocarbon resources, development of alternative energy, increased production costs, deteriorating structure and quality of reserves.

Russia’s reserves of raw materials should be developed to ensure the country’s further economic growth. This includes, in particular, geological exploration on a larger scale, increased production volumes at the developed fields due to innovative technologies for enhanced oil recovery, and commissioning of deposits in the Arctic waters.
Based on the data currently obtained through geological surveys, offshore oil and gas fields can be regarded as strategic potential and long-term reserve of hydrocarbons. Development of shelf deposits has high capital intensity, relatively low rates of return and high payback periods, strongly depending on the prices in the world energy market.

Innovative technologies should make commercial production of hydrocarbons in the Arctic shelf possible over time. However, state participation encompassing issues of legal regulation, geological exploration on the shelf, ensuring environmental safety and reducing environmental risks, is necessary to generate the economic and institutional conditions for intensified industrial development of hydrocarbons. Economic incentives stimulating investments in the development of shelf resources should be created, as well as consolidated responsibility for investment risks between the state and the extracting companies.

As a final consideration, we strongly believe that delayed development of deposits in the Arctic shelf is not a negative factor for Russia. The country owns the world’s largest hydrocarbon reserves. From an economic standpoint, resources should be best directed to deposits with lower costs for development, allowing to save non-renewable resources. At the same time, new technologies emerging against the backdrop of field depletion and changes in world prices for hydrocarbons can eventually make development of Arctic deposits more economically attractive.

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