Sustainable development of resource regions on the declining stage of production: innovative technologies and economic efficiency

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Abstract. The article analyzes the problems of sustainable development of Russia's resource regions, where the extraction of natural resources is at a declining stage. The economic indicators of the development projects with application of advanced extraction technologies to increase production efficiency were estimated. It was revealed that high costs of installation and application of advanced technologies do not allow for the full application, especially under the conditions of highly volatile oil prices and limitations on usage of foreign technologies. Measures to optimize the structure of costs and increase the overall efficiency of implementation of innovations in resource regions were proposed.

1. Introduction

The drastic drop in oil prices has affected different sectors of the petroleum industry in Russia but mainly the upstream sector [1]. In this scenario, investments in new or ongoing petroleum projects faces different challenges due to high development cost for some areas and limited budget structure of companies. As a response, each project has to be adjusted taking into consideration the market expectation of low oil price outlook to avoid being postponed or canceled [2].

The research aim is efficiency evaluation of application of oil production technologies for oilfield during declining stage of production. To achieve this goal, the following tasks were accomplished: (1) to analyze current condition of the oil industry in Russia and define main problems of developed regions, (2) to develop scenarios of technology implementation to increase future oil production of the oilfield in the Western Siberia, (3) carry out calculation and analyze the results for evaluation of efficiency for the chosen scenarios.

Nowadays, advanced production technologies are considered a vital part of the oil industry in Russia [3]. Under sanctions, Russia is facing a complicated situation since it is necessary to develop import substitution in the oil sector and create a Russian technological base for a new project in term of development of new and traditional fields (Bobylev, 2016) [4]. Such techniques as horizontal drilling and hydraulic fracturing have played an important role in enhancement of reservoir...
productivity in fields which have reached a peak in production, as well as in development of unconventional resources (Akangbou et al. 2016) [5].

Some issues during the oil production are results of water invasion into the reservoir. For most significant deposits, the average of water cut of developed deposits may be more than 80% (Bailey et al. 2000) [6]. Considering that water flooding is a technique for maintain reservoir pressure and obtain additional oil recovery (Hourfar et al. 2017), it may present a progressive increase in the ratio of produced water to the oil extraction in oilfields in Russia [7].

Most of the companies in the oil and gas sector use two methods associated with the investment valuation; (a) allocation of capital in a systematic manner and (b) implementation of specific methods of investment analysis. Therefore, the investment process in the development of oil projects must consider essential aspects such as; valuation, strategic thinking and risk exposure (Lima & Suslick 2005; Lyons et al. 2016) [8]. Evaluation's indicators are usually calculating according to particular formulas and equations, classified into two categories: the first category considers the value of money over time such as Net Present Value (NPV), Internal Rate of Return (IRR), Discounted Payback and Profitability Index. The second category covers non-discounted methods such as Break-even Analysis, Cost/Benefit Ratio, Exposure Point, and Sensitivity Analysis (Hisham, 2010) [9].

2. Methods of research
The evaluation of economic efficiency of project development was carried out via complex model of geological and economic evaluation. The model includes evaluation of production profile, based on physical properties of rocks and liquids; assessment of main items of cash flow such as revenues, capital and operational expenditures, taxes based on analysis of current and forecasted market situation; calculation of resulting indicators such as cash flow, profits, NPV, IRR [10].

The estimation of the annual production allows creating the production profile of an oilfield which has a pi-shaped pattern and consists of three stages (build up, plateau, and decline). Moreover, the graphical representation of the oil production profile shows can be estimated through a function (formula 1).

$$Q_t = \begin{cases} 
  r \cdot t + s, & t_1 < t < t_2 \\
  u, & t_2 > t < t_3 \\
  -w \cdot t + x, & t_3 < t < t_4 
\end{cases}$$  

(1)

Where, $Q_t$ – annual oil production; $r, s, u, w, x$ – constants; $t_i$ – start and end of oil production for each stage ($i = 1, 2, 3, 4 \ldots n$).

According to the line of the research, forecasted production for basic strategy was varied according to the probable implications of technologies.

3. Results and discussion
During the first stage of research, extensive analysis of Russian oil and gas industry was carried out to define main problems connected with technological development of extraction industries of resource regions.

The traditional macroregions of the Russian oil industry are Western Siberia and European part of Russia. Western Siberia remains the leader in oil production with a production level of 57.3% of the total Russian output [11]. However, the share of the region tend to decrease during the past decade. Share of European part has remained stable for the recent years and had the level of is 29.9% in 2017. Regions with the most dynamically developing oil production are East Siberia and the Far East. The share of these regions was less than 3% in the total oil production in 2008, and has risen up to 12.8% in 2017 (figure 1).

The currents problems in Russian oil industry include growing number of mature oilfields in declining stage of production; high percentage of water produced from the reservoir in mature and new fields due to the applied technologies of oil production; low development level of hard-to-access areas, mainly in Arctic Region; low production of unconventional resources.
The increase in production in traditional areas of oil production can become possible due to the active introduction of new technologies in fields with a high degree of depletion, water cut and lower quality of crudes characterized by high viscosity and sulfur content.

During the next stage, the typical development project of Koltogor oilfield in Western Siberia was chosen for evaluation of economic efficiency from point of view of implementation of advanced technologies of oil production [12].

Seven strategies, reflecting different levels of technologies implementation and consequently different extraction profiles and cumulative oil production, were justified and modeled on the basis of the characteristics of reservoir and liquids [13]. The cumulative production in the scenario based on free flow extraction is 14.6 million tons of oil, which is accounted for extraction of 42% of recoverable oil. The maximum implementation of artificial list system allows for extraction of up to 62% of recoverable reserves in the planning horizon of the project (figure 2).

Figure 1. Shares of macroregions in Oil Production of Russia in 2017, %.

Figure 2. Oil production profiles for different production strategies.
Four essential elements (capital expenditure, cost of production, product price, product schedule) of the economic evaluation were considered and developed into a cash flow model spread over 30 years. Implementation of advanced technologies in oil production (such as ALS) influences the efficiency of the project in different directions: positive influence on revenues, negative influence on CAPEX and OPEX, which results in the existence of a point of inflection, reflecting the optimal level of technology implementation under current conditions (table 1).

Table 1. Main economic indicators of implementation of production strategies, billion rubles.

| Indicator          | PS-(30%) | PS-(50%) | PS-(70%) | PS-(90%) | PS-(110%) | PS-(130%) |
|--------------------|----------|----------|----------|----------|-----------|-----------|
| Oil production     | 16.26    | 17.34    | 18.42    | 19.50    | 20.58     | 21.66     |
| (Million Tons)     |          |          |          |          |           |           |
| Revenues           | 352.2    | 375.4    | 398.8    | 422.1    | 445.5     | 468.8     |
| CAPEX              | 90.0     | 90.6     | 91.2     | 93.1     | 93.1      | 93.8      |
| OPEX               | 214.0    | 218.4    | 224.4    | 250.7    | 261.8     | 295.3     |
| NPV                | 7291.4   | 9392.3   | 11243.0  | 9958.8   | 9672.1    | 9357.6    |
| IRR, %             | 17%      | 18%      | 19%      | 18%      | 18%       | 17%       |

For the current economic and financial situation it was revealed that high costs of installation and application of advanced technologies do not allow for its full application. Shown results were calculated under positive scenario for oil prices at level of 85 dollars per barrel. However, application of the model under lower prices 45-65 dollars per barrel showed different results with negative NPV for most productive strategies.

In the current conditions with unstable oil prices and restrictions on the use of foreign technologies and equipment, optimization and cost reduction, as well as the development and use of import substitution technologies at all stages of oil and gas production, are of particular importance. At the same time, the development, testing and introduction of new processes and equipment can take a considerable time, which is the reason for the need to reduce total costs in the short-term period due to other cost categories [14]. One of these categories are tax payments, the regulation of which can be implemented quickly and selectively for individual projects and regions.

Another constraining factor is overall low level of complex development of most of the resource regions of Russia [15]. In absence of developed intraregional economy and innovative type of specialization, this can lead to decreasing production efficiency and lowering economic growth. Directions of innovative development should include processing, related and associated industries, such as chemistry, engineering, construction, services, financial sector, IT industries.

4. Conclusion
Russia faces significant challenges in issues related to increasing the oil production in the country, since a part of the currently developing oilfields are in the decline phase, and new fields can face an early depletion due to the rates and methods of oil production. This situation affects in the short and long run different regions of the country, especially traditionally developed region of Western Siberia which produces almost 58% of the total oil in Russia.

The oil production in the country is expected to decline after 2020 due to a peak in production of Brownfields and Greenfields and existing problems in developed producing regions such as declining rate of production, high water cut and deterioration of reserves in mature fields.

Implementation of advanced technologies in oil production influences the efficiency of the project in different directions: positive influence on revenues, negative influence on CAPEX and OPEX, which results in the existence of a point of inflection, reflecting the optimal level of technology implementation under current conditions. Evaluation result for Western Siberia shows that high costs of installation and application of advanced technologies do not allow for the full implementation,
especially under the conditions of highly volatile oil prices and limitations on usage of foreign technologies.

Acknowledgements
The research was supported by the grant No. 17-78-20218 of the Russian Science Foundation.

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