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# Critical analysis of methodological approaches to assessing sustainability of arctic oil and gas projects

**Alexey E. CHEREPOVITSYN, Pavel S. TSVETKOV✉, Olga O. EVSEEVA**
*Saint Petersburg State Mining University, Saint Petersburg, Russia*

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***Abstract.*** Development of hydrocarbon resources in the Arctic is one of the priority tasks for the economy of the Russian Federation; however, such projects are associated with significant risks for the environment of nearby regions. Large-scale development of hydrocarbon resources in the Arctic should be based on the principles of sustainable development, which imply a balance between socio-economic benefits and environmental risks. The purpose of this study is to analyze the gaps in scientific knowledge on the issues of assessing sustainability of Arctic oil and gas projects (OGPs) and systematize the key problematic elements of such assessments. The analysis was carried out in terms of four key elements that determine the feasibility of implementing Arctic OGPs in the context of sustainable development: economic efficiency, social effects, environmental safety and technological availability. The methodology for conducting bibliometric analysis, which included more than 15.227 sources from the Scopus database over the period of 2005-2020, was based on PRISMA recommendations for compiling systematic reviews and meta-analyses. Methodological problems of assessing sustainability of Arctic OGPs were mapped and divided into four key sectors: consideration of factors that determine sustainability; sustainability assessment; interpretation of assessment results; sustainability management. This map can serve as a basis for conducting a series of point studies, aimed at eliminating existing methodological shortcomings of the sustainable development concept with respect to Arctic OGPs.

***Key words*:** sustainable development; Arctic oil and gas projects; sustainability assessment; environmental and economic balance; Arctic region; bibliometric analysis; PRISMA

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**Introduction.** For Russia, development of the Arctic is a strategically important task for the next few decades due to the need to extend the resource potential of hydrocarbon raw materials, create and test new technological solutions in the oil and gas industry (OGI), enhance geo-political influence, etc. Inferred reserves of hydrocarbon resources account for “about 30 % of the world's undiscovered natural gas and 13 % of undiscovered oil” [1]. Presumably, most of these resources are concentrated in the north of Alaska and in the western part of the Russian Arctic zone [2]. In this regard, it can be assumed that the upcoming depletion of hydrocarbon reserves [3] does not correspond to reality. However, taking into account production rates of easily recoverable reserves, as well as the growth of world energy consumption [4], depletion of “cheap” oil reserves remains an unresolved problem [5].

Development of hydrocarbon resources in the Arctic could significantly replenish gradually decreasing reserves of old oilfield regions [6]. Here it should be noted that to ensure the profitability of Arctic oil and gas projects (OGPs), it is necessary to have stable demand for the final product accompanied by high prices [7, 8], which is explained by high capital intensity of the projects and significant investment, market, geological and environmental risks. In paper [9], it is demonstrated that specific production costs for Arctic oil can be 2-10 times higher compared to recovery from conventional sources, especially when it comes to offshore fields, which account for 84 % of the inferred resources in the Arctic [10]. Nevertheless, global technological progress has made it possible to reduce the break-even point of deep-sea offshore projects from 80-100 to 50-70 USD per barrel. Currently, in Russia there are certain problems with the availability of full-cycle domestic technologies required for offshore development. The main barriers that hinder intensification of reserve development in the Arctic include objective cost factors, as well as the effect of sectoral sanctions, due to which Russia

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does not have access to some advanced technologies of hydrocarbon recovery [11] that could have reduced the cost of developing oil and gas fields.

Almost all scientific papers [12] point out the need to consider the principles of sustainable development (SD) when implementing any production and economic activity in the territory of the Arctic regions, primarily due to the vulnerability of local ecosystems [13, 14]. This is especially true for companies engaged in the extraction of mineral resources, which in their essence are environmentally hazardous production facilities. This factor determines a complex scientific and practical task of justifying the criteria for assessing sustainability of Arctic OGPs that could be used to determine the feasibility of their implementation and, at the same time, would not become an insurmountable barrier, considering in many cases the marginal profitability of oil and gas projects in these regions.

Despite the fact that the issues of sustainable development of various-level systems (micro, mezo, macro), as well as the issues of sustainable functioning of industrial systems in the Arctic, are being actively developed in the recent years, the principles and approaches of assessing sustainability of Arctic OGPs are at their early stage of development. Hence, the research object of this study involves Arctic OGPs, while the subject of research is their "stability", as its assessment and analysis contains a number of theoretical and methodological problems. The purpose of this study is to analyze the gaps in scientific knowledge on the issues of assessing sustainability of Arctic OGPs and systematize the key problematic elements of such assessments.

**Problem statement.** The task of searching for sustainable approaches to the development of Arctic OGPs is, on the one hand, a practical issue; on the other hand, it is associated with the need to solve a number of theoretical and methodological problems.

From a practical point of view, it is important to find a balance between the commercial interests of mining companies and the key provisions of sustainable development, which is extremely important in the context of implementing offshore Arctic OGPs. Significant capital intensity of such projects leads to low profitability, and in some cases it is incomparable with alternative investment options, for example, with the implementation of onshore oil and gas projects in the developed regions [15]. In its own turn, marginal profitability or its absence is associated with the state of the global energy market, natural climatic conditions and geographical locations of oil and gas fields or prospecting sites. The main problem is the formulation of practice-oriented approaches to sustainable development of Arctic OGPs, which can ensure their viability and competitiveness [16], while simultaneously controlling their environmental impact and facilitating social development of the Arctic regions. Management of sustainable development cannot take place without an assessment system, despite the fact that the issue of its quantitative and qualitative content is debatable [17].

From theoretical and methodological viewpoint, there is a relatively small number of studies dedicated to sustainable development of Arctic OGPs. "Simple" (without using additional filters) search queries (SQ) in the Scopus database (Table 1) demonstrate that there is a significant number of scientific papers both in the area of sustainable development of oil and gas projects (9.743 publications) and in the area of Arctic OGP implementation (7.038 publications). Only 52 publications are dedicated to the specifics of sustainable development of Arctic OGPs, which indicates a limited amount of research and the presence of possible gaps in this scientific area.

*Table 1*

**Description and results of "simple" SQs in the Scopus database**

| Query N | Number of results | Query description |
|---|---|---|
| 1 | 52 | TITLE (arctic AND sustainab* AND (oil OR "natural gas" OR petroleum) OR KEY (arctic AND sustainab* AND (oil OR "natural gas" OR petroleum) |
| 2 | 9.743 | TITLE ( sustainab* AND (oil OR "natural gas" OR petroleum) OR KEY (sustainab* AND (oil OR "natural gas" OR petroleum) |
| 3 | 7.038 | TITLE ( arctic AND (oil OR "natural gas" OR petroleum) OR KEY ( arctic AND (oil OR "natural gas" OR petroleum) |

These gaps are manifested in a comprehensive list of methodological problems. Existing approaches to assessing sustainability of oil and gas projects usually do not take into account all stages of their life cycle, which is critically important from the perspective of industry specifics due to the long period of field development and reaching design capacity, followed by transition to a stage of declining production and well conservation.

Sustainability of a complex industrial system formed within the scope of an oil and gas project is assessed using controversial indicators, which are usually determined by three basic aspects (ecological, social and economic effects) and do not imply further decomposition, which makes them inapplicable for strategic and tactical management. For example, the system of indicators pays insufficient attention to the economic risks of such projects, as well as their technological stability and the ability to form an innovative product [18] in the context of implementing complex projects of Arctic shelf development. For Russia, this issue is of particular importance due to the current geopolitical situation, with a closed access to a number of advanced foreign technologies for hydrocarbon recovery and intensification of the import substitution policy.

Another unreasonably ignored aspect is national and regional specifics of project implementation, despite it being one of the key factors that determine the feasibility of field development. Furthermore, considering the role of projects in the economy of Arctic regions, social effects from their implementation should also be taken into account, which is a separate scientific problem.

Large-scale implementation of oil and gas projects in the Russian Arctic requires elimination of the indicated gaps in the scientific knowledge and identification of new guidelines for scientific research, which will allow to make a transition from the theory of sustainable development to its practical implementation.

**Bibliomeric analysis.** The purpose of bibliometric analysis is to identify gaps in scientific knowledge on the issues of sustainable development, in particular associated with Arctic OGPs. As the main source of information, we chose the Scopus database. The general procedure for selecting scientific publications is shown in Table 2. To clarify specific features of the Russian Arctic, we used some publications obtained from the Elibrary database. Individual issues of sustainable development theory were clarified by means of a selective search in the Google Scholar database.

*Table 2*

**Procedure for selecting publications from the Scopus database**

| Analysis stage | Results of individual SQs | | |
|---|---|---|---|
| Defining the objectives of SQs | Analysis of publications in the field of SD of Arctic OGPs (SQ 1) | Analysis of SD specifics of OGPs (SQ 2) | Analysis of specifics of Arctic OGPs (SQ 3) |
| Formation of SQ (results) | 52 | 9.743 | 7.038 |
| Applying filters: | | | |
| • only journal articles and conference proceedings | –3 | –1.319 | –333 |
| • only articles, conference abstracts, scientific reviews | –3 | –160 | –98 |
| • knowledge areas: Energy; Earth and Planetary Sciences; Science; Social Sciences; Economics and Finance; Business, Management and Accounting; Multidisciplinary; Decision Sciences | –30 | –4.251 | –4.590 |
| • publications over the period of 2005-2020 | –1 | –500 | –1.053 |
| • elimination of irrelevant key words | –7 | –3.481 | –928 |
| **Number of publications for a full-text analysis** | **8** | **32** | **36** |

Based on the objectives of the study, we formulated three SQs in the Scopus database. Numerous filters were used in the selection, since a simple search by key words and title (Table 1) did not allow to discard all the irrelevant results (for example, *oil* as a part of *palm oil*). Another restriction that we introduced was the time period: 2005-2020 for all SQs, except for the second one, for which the range of papers was limited to years 2015-2020 (as of 01.02.2020). This is explained by the fact that its main purpose was to collect information about the specifics of sustainable development of OGPs, not

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to analyze development history of this concept, which is dynamically changing and expanding. Moreover, it was in 2015 that the UN General Assembly adopted the global 2030 agenda for sustainable development [19], which can be considered the starting point for a new stage of research in this area.

Analysis of the final list of publications showed that the majority of works were published in the journals with high bibliometric indicators (ranked Q1 and Q2 according to scima-gojr.com). The papers are fairly evenly distributed among different periodicals, which indicates wide scientific coverage of this problem. Table 3 contains periodicals with the maximum specific number of citations, calculated for the selected publications.

*Table 3*

**Review of periodicals that published selected papers**

| Periodical | Citations | Publications | Specific number of publications |
|---|---|---|---|
| Atmospheric Chemistry and Physics | 72 | 1 | 72.00 |
| Water, Air, and Soil Pollution | 35 | 1 | 35.00 |
| Marine and Petroleum Geology | 101 | 3 | 33.67 |
| Renewable and Sustainable Energy Reviews | 25 | 1 | 25.00 |
| Energy Research and Social Science | 24 | 1 | 24.00 |
| Izvestiya – Atmospheric and Ocean Physics | 24 | 1 | 24.00 |
| Geoforum | 24 | 1 | 24.00 |
| Russian Geology and Geophysics | 59 | 3 | 19.67 |
| Energy Policy | 101 | 6 | 16.83 |
| Journal of the Knowledge Economy | 16 | 1 | 16.00 |
| Natural Resources Journal | 16 | 1 | 16.00 |
| Energy Economics | 59 | 4 | 14.75 |
| Impact Assessment and Project Appraisal | 13 | 1 | 13.00 |
| Cold Regions Science and Technology | 13 | 1 | 13.00 |
| Sustainable Development | 12 | 1 | 12.00 |
| AAPG Bulletin | 22 | 2 | 11.00 |
| Corporate Social Responsibility and Environmental Management | 11 | 1 | 11.00 |
| Resources Policy | 31 | 3 | 10.33 |
| Environmental Reviews | 10 | 1 | 10.00 |
| Science of the Total Environment | 19 | 2 | 9.50 |
| Journal of Cleaner Production | 75 | 8 | 9.38 |

Total number of citations per one publication ranges from 6 to 8, depending on the year (Table 4). In general, despite the conventionality of this indicator, these values seem to be quite high, which suggests high quality of the studied sample.

*Table 4*

**Dynamics of the cumulative number of citations and publications arranged by year**

| Indicator | Year | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
| Publications | 5 | 6 | 11 | 18 | 19 | 27 | 40 | 43 | 50 | 56 | 64 | 86 | 107 | 119 | 150 | 154 |
| Citations | 95 | 95 | 100 | 172 | 172 | 277 | 465 | 504 | 517 | 532 | 583 | 695 | 842 | 905 | 939 | 939 |

Tables 1 and 2 indicate the presence of an intersection between SQs 2 and 3 but do not permit to see their interdependence, which would make it possible to draw conclusions, first of all, about the feasibility of considering selected literary sources in the context of a single methodological framework, and secondly, about the concentration points for the topics of these studies, which is important due to the presence of multiple irrelevant search results in the initial samples. Cluster analysis of selected publications was carried out using VOSViewer software [20].

The results show two clear correlations. First of all, key word analysis allowed to identify the focus of studies on the issues closely related to the topic of this paper (Fig.1). In addition to the obvious fundamental role of the term *sustainable development*, scientific areas of individual SQs, as

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well as areas of their intersection, were clearly distinguishable. It should be noted that in the context of SQ 3, a relatively high weight is attributed to the term *Russian Federation* (the only country that stands out). The absence of other countries, including ones in the Arctic Circle [21], in the list of the most common key words indicates either a small number of publications, or low priority of issues related to sustainable development of OGPs.

Secondly, one can observe international scientific collaborations, both among individual scientists and groups of authors (Fig.2). It should be noted that studies on sustainable development of the Arctic systems are carried out not only in the northern countries, but also in the countries that are interested in increasing import volumes of energy resources – for example, in China [22, 23].

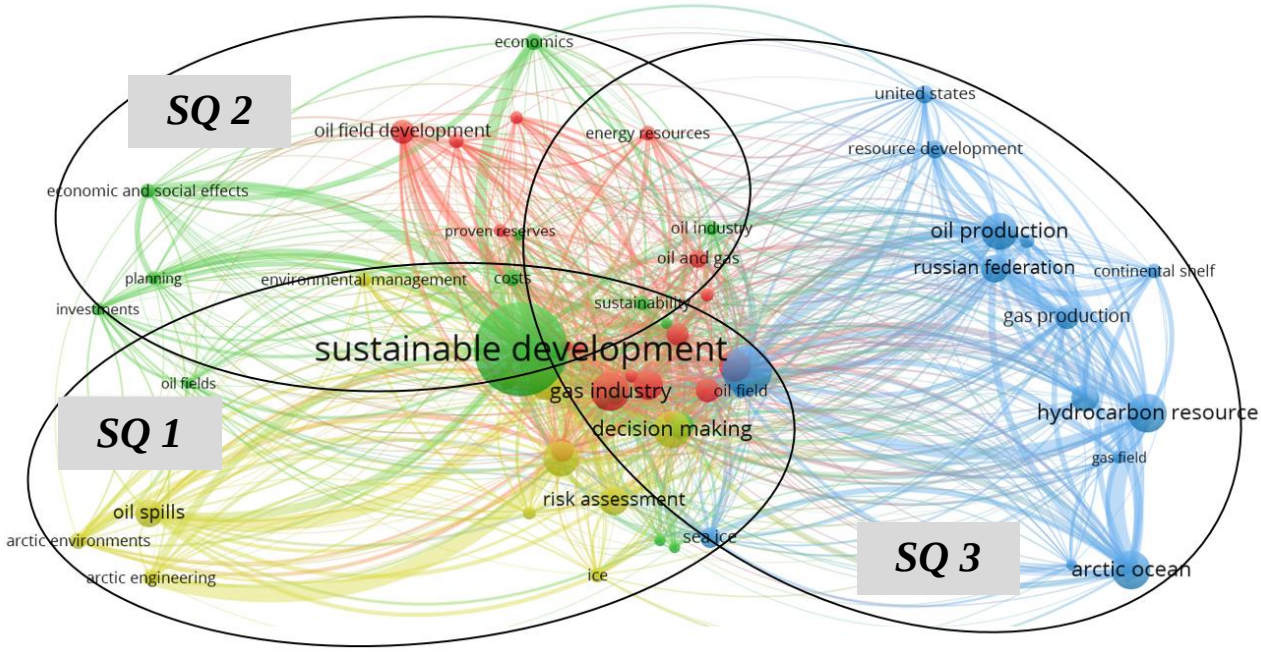



Fig.1. Visualization of cluster analysis by key words for the selected papers

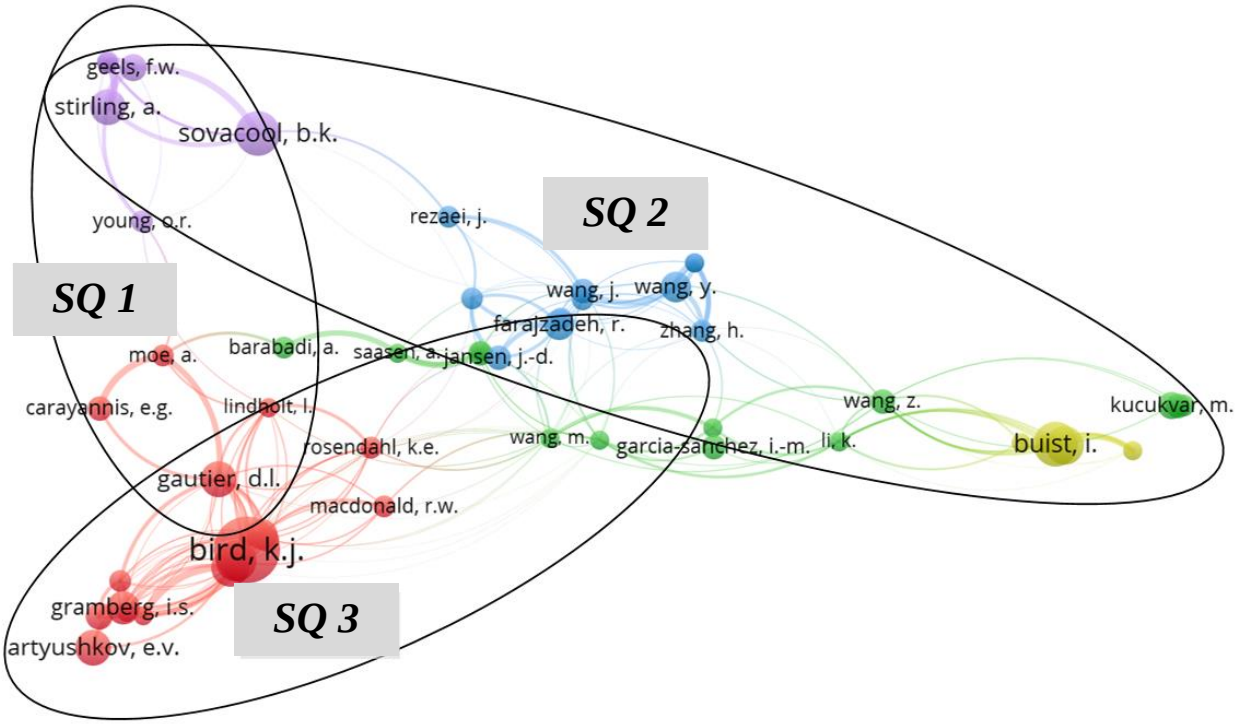



Fig.2. Visualization of cluster analysis by authors for the selected papers

Some studies focus on unfeasibility of developing production of energy resources in the Arctic, as this will accelerate the growth rates of greenhouse gas emissions by increasing consumption of fossil fuels and elevating the risks of sustainable functioning of Arctic ecosystems [24]. Extensive geography of research, as well as presence of contradictory results, indicate the relevance and global nature of the problem associated with sustainable development of Arctic OGPs.

**Methodological foundations of the concept of sustainable development of Arctic OGPs.** First of all, one should note the ambiguity of terminology in this area. Initially, as well as in some modern studies [25], the term *sustainability* was associated mainly with environmental aspects of human activity. At the same time, *sustainable development* is understood in a broader sense and apart from ecological factors and includes economic, social and other aspects. In this study, we will adhere to the most widespread approach today, according to which *sustainability* is a stationary characteristic of the research object within the framework of the dynamic process defined as *sustainable development* [26].

As a rule, there are two forms of sustainability [27, 28, 29] that have their own specific features. The first one is *weak sustainability*, which implies the possibility of replacing depleted natural capital with a man-made capital. This form of sustainability is based on the optimism regarding the prospects of technological progress.

*Strong sustainability* implies that some types of natural capital cannot be substituted. Despite the fact that at first glance this division has a purely theoretical significance, upon closer examination it becomes evident that it determines the differences in the methods of sustainability assessment [30].

From the viewpoint of implementing Arctic OGPs at the stage of hydrocarbon recovery, the authors of this paper mostly adhere to the position of weak sustainability with certain adjustments. In their essence, recovery and use of fossil fuels cannot be considered fully sustainable activities, since they do not allow to preserve natural resources for future generations [31]. However, nowadays oil and natural gas are being actively replaced by renewable energy sources. Rapid development rates of energy technologies suggest that in the near future the share of fossil fuels in the global economy will decrease, and therefore, with a certain degree of convention, they can be considered "replaceable" [32]. Substitute resources can also be found for hydrocarbon processing industries.

There is somewhat more ambiguity in the issues of environmental impact [33], for example, due to oil spills. Even after ten years, the man-made disaster on the Deepwater Horizon drilling platform affects the ecosystems in the polluted zone [34], despite multibillion-dollar remediation costs paid by BP company. Such disasters are an unforeseen, kind of "shock" (rarely occurring) situation, while operational activities do much less damage to the environment provided that proper security measures are taken. In this regard, theoretical possibility of a large-scale negative impact is quite difficult to assess, both in monetary and physical terms [35]. Therefore, if we can consider depletion of hydrocarbon reserves from the standpoint of weak sustainability, potential environmental harm from the occurrence of unforeseen "shock" situations cannot be compensated for by any other form of capital, which needs to be considered when developing methods for assessing sustainability of OGPs.

It should be taken into account that high economic performance can be inversely proportional to the negative environmental impact of the company [26], which indicates the need to create favorable institutional conditions for the operation of enterprises that can ensure maintenance of environmental safety and prevent potential man-made disasters.

Traditionally, there are three basic aspects distinguished in the context of assessing sustainable development: environment, economy and society. It should be taken into account that due to the specifics of the Arctic, in some cases, instead of talking about sustainability of an individual project, one should consider sustainable development of the entire region, which would facilitate sustainable development of other resource projects, development projects of related industries and social projects [37, 38]. Depending on the amount of hydrocarbon reserves, one can select various strategies for

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managing development of the region [39]. In particular, when developing a regional strategy of sustainable development, it is possible to consider several projects that constitute a part of one vertically or horizontally integrated chain [40]. Such strategies require different research approaches [41] and are beyond the scope of this study; however, the possibility of integration with sustainable development concepts of higher-level systems should be taken into account.

Sustainable development of Arctic OGPs cannot be considered only from the standpoint of ecological, economic and social aspects, since they do not allow full identification of the specifics of the research object, nor do they reflect the external environment of project implementation. In the context of this study, it is more preferable to adapt the methodology of PESTEL analysis [42] due to the importance of political, technological and regulatory aspects. To achieve the goals of this study, we propose an adapted approach to decomposition of factors that determine sustainability of Arctic OGPs (Fig.3).

1. The most important component that determines sustainable development of OGPs is the technology (technological sustainability) that makes it possible to develop oil and gas fields under difficult geological, production and natural climatic conditions. The ideas of developing the Arctic and its oil and gas potential are not new; their emergence can be traced to the middle of the previous century [43]. However, in those times, due to insufficient technical and technological infrastructure, development of a great number of OGPs could not be implemented. Nowadays, oil and gas sector has made substantial progress in technological development, but stringent requirements for ensuring environmental safety of production, as well as price volatility on the markets of energy sources and electric supply, remain significant barriers to sustainable development of Arctic OGPs [44].

Numerous studies are dedicated to the issues of supplying Arctic industrial facilities with renewable energy. Most of the works consider renewable energy as a substitute for fossil fuels, both for individual projects and for the entire decentralized energy system of the Arctic [45], and only some studies mention its possible use for energy supply of Arctic OGPs [46]. This is a promising possibility in case the use of extracted energy resources is less cost-efficient compared to renewable energy, which has an extensive resource potential in these regions [47].

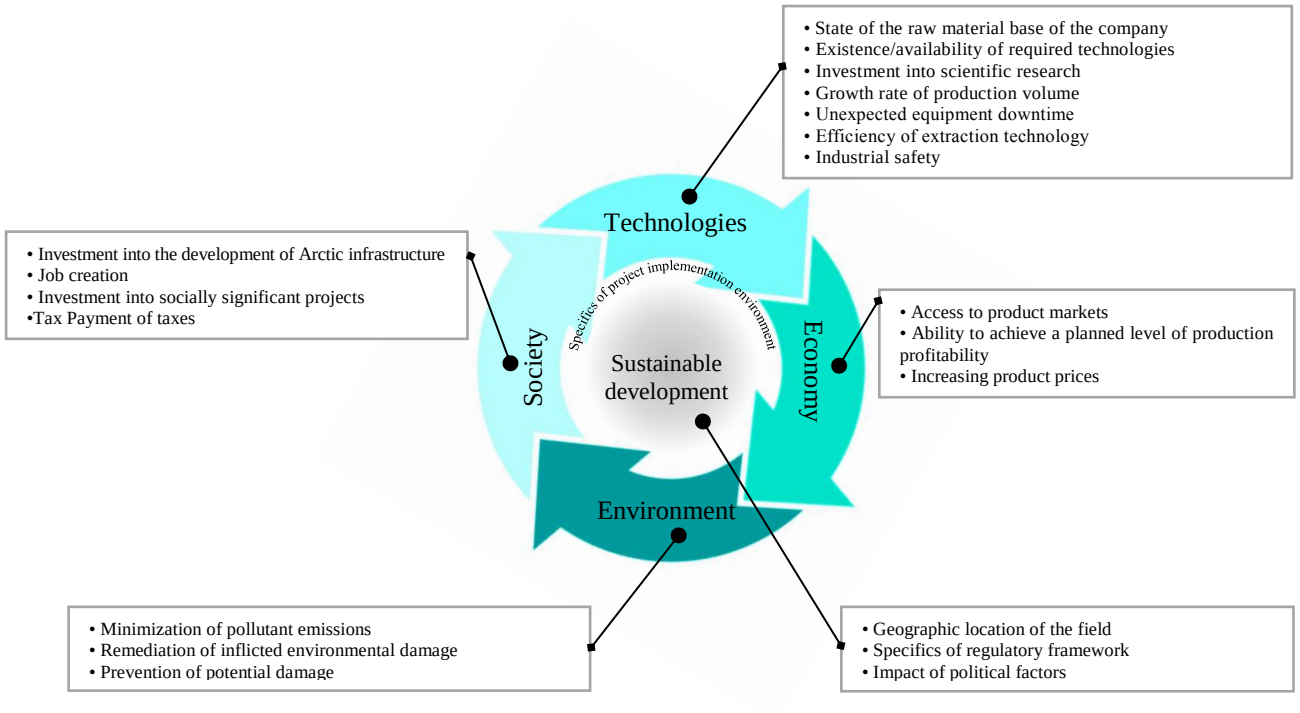



Fig.3. Decomposition of key SD factors of Arctic OGPs

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Technologies, as well as prospects of their emergence and development, can lead to significant changes in the efficiency of field development [48], indicated by an increase in the hydrocarbon recovery factor and a decrease in the operating costs [49]. Technologies play an important role in the issues of safety promotion and allow to minimize the likelihood of human error, as well as provide continuous monitoring of the environment and operation of industrial facilities. For example, this is important when managing ice conditions [50], providing a fast response in case of emergency oil spills [51] and implementing control over stable operation at the stages of production and facilities installation, as well as in other production, organizational and management tasks within the scope of the project [52]. On the other hand, given the capital intensity of such projects, in some regions of the Arctic development may be technically feasible but economically impractical [53].

2. Economic aspects of sustainable development (economic sustainability – EconS) are usually associated with the ability of the company to produce various effects (estimable in monetary terms) in the amount that significantly exceeds the costs incurred to obtain them, regardless of the external influence of the environment. With regard to OGPs, as well as any other mining company, it is usually impossible to maintain stable economic sustainability throughout the entire length of the project.

Such situation is explained by the impact of several objective factors, for example, the specifics of project life cycle (Fig.4). Consideration of these specifics is an indispensable part of assessing sustainability of OGPs [54], which is practically ignored in the scientific papers.

In the majority of studies, authors single out three stages of OGP implementation (in Fig.4 denoted as S2.1, S2.2 and S2.3). Largely, economic sustainability of OGP is achieved at the production stage, when the process layout and engineering design of field development are created and key economic results are obtained. At this stage the project breaks even ($T_{e-1}$), then follows a period of intensive increase in discounted cashflow of the subsoil user and the state. The stage of decreasing production volumes ($T_{e-2}$) is usually characterized by worsening geological conditions of reservoirs, increasing water encroachment of the wells, growing specific operating costs, which all leads to rapidly decreasing economic performance. Subsequent implementation of the project requires new capital and operating costs, for example, associated with drilling additional wells and (or) using different methods of enhanced oil and gas recovery. Pre-production stage, as well as the stage of field conservation, are usually left out of consideration [55].

The pre-production stage is fundamental, since within its scope the raw material base of the potential project is specified and, based on this information, preliminary conclusions are drawn about

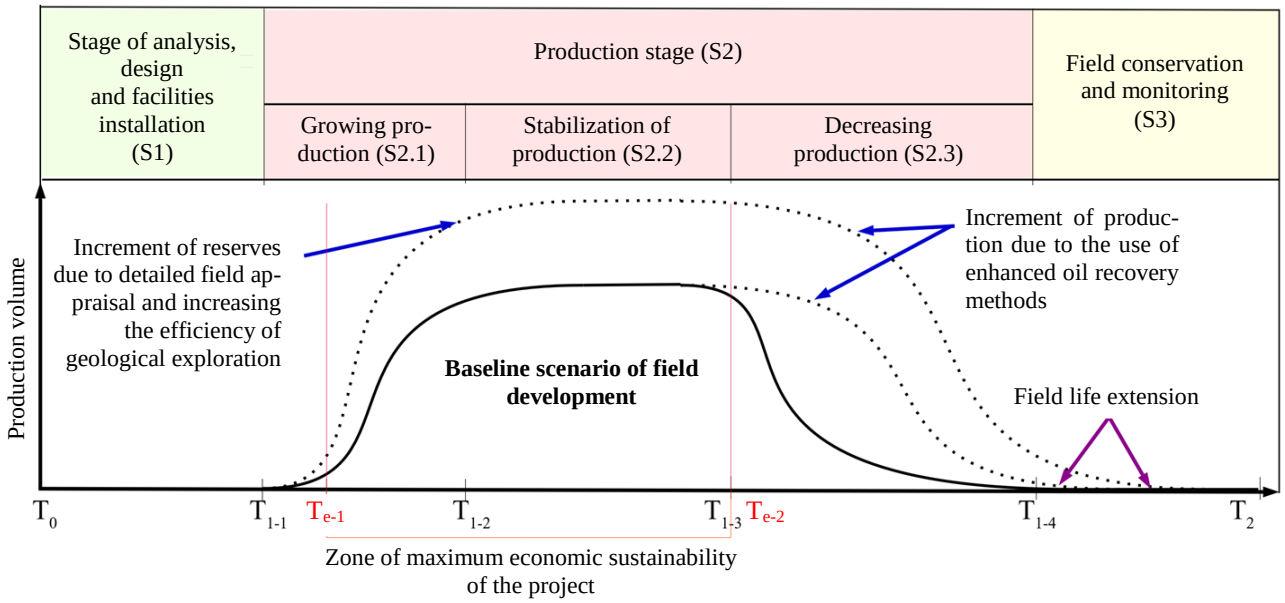



Fig.4. Life cycle stages of an oil and gas project

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the feasibility of field development and its economic potential. Increasing further sustainability of the project is ensured by building the most accurate and reliable geological models of the field, on the basis of which it is possible to make high-accuracy predictions about production volumes and field life [56]. For Russia, the issues of increasing the efficiency of geological exploration are extremely acute, including at the stages of commercial field development, where great importance is placed on detailed appraisal of reservoirs and obtaining a possible increment of hydrocarbon reserves [57]. Arctic OGPs can compensate for the decline in easily recoverable hydrocarbon reserves in the old oilfield regions, but it should be noted that the level of exploration in some territories of the Arctic economic zone is still quite low [58].

The last stage of the life cycle is aimed at ensuring environmental safety of the well conservation process to prevent possible oil spills. At this stage, no economic effects are obtained, and therefore assessment of its sustainability can be limited to environmental aspects of sustainable development.

In addition to lifestyle analysis, another way to examine the project in the context of sustainability analysis is the organization of production and supply chains (Fig.5).

The issues of supply chain optimization are covered quite extensively for many industries [59], although they are usually associated with sales and distribution of products. Resource supply, in particular that of OGPs, has been considered in a limited number of publications [60, 61], despite the importance of this aspect for Arctic projects. High risks associated with resource supply are expressed in the inability to perform production activities without the necessary resources (for example, material or labor ones) being available in the required amount and, as a consequence, a decrease in average indicators of operational efficiency [62]. In this regard, supply chain management requires a much more detailed study in the context of sustainable development of Arctic OGPs.

The stages of production activity management in the context of OGPs [63] are widely covered in scientific literature, unlike the approaches to their strategic management, including the obvious

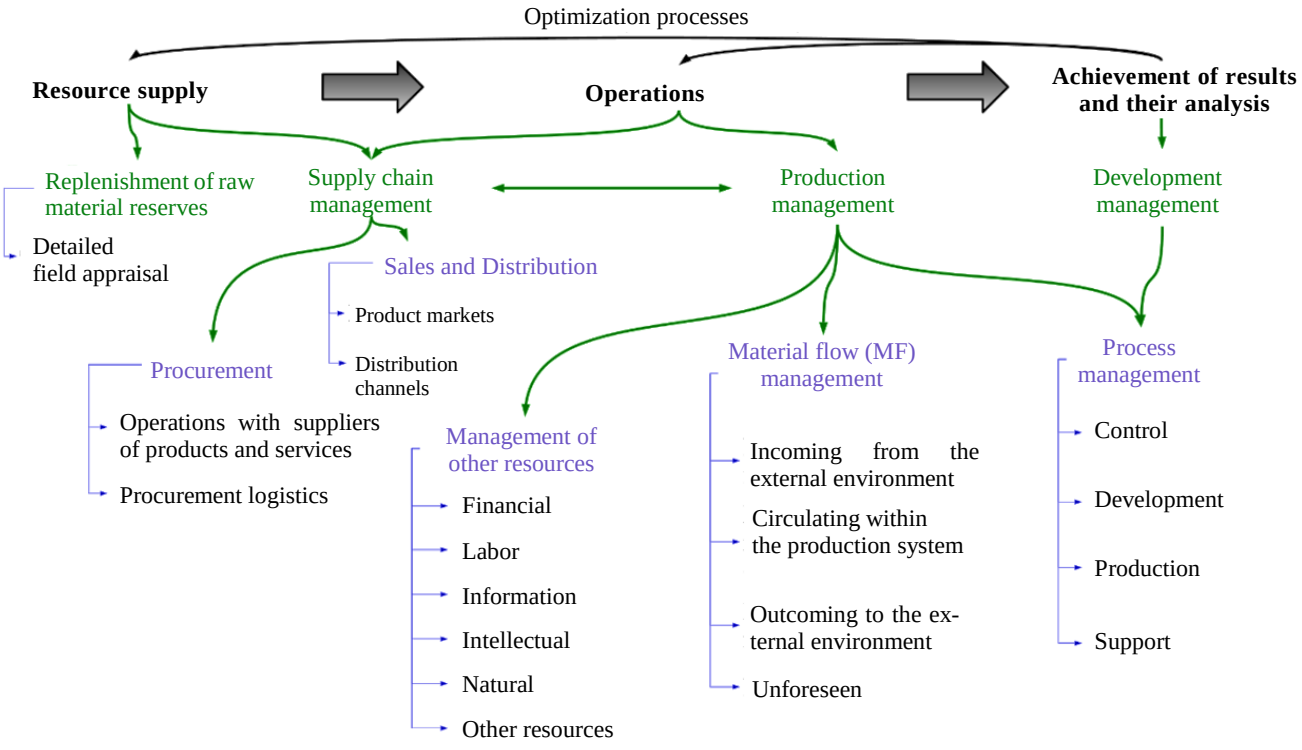



Fig.5. Decomposition of the aspects of production and economic activity within the scope of OGP

problems with the integration of methods used at different planning horizons [64]. The issues of strategic management are usually not considered in the context of sustainable development in general, only within certain aspects, for example, environmental ones [65].

3. Social effects (social sustainability – SS) can be very diverse and, in a number of cases, inestimable in monetary terms. The issue of how exactly the company should "share" created effects with the society is rather controversial. For example, in a number of papers [66] authors emphasize the need to communicate with the local population; however, the Russian Arctic is an extremely sparsely populated region. The project is highly likely to be implemented far from inhabited areas by means of recruiting fly-in fly-out workforce. Due to such ambiguity, the influence of the local population is considered either in theoretical works, or when describing individual experience of certain companies; however, no significant achievements in the development of universal communication mechanisms have yet been made.

Improving industrial safety in order to minimize the risks of environmental disaster can clearly be beneficial for the ability of future generations to satisfy their needs. For example, the territory of the Russian Arctic has poorly developed infrastructure [67] – its strengthening will also contribute to reaching the goals of sustainable development according to its classical definition. In this regard, sustainable development of Arctic OGPs can have a slightly different focus compared to other industries and regions [68].

In modern literature, there is a clearly visible focus of research on corporate social responsibility (CSR) [69, 70], this concept is associated with social aspects of sustainable development. Unlike CSR, which is a way of company self-regulation aimed at dividing created effects among the stakeholders, sustainable development, as perceived by the public, is an assessment of the results of such division and it should not so much focus on the private aspects, as determine general vector of company's development in this area.

Pronounced focus of the papers on the need to maximize social effects overlooks the fact that implementation of Arctic projects is extremely capital-intensive and low-profit and primarily requires economic efficiency of production, which can be followed by various social effects [71]. It should be understood that the key to sustainable development is finding a balance between the interests of all stakeholders, including the company itself [72, 73], not pursuing a discriminatory socially oriented policy for the right to implement projects with high technical and economic risks. Finding such a balance requires direct participation of the state – on the one hand, as a regulator of communication between project stakeholders [74], and on the other, as one of the direct participants of the project, which can create conditions for its sustainable development [75] and enhancement of social effects.

4. Despite the fact that studying environmental aspects is one of the most common topics in the context of sustainable development, assessment of ecological sustainability (EcoS) of OGPs is one of the most controversial problems [76, 77]. Practically all the proposed methods can be reduced to two approaches. The first one is cost estimation of pollutant emissions based on certain standards. The disadvantage of this approach is the absence of effective methods for estimating large-scale pollutant emissions, as in the case with the mentioned earlier Deep Water Horizon project. Moreover, cost assessments from different sources vary significantly. In some countries, a carbon tax can reach tens of USD per ton of $CO_2$ [78], whereas in others it is altogether absent despite the fact that climate change is a global problem [79].

The second approach is based on the estimation of specific pollutant emissions over a certain period [80] and EcoS assessment by means of comparison to similar companies [81] or previous state of the research object. This approach is more preferable, although the feasibility of comparing different OGPs, even on the basis of specific indicators, is a debatable issue, as every project is a combination of unique characteristics, ranging from production composition to the limited choice of resources and technologies required for the operation process.

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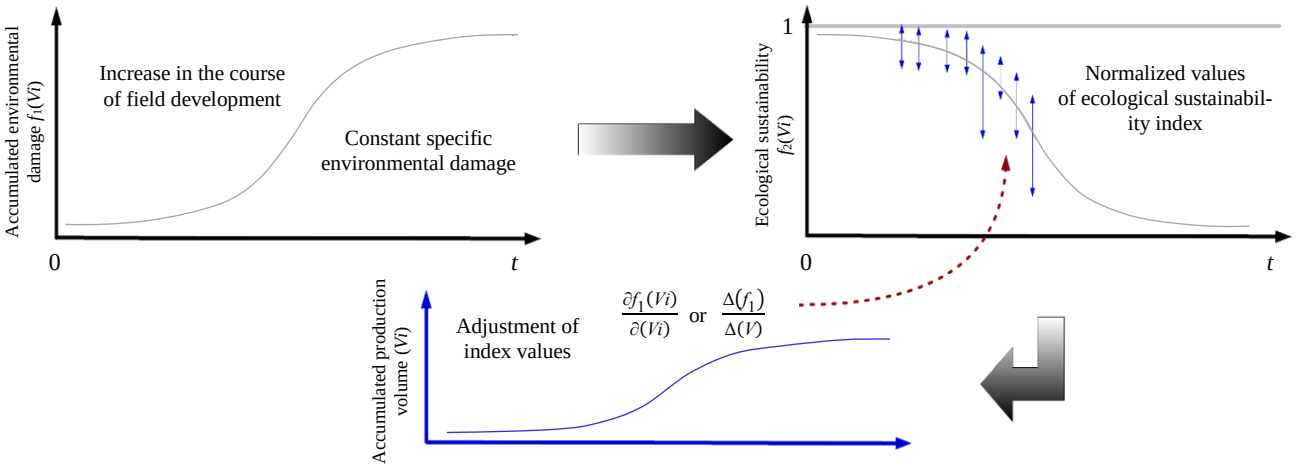



Fig.6. Approach to understanding ecological sustainability of OGPs

Regardless of the approach, EcoS is regarded as the ability of the company to exert minimal impact on the environment. Taking this into account, it seems rational to consider EcoS from the view point of the negative impact on the environment accumulated over the period of project implementation. There is a sufficiently objective assumption that with the development of the project, accumulated environmental damage can be described by an increasing S-shaped curve (Fig.6).

Initial stages of project implementation are associated with minimal environmental damage, then their growth rates increase with transition to the second and third stages (see Fig.4). At the stage of decreasing production volumes, the growth rates of damage decrease as well. Estimation of pollutant emissions should be carried out in physical terms by bringing them to a single denominator according to standards or expert appraisal, which will yield more reliable results than cost estimation. This approach will allow to estimate emission volumes from the view point of existing standards and material flow analysis (for example, in relation to $CO_2$ emissions) [82], as well as to avoid leaps from environmentally unsustainable to sustainable state (for no objective reason). Moreover, the use of physical estimates allows to manage ecological sustainability in the context of any currently existing concept of environmentally balanced production activity [83], for example, based on life cycle analysis of the products.

**Systematization of gaps in scientific knowledge on the issues of sustainable development of Arctic OGPs.** Literature analysis, performed for the studied area, is not exhaustive, since almost any work dedicated to the development of economic entities can be attributed to the topic of sustainable development to a greater or lesser degree. Nevertheless, the analysis allowed to generalize existing methodological framework and identify the scientific gaps in it (Fig.7).

The color of an arrow corresponds to authors' conclusions about the extent of prior research dedicated to the element at its tail:

• green – from the view point of sustainable development, the area is thoroughly researched; its theoretical and applied aspects are developed to the extent sufficient for their objective application; further development can be associated with transition to new global development concepts;

• yellow – the area is quite common in scientific literature, but it contains objectively problematic issues that have not been resolved yet;

• red – the area can be widely discussed or not, but it almost completely lacks well-established methods and approaches, while practical solutions are characterized by certain subjectivity.

The *factor consideration* stage seems to be quite well-developed. Identification of various sustainability aspects does not cause any methodological problems, since they are usually intuitively comprehensible. On the other hand, the fact that sustainability of research object is perceived similarly to its efficiency creates numerous problems either when identifying such aspects as *political*

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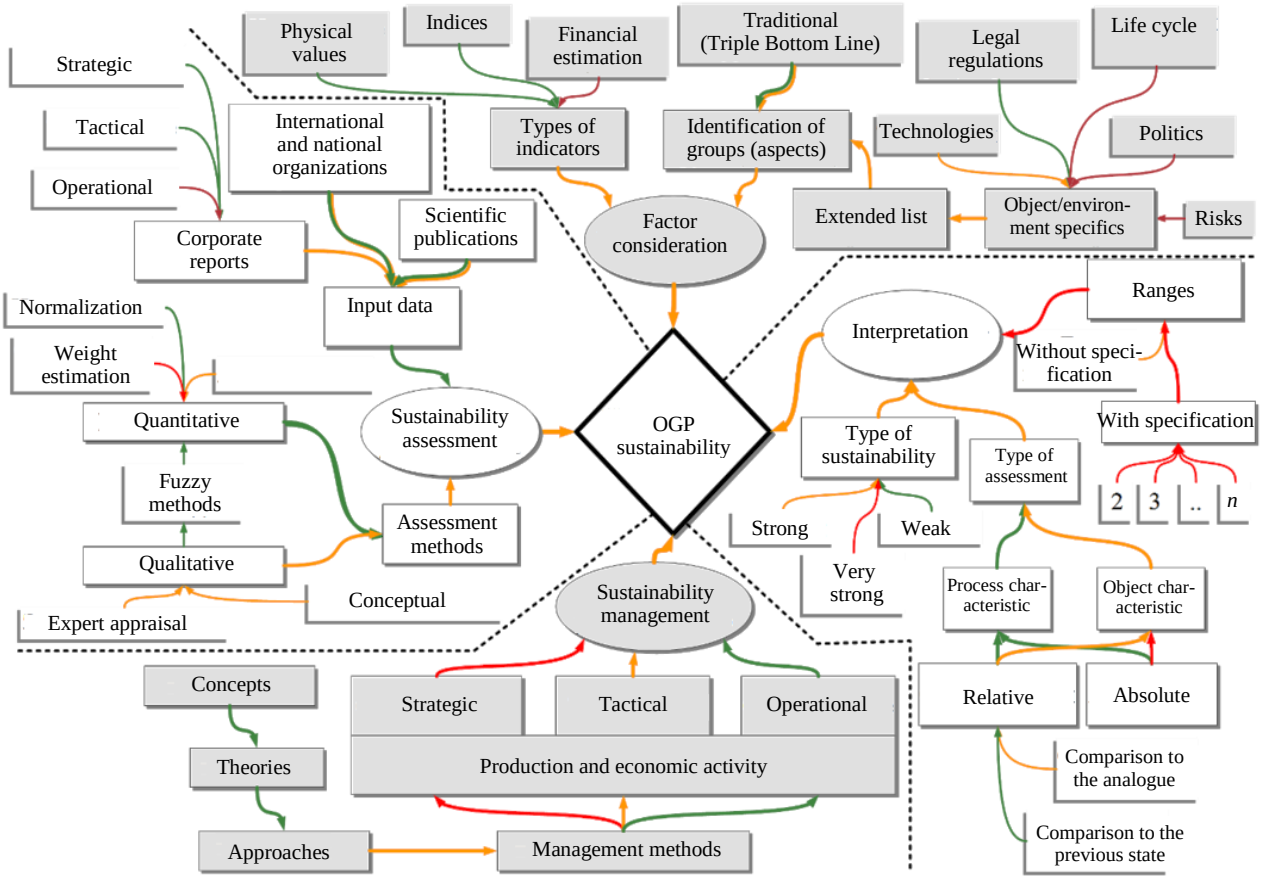



Fig.7. Map of the elements of sustainable development methodology

*sustainability* or assessing risks, i.e. the same aspects that have an insufficiently developed methodology of efficiency assessment. As for selecting the list of indicators, the only objective problem is associated with the conversion of qualitative and physical indicators into monetary terms, which is explained by the absence of objective coefficients that would allow to perform this conversion without making numerous assumptions.

*Sustainability assessment*, based on the list of indicators that characterize different aspects (factors) of sustainability, has an extensive methodological and methodical foundation, which can be adapted to almost any specific conditions of assessment. In the scope of literature analysis, we managed to identify just one critical area – weight estimation for different indicators (aspects). This process cannot be standardized, and usually it largely depends on the researcher's opinion. It should be noted that partial solution to the problems of this area is offered by the methods of fuzzy logic and approaches to weight estimation based on statistical analysis.

To some extent, *sustainability management* is an ambivalent area. Considering the fact that in most studies one can clearly observe a relation between efficiency and sustainability, the methods of operational management are extensive, comprehensive and have a high degree of approbation under real-life conditions. On the other hand, methods of strategic sustainability management are almost completely absent in the scientific literature, despite the fact that in its essence the concept of sustainable development implies long-term perspective of planning and analysis.

*Interpretation* is the most problematic area of sustainability assessment. This is primarily manifested at the stage of determining its type, because scientific research in the area of assessing the impact of human activity on the environment is far from complete. Another factor that causes uncertainty is associated with poorly developed methods and approaches to technological forecasting, which could provide opportunities to assess the potential for natural capital replacement. In addition, at the final stage of assessment there are problems with estimating the ranges of sustainability. In the

literature, one can find numerous gradations of authors' indicators that have from one to more than six ranges. The main problem seems to be that there are no objective ways to identify ranges of values for composite indicators, especially when they are based on heterogeneous data normalized with non-linear functions.

**Conclusions.** Sustainable development of Arctic OGPs is a relevant direction of research, which is determined, on the one hand, by the need to expand the resource base of the fuel and energy sector, which is especially important for Russia due to rapid depletion of easily recoverable hydrocarbon reserves, and on the other hand, by the need to take into account numerous technological, ecological and social factors in the implementation of such projects. Development of Arctic hydrocarbons is important not only for countries with direct access to these reserves, but also for those interested in increasing import volumes of energy resources – for example, for China.

In modern scientific literature, the issues of sustainable development of Arctic OGPs are considered in a very fragmented way compared to other industries, that is why there are many gaps in scientific knowledge related to the specifics of implementing such projects. At the same time, despite the prodigious amount of publications, the concept of sustainable development itself has many unresolved issues, both methodological and applied ones.

This study contains analysis of the current state of research in the area of sustainable development, based on which the following results were obtained:

• the strength and weaknesses of existing methodological approaches to assessing project sustainability were identified;

• the specifics of OGP implementation in the Arctic and analyzed significance of different life cycle stages for such projects were examined;

• the key scientific issues, that have not been resolved but can be of great significance for making a transition from theoretical studies to practical implementation of sustainable development principles in hydrocarbon production in the Arctic, were defined.

In conclusion, it should be noted that currently existing barriers to implementing Arctic OGPs bring significant uncertainty into medium- and long-term assessments of their feasibility. Specifically, at the present level of production technology development, as well as considering existing competition in the market, the exploitation of Arctic deposits can be efficient at relatively high oil prices (according to some estimates, over 80 USD per barrel) and stable demand. The macroeconomic situation in early March 2020 showed that none of these conditions can be guaranteed in the long term, and therefore acceleration of hydrocarbon recovery rates in the Arctic can only become possible due to a high-quality leap forward in the development of production technologies. There is another assumption that holds true. If a visible increase in the efficiency of renewable energy technologies occurs during the period of decline of oil prices, this may lead to a loss or, at least, a decrease of feasibility to develop Arctic hydrocarbons for the sake of meeting energy needs.

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***Authors:*** **Aleksei E. Cherepovitsyn,** *Doctor of Economics, Professor, alekseicherepov@inbox.ru, https://orcid.org/0000-0003-0472-026X* (*Saint Petersburg Mining University, Saint Petersburg, Russia*), **Pavel S. Tsvetkov,** *Candidate of Economics, Associate Professor, Tsvetkov_PS@pers.spmi.ru, https://orcid.org/0000-0002-3049-7893* (*Saint Petersburg Mining University, Saint Petersburg, Russia*), **Olga O. Evseeva,** *Postgraduate Student, olgaevs@yandex.ru, https://orcid.org/0000-0002-1002-8061* (*Saint Petersburg Mining University, Saint Petersburg, Russia*).

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