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Sustainable Development of Oil and Gas Resources: A System of Environmental, Socio-Economic, and Innovation Indicators

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Abstract: Following the principles of sustainable development in the development of oil and gas fields in the Arctic will ensure that hydrocarbon production and transportation operations comply with stringent environmental regulations, the economies of the northern regions become integrated into the national economy of Russia, production systems in the oil and gas sector are upgraded in an innovative manner, and further development of this region is balanced from the environmental perspective. The purpose of the study is to develop and provide a rationale for a balanced system of environmental, socio-economic, and innovative indicators for assessing whether the development of the Arctic's unique hydrocarbon reserves is sustainable. The theoretical framework of the study draws upon the foundations and key principles of the sustainable development concept and upon modern approaches and methods for assessing the sustainability of production systems. The study presents an analysis of conceptual approaches to defining sustainable development in reference to oil and gas resources, including those found in the Arctic, defines target priorities for the sustainable development of the Arctic's resource potential, and identifies the relationship between the environmental, socio-economic, and innovative domains of sustainability in the context of Arctic resource development. The results of the study demonstrate how large-scale gas projects can influence regional development and provide for making informed conclusions about whether the development of the Arctic's oil and gas reserves can be considered sustainable (in accordance with the basic principles of the sustainable development concept).

Keywords: sustainable development; Arctic shelf; hydrocarbon resources; oil and gas projects; Arctic; environmental criteria; economic criteria; social criteria; indicator system; energy innovation

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1. Introduction

As a result of the growing demand for energy sources and stiff competition in the global oil and gas market, the top hydrocarbon producers, including both countries and businesses, are becoming increasingly interested in the development of Arctic offshore hydrocarbon fields. The Arctic is a region with the biggest untapped hydrocarbon potential in the world, wherein most of its hydrocarbon reserves (84%) are concentrated on the shelf of the Arctic Ocean [1].

Oil and gas have been explored and produced in the Arctic for more than a decade. Russia was among the first countries to start studying and exploiting the Arctic's hydrocarbon resources. For Russia's Arctic sector, the last decade has been a period of key decisions, large-scale infrastructure and production projects, investment flows, and active business participation. Today, developing both the Arctic's unique resource base and the economic potential of the northern territories is considered to be an important tool for ensuring national economic growth. Oil and gas production in the Arctic will play a key role in the country's energy mix as it will substitute for the decline in hydrocarbon production from mature fields after 2035. In the future, the Arctic shelf can become a strategic reserve of conventional hydrocarbon resources for both Russia and the global energy market as a whole [2].

Russia's Arctic sector contains about 41% of the region's total oil reserves and 70% of its gas reserves [3]. A total of 91% of offshore hydrocarbons and 53% of hydrocarbon resources on land are accounted for by undiscovered reserves [4]. Low development rates are explained by such characteristics of northern regions as difficult geological conditions, severe climatic conditions, the high instability of the Arctic's ecosystems, underdevelopment of transportation, logistics, and production infrastructure, and the remoteness from developed industrial centers [5]. These characteristics, together with limited access to foreign technologies and investments, significantly increase the capital and operating expenses associated with implementing hydrocarbon projects in the Arctic, which ultimately affects the profitability and investment prospects of operations in the region.

In addition, the Arctic's resources are being developed against the background of the global instability in the energy market. The COVID-19 pandemic has changed the course of the global economy and the prospects for the development of the oil and gas sector. It is predicted that the decline in global demand for hydrocarbons and price volatility may remain for the long term [6]. The structure of the global oil and gas market is changing greatly and the competition between different types of fuels is growing under the influence of decarbonization processes and the intensive development of the renewable energy sector. As new players and production regions emerge, it causes changes in market shares and the pricing mechanism for resources, with competition growing in both traditional and new markets. To grow and prosper, the oil and gas industry needs to introduce advanced technologies and take the path of innovative upgrading.

The high complexity of Arctic hydrocarbon projects, which is exacerbated by the turbulence of the global energy system, forces oil and gas companies to place their focus on the short term and prioritize getting fast financial results, improving production efficiency, and reducing costs. At the same time, the current trend in the global energy industry demonstrates a shift in the attitudes towards hydrocarbon resources from maximizing profits to rationalizing consumption, adhering to stringent environmental regulations, introducing innovations, and solving social problems in the regions where oil and gas companies operate.

Consequently, a new view is emerging on the prospects for the development of the oil and gas industry in the Arctic, which is influenced by the current trends in the global energy system, the reorientation of government policies towards the social sphere, the urgency of environmental issues in the resource sector, and the adoption of knowledge-intensive technologies in the oil and gas industry. The foundation for the sustainable development of the Arctic's oil and gas resources lies in integrating work on the socio-economic development of the region, the protection and preservation of the Far North's vulnerable ecosystems, and the extensive use of innovations in science and technology to solve production and management problems.

The important role of the Arctic's hydrocarbon potential for the Russian economy and the growing importance of both environmental and socio-economic aspects in the resource sector make it relevant to study issues associated with the sustainable development of the Arctic's oil and gas resources and validate criteria for its assessment.

The purpose of the study is to develop a balanced system of environmental, socio-economic, and innovation indicators in accordance with the targets for the sustainable development of the Arctic's oil and gas resources that factors in the specific features of oil and gas development in the Arctic and the impact of price shocks on the energy sector.

This article solves the following research problems:

- It presents an analysis of modern conceptual approaches to defining sustainable development based on such indicators as environmental safety, socio-economic efficiency, and innovative development in reference to oil and gas resources in the Arctic;
- It identifies the relationship between the strategic imperatives of sustainable development in the context of the development of the Arctic's resources;

- It provides a rationale for a set of sustainability criteria in environmental, socio-economic, and innovative domains based on the priorities in the implementation of oil and gas projects in the Arctic;
- It presents the results of a retrospective analysis, forecasting, and assessment of quantitative indicators reflecting the development of regional economic systems that are based on the proposed sustainability criteria;
- It gives recommendations for the development of a system of sustainable development indicators for oil and gas resources in the Arctic.

2. Materials and Methods

The article is based on an extensive literature review that covers sources discussing today's trends in the oil and gas market and the global energy sector, and the key features of developing the resource potential of the Russian Arctic or of implementing oil and gas projects. Content analysis was used to study domestic and international sources, articles, and reports. The theoretical framework of the study consists of the foundations and principles of the sustainable development concept that integrates three key components: environment, society, and economy. It also encompasses methods and approaches to assessing the sustainability of implementing investment projects, which is an indicator of their contribution to the socio-economic development of the regions where oil and gas companies operate. Research methods include analysis and synthesis, generalization, decomposition, elements of strategic analysis, planning and forecasting, statistical methods, and econometric modeling methods.

2.1. Methodological Approaches to Assessing Sustainability: Developing a System of Indicators

The problem of assessing whether production systems or industry projects develop in a sustainable manner today is particularly topical in view of the trends associated with the transition to a low-carbon future, the rise in environmental awareness, an increase in the degree of public involvement in decision-making, and the emergence of new requirements from investors (ESGR criteria).

Today, indicative planning and assessment are important components of sustainable development (SD), with the help of which this process becomes controllable and quantitatively measurable rather than abstract. Indicators make it possible to measure, monitor, and analyze the movement towards goals and, if necessary, adjust the vector of development. Developing a system of indicators implies maintaining a balance between ambitious global goals, the national and regional contexts of sustainable development, and the company's goals. Sustainability indicators should serve as a benchmark for both decision-makers and the general public. In some cases, they can serve as a foundation for decision-making in legislation.

The need to develop a comprehensive system of sustainable development indicators for making informed decisions at different management levels was outlined at the UN Conference on Environment and Development in Rio de Janeiro in 1992. Today there is a huge variety of sustainable development criteria and indicators for systems of different scales, ranging from global to local ones. They are developed by such international organizations as the United Nations [7,8], the World Bank [9], the Organization for Economic Co-operation and Development (OECD) [10], and others. The key example of a system of SD indicators is the global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development (SDG Indicators) [11].

Currently, the main emphasis is placed on the practical implementation of the principles of sustainable development. For example, The Arctic Council is implementing a project aimed at developing new assessment tools and meeting the global SD goals in practice [12]. Wu et al. provide a rationale for developing quantitative indicators for assessing sustainable development with the aim of harmonizing complex relationships between individual SD components and ensuring that sustainability can be managed [13].

It can be stated that SD indicators are treated as key performance indicators, which make it possible to measure how effectively a company is achieving its objectives.

As a framework for developing a system of SD indicators, the Balanced Scorecard proposed by R. Kaplan and D. Norton is often used. This model is based on the interconnection of the existing causal relationships with the established strategic priorities. It is used at various management levels ranging from individual companies to industrial structures.

As a rule, one of the following two methods is used when developing a system of SD indicators [14]:

1. Integrating three groups of indicators reflecting the key areas of sustainable development (economy, society, and environment), which results in an aggregate indicator that serves in making conclusions about the degree of sustainability of a particular system;
2. Designing a system of indicators that reflect separate aspects of sustainable development (without using an aggregate indicator).

In the first method, as a rule, weights are distributed when integrating various groups of indicators to reflect the importance of individual indicators for the overall system. However, this does not always ensure the required degree of objectivity due to the prevalence of expert assessments. The second method does not allow for identifying the relationship between the indicators. The heterogeneity of the indicators and the lack of a clear ranking of their roles in the total system make it impossible to compare individual objects, projects, or systems in terms of their levels of sustainability. In general, differences in both the methods used and the SD indicators themselves deem the criteria for assessing sustainable development ambiguous, making it unclear which values of indicators signal that the system under consideration is sustainable.

Turning to the practical experience of assessing sustainability, it is important to highlight a number of widespread techniques. One of them is the Global 100 Index by Corporate Knights, which is used to rank companies by their level of sustainable development. The assessment indicators are divided into the following four groups: financial management, resource management, employee management, and deductions due to sanctions. The first group (financial management) includes such indicators as innovation capacity, CEO-average employee pay, pension fund status, and percentage tax paid. The second group (resource management) includes energy productivity, waste productivity, water productivity, and emissions productivity, including SOx, NOx, and particulate matter. The third group (employee management) includes employee turnover, injuries, etc. Of particular interest is the last group, which compares total fines, penalties, and settlements and the company's annual revenue [15].

Another well-known methodology is SAM Corporate Sustainability Assessment proposed by RobecoSAM in order to conduct a comparative assessment of economic entities by means of indicators reflecting the efficiency of corporate management and compliance with the principles of environmental and social responsibility. This methodology has found an application in developing the Dow Jones Sustainability Index family (DJSI). It is based on analyzing three components (i.e., environment, economy, and society) that form the foundation of sustainable development. Each component includes certain indicators. When evaluated, each of them has the same weight in the total structure, thereby reflecting the balance between these areas. According to this methodology, environmental, social, and economic parameters are equally important [16].

A methodology by the Global Reporting Initiative (GRI) is used in corporate reporting. It contains three groups of indicators, including economic performance (efficiency and market share), environmental performance (energy and resource efficiency, resource consumption, and compliance with regulations and generally accepted standards), and social performance (observance of human rights and working conditions) [17].

Despite the fact that there are a variety of approaches, methods, and criteria for assessing sustainability, most of them are universal. However, when considering individual systems, it is necessary to take into account their characteristics, the way they interact

with the environment, potential risks they pose to the environment, and whether there is an opportunity to implement sustainable development principles. In view of this, when narrowing the focus on specific economic systems, it is advisable not to adjust universal indicators but instead to develop new indicators that better reflect the features of the object under consideration.

The following should act as the basic principles for developing a comprehensive system of indicators for assessing the sustainable development of resources:

- Reflection of the key domains of sustainable development, which are environment, economy, and society (if necessary, other domains can be added depending on the specific features of the object under consideration);
- Balance between the components of sustainable development;
- Sufficiency of indicators to ensure an objective assessment of sustainable development;
- Measurability of indicators to ensure that they are comparable;
- Mutual exclusion and complementarity of sustainable development indicators;
- Ease of interpretation and reliability of the results;
- Factoring in the specific features of the objects under study.

2.2. Development of Oil and Gas Resources in the Arctic: Sustainability Assessment

It is a common fact that the development of the Arctic's oil and gas resources is associated with significant difficulties, which creates fundamentally new requirements for management and makes it necessary to use special approaches to assessing the sustainability of this process.

In recent years, the global scientific community has been demonstrating a growing interest in the development of oil and gas resources in the Arctic despite the ongoing discussions about the changing role of traditional energy sources and the growth in turbulence in the global energy sector (price volatility, predicted reduction in demand for traditional energy sources, etc.) [6]. At the same time, the emergence of trends towards environmental friendliness means that for the successful implementation of Arctic projects, it becomes insufficient to focus solely on economic results. The scale of projects for the development of the Arctic's resources encompasses not only the volumes of production but also the impact they have on the region, including its social and environmental parameters.

Whether it is possible to exploit natural resources in a sustainable manner has been a controversial topic for many years. In his study, S. Kirsch comes to the conclusion that sustainable extraction of non-renewable resources is impossible [18]. B. Kristoffersen and O. Langhelle argue that the development of the Arctic's resources contradicts the environmental aspect of sustainable development [19]. Amezaga at al. assume that the process of natural resource development can be compatible with the principles of sustainability if the long-term benefits (environmental and/or social and/or economic) are equal to or exceed the values that existed before resource development started [20]. M. Jacobsen notes that despite the conflicting ideas about how the development of the oil and gas sector in the Arctic will affect solving regional and global problems, the concept of sustainability is becoming an integral part of exploiting the Arctic's resources [21].

The sustainability has been identified as a main priority in the exploration of the Artic oil and gas reserves by the World Wildlife Fund (WWF) [22]. The reason for that is a fragility of northern eco-systems. Any production activities might cause an irreversible impact on the natural environment. Therefore, high level of ecological risks has to be taken into consideration. Not coincidently, the Arctic oil and gas projects are widely discussed through the prism of the rational use of mineral resources and a minimization of environmental threats [23,24]. The above literature review makes it clear that in the context of developing the Arctic's oil and gas resources, sustainability, as a rule, is reduced to its environmental domain. This is explained by the high risks of environmental consequences (such as oil spills and environmental pollution) and the impossibility to react promptly due to difficult climatic conditions.

High environmental standards require the need to implement Arctic projects in accordance with the principles of SD [25]. In 2020, a number of foreign banks—UBS (Zurich, Basel, Switzerland), Wells Fargo and Company (San Francisco, CA, USA) and Goldman Sachs (New York, NY, USA) announced restrictions on investments in offshore oil and gas projects, as they do not meet the targets of the climate agenda [26].

The relevant issue is that how to assess the level of the projects' sustainability. There is an approach to evaluate this criterion by conducting a comprehensive analysis of stakeholders [27]. In this case the important indicators are the target priorities of different groups, the tools for collaboration with parties involved, etc. Obviously, a balance of interests is a significant pillar, but it is not the only one.

Russian researchers widely discuss factors influencing the prospects for the implementation of Arctic projects. As a rule, economic efficiency is the most popular indicator [28]. Gazeev et al. propose a methodological approach to assessing the effectiveness of the implementation of Arctic projects that is based on assessing three domains (economy, innovation (technology), and environment). Despite the fact that the term 'sustainable development' is not used in this study, the very idea of moving away from focusing exclusively on financial and economic aspects when assessing the prospects for the implementation of Arctic projects corresponds to the concept of sustainability [29].

Patterns of sustainable economic growth at the state level differ significantly [30]. Of particular interest for the study are the definitions of sustainability criteria given by the Arctic nations. An analysis of their strategic documents allows us to say that they prioritize the environmental aspects of the operation of oil and gas fields and pay a lot of attention to the protection of the indigenous peoples of the Far North. It is important to note the insignificant share of quantitative indicators for assessing sustainability.

Norway's current strategy titled 'Norway's Arctic Strategy—Between Geopolitics and Social Development' was adopted in April 2017 [31]. The main goal declared by the government for the long term is to make the northern territories of Norway the most innovative and sustainable region in the country. It has planned to achieve this through government support for businesses operating in the region, primarily those involved in offshore oil and gas production, the development of an efficient and environmentally friendly infrastructure, and strengthening the region's innovative potential.

Canada's Northern Strategy: Our North, Our Heritage, Our Future (2009) reflects the principles of sustainable development in protecting the country's environmental heritage and promoting the socio-economic development of the region. The strategy recognizes the important role of large oil and gas production projects in ensuring the economic sustainability of the northern territories and the well-being of indigenous peoples, as well as in the development of innovations [32].

While not being an Arctic nation, China believes that developing the potential of the Arctic associated with resources, logistics, and research directly affects its environmental, economic, and public interests and is important for the sustainable development of the country. In 2018, a white paper titled 'China's Arctic Policy' was approved [33]. The document notes that the need to combine the development of natural resources, environmental protection, and solving the problems of climate change has become the main contradiction in the modern management of the Arctic. The principle of SD proposed in the document reflects China's desire to ensure a balance between the exploitation of natural resources, environmental protection, and social development of the region.

In contrast to the strategies discussed above, Russian documents regulating the country's interests in the region [34,35] present quantitative indicators for development assessment. It is important to note that along with the target indicators focused on the intensive development of the resource potential of the Arctic (oil, gas, and LNG production), the desired values are presented that reflect the key SD principles (investments in the protection and rational use of natural resources, costs of technological innovations, social metrics).

A number of studies attempt to identify sustainable development indicators applicable to the oil and gas industry, including to its Arctic sector.

V.V. Biryukova proposes a methodology for rapid assessment of the level of sustainable development of oil companies without the use of expert assessments. It is based on equally weighted economic, social, environmental, and innovation indicators [36].

Varfolomeev et al. propose to use as an aggregate indicator the sum of normalized values of sustainable development indicators that are calculated based on data from open reports. According to the authors, it is the aggregate indicator that makes it possible to compare oil and gas companies at the national and international levels [37].

In his dissertation, N.S. Kondratenko [38] developed an aggregate indicator of the efficiency of the development of offshore resources in the Arctic based on a multi-criteria analysis of environmental, social, economic, and technological groups of factors. The study emphasizes the importance of the ecosystem and innovative approach, focusing on the need to realize the socio-economic potential of offshore projects when designing a model for the step-by-step development of offshore oil and gas resources.

Ponomarenko et al. offer a methodology for assessing corporate sustainability and changes in the sustainable development of oil and gas companies. The choice of target indicators is substantiated by the need to assess the impact in three areas (economy, ecology, and the environment) and to analyze the long-term development of the company (by analyzing its revenue, profitability, and natural resource assets) [39].

In addition, a wide range of works are devoted to the search for principles and criteria for sustainable development of the Arctic regions [40], including aspects of social development [41,42], issues of territorial and industrial development [43], the specifics of the economy [44], factors that support or weaken the stability of the Arctic [45,46], and the adaptation of global sustainable development goals to northern conditions [47].

It should be noted that despite the fact that the problem of the SD of the Arctic's oil and gas reserves is discussed at the national and global levels, there are no uniform approaches to assessing the degree of sustainability. It is not clear what indicators are required to be used, how to calculate them, and how to interpret the results.

Sustainability in the context of developing the Arctic's oil and gas resources should move from the category of abstract concepts to a category that provides for making comparisons and can be assessed. The first step in this direction should be the development of a system of indicators reflecting the sustainability of the development of the Arctic's resources and taking into account the generated effects and prerequisites for the transformation of the environmental, economic, and social domains at various levels.

3. Issues Associated with the Sustainable Development of Oil and Gas Resources in the Arctic

Published in 1987, the report titled 'Our Common Future' [48] defined the new foundations for the view of the world and proposed a universal model of development, the focus of which is the balance of economic, social, and environmental components. The concept of sustainable development started to be adopted by the oil and gas industry as an important subsystem of the economy that has a significant impact on the economic development of society and the quality of the environment. Initially, the focus was placed on studying the issues of environmental safety in resource exploitation [19]. In 1996, the establishment of the Arctic Council contributed to documenting SD principles for the Arctic regions [49]. In 2013, on the occasion of the Eighth Ministerial Meeting of the Arctic Council, the Kiruna Declaration recognized the "importance of the sustainable use of resources" in the Arctic [50]. In a later interpretation, the SD philosophy was reflected in the Sustainable Development Goals (SDGs) described in the UN's strategic documents for 2012–2015 [51,52]. Since then, the oil and gas sector, which is going through a crisis, has demonstrated a shift from the desire to maximize the traditional quantitative indicators to qualitative development and a new concept of values. In 2017, the report titled 'Mapping the Oil and Gas Industry to the Sustainable Development Goals: An Atlas' reflected the relationship between SD goals and oil and gas production, presenting examples and practices of including SDGs in the business operations of oil and gas companies [53].

Traditionally, sustainable development is understood as development that meets the needs of the present without compromising the ability of future generations to meet their own needs [48]. The modern interpretation is most accurately expressed by R. M. Nurtdinov and A. R. Nurtdinov, defining it as a qualitatively new stage in the evolution of ecological and economic relations that is associated with building a harmoniously organized society that is able to ensure an equilibrium and balanced interaction of environmental, social, and economic factors of development [54]. Sustainable development and sustainability are often viewed as synonyms, but there are differences between them [55]. M. Diesendorf defines sustainability as the target, or the desired outcome of the sustainable development process [56].

Sustainable development of oil and gas resources as a concept is characterized by complexity and multidimensionality. As a result, there is no unanimous agreement as to how to understand its essence. Research devoted to this issue focuses on the theoretical substantiation and development of methodological approaches to assessing the level of sustainability. As a rule, scientific articles contain an analysis of individual aspects of the generally accepted concept of SD in the context of the resource sector, and the sustainability indicators discussed do not form a system. Neither do they take into consideration the global instability affecting the energy sector.

In addition, it is important to note that the sustainable development of the hydrocarbon potential of the Arctic regions has not received much attention. Today, there is a limited understanding of the possibilities of implementing SD principles in the development of the Arctic's oil and gas resources, and not enough rationale is provided to justify priorities when ranking economic, social, and environmental problems. Consequently, there is no generally accepted methodology for SD assessment.

The need to identify criteria and assess the sustainable development of the resource potential of the Arctic is determined by the uniqueness of the territory in comparison with traditional production regions [57,58]. The nature of ecosystems, the high complexity of operations, the need to use innovative solutions, and the heterogeneity of socio-economic processes in the region require the integration of sustainable development principles into the strategic management of the oil and gas sector of the Arctic [59].

A number of mutually complementary goals follow from the concept of sustainable development such as preservation of the natural environment, economic and technological development, social well-being, etc. Experts note that there is often no balance between the formulated guidelines. How to ensure that different development directions are interconnected? Which aspect should be prioritized? The weakness of the concept of sustainable development is highlighted by C. Humrich, who argues that it has not managed to solve the problem of striking a balance between environmental aspects, economic growth, and social justice [60]. In the context of the development of oil and gas resources, particularly those in the Arctic, the conflict of goals becomes especially prominent. On the one hand, as the economy of the region focuses on providing raw material, extraction of hydrocarbons seems to be a solution to socio-economic problems. On the other hand, it leads to significant negative consequences for the environment. Developing a multi-criteria system for assessing the sustainable development of oil and gas resources that will ensure a balance between environmental safety, economic benefits, and social interests is the top priority at the current stage of the development of the Arctic.

In addition to the three generally accepted sustainable development principles, we consider it necessary to take innovative upgrading into account and consider the sustainability of the development of the Arctic's hydrocarbon resources as interrelatedness of environmental and socio-economic aspects and technological innovation.

3.1. Environmental Sustainability of the Development of Oil and Gas Resources in the Arctic

Governments, energy market players, and scientific communities show a special interest in the exploitation of oil and gas fields in the Arctic. This is explained by the need to solve the environmental and climatic problems associated with the development of the Arc-

tic's resources as there is data on the rapid melting of ice in the region. Also, carbon-neutral practices, resource efficiency, and low energy intensity are becoming more important. Environmental friendliness in resource exploitation is becoming vital as international credit organizations deem oil and gas production projects in the Arctic dangerous and the largest hydrocarbon exporters switch to environmentally friendly energy sources [61–64]. Focusing on environmental priorities in the Arctic is seen as an important component of the national ideas of the leading oil and gas producing countries and an element of the international identity of the largest companies in the energy market.

Bobylev et al. point out that development based on environmental degradation cannot be sustainable in the long term [65]. Today, oil and gas operations in the Arctic, especially offshore ones, are seen as the key factor accelerating the growth rate of greenhouse gas emissions, causing pollution of natural systems, and creating man-made disasters [66]. In this regard, an increasing number of experts declare that the production and transportation of hydrocarbons in the Arctic contradicts the environmental dimension of sustainable development and violates the fundamental requirement not to endanger the natural systems that support life on Earth [19,67]. Russian researchers recognize the importance of oil and gas production for the country's economy, while also noting the potential danger of the implementation of large-scale production and infrastructure projects for the sustainable development of the Arctic [68].

Researchers are especially concerned about the offshore production of hydrocarbons in the Arctic, which may lead to a reduction in the biological diversity of the Arctic flora and fauna. Melting of perennial ice provides opportunity for large-scale implementation of oil and gas projects, causing a conflict between economic and environmental interests [69,70]. Many of the largest oil and gas companies share this fear and are shedding volatile assets. For example, in 2015, the Norwegian company Equinor (Statoil) withdrew from the offshore projects in the Chukchi Sea [71]. In 2017, the British BP announced the sale of its assets in Alaska [72]. This makes it is necessary to consider the main conditions that determine the environmental sustainability of the development of oil and gas resources in the Arctic.

Oil and gas projects in the Arctic can become more focused on the environment by the use of technological innovations and environmentally friendly methods of production and transportation of hydrocarbons, as well as by adjusting production processes to northern conditions [73]. Improving the procedures for preventing and responding to negative consequences caused by industrial activity and modeling possible accident scenarios will reduce the environmental risks of oil and gas projects [74]. In addition, considerable attention should be paid to the approach taken by resource users to the integration of the principles of environmental safety of production in their business models, the development of an environmental management system, and compliance with national and international environmental standards [75].

The most important aspect of environmental sustainability in the development of hydrocarbon resources is the fight against climate change by reducing greenhouse gas emissions. Emissions from the oil and gas sector account for 12% of total global emissions, having increased by 5% over the past 15 years [61,76]. The climate agenda is especially relevant for the Arctic region, where the rate of warming is twice the global one [77]. Decarbonization of the oil and gas industry is a complex and multi-level process. An efficient and economically attractive way to reduce emissions of greenhouses gases implies using energy resources rationally and monetizing gas resources (methane and associated petroleum gas (APG)) instead of wasting them in the form of emissions and flaring. In addition, great opportunities are opening up due to the electrification of oil and gas operations using renewable energy, the production of hydrogen for industrial needs, and the transition to low-carbon fuels for transporting the extracted materials [61]. The rational use of energy resources is of particular importance. Today, energy efficiency is an important environmental, technological, and socio-economic indicator of the development of society, which occupies an important place in the forecasts of industrial policy. The ideology of

energy efficiency replaces the paradigm of unlimited and inexhaustible natural potential with the principles of SD and the need to provide resources for future generations.

Global practice uses emissions trading as an effective mechanism for reducing CO_2 emissions. In Russia, the quota system is being tested in a number of regions [78]. The topic of carbon regulation for the Russian oil and gas industry has become especially relevant after the announcement of the EU's plans to introduce a cross-border carbon tax. Boston Consulting Group experts predict an additional burden on the Russian oil and gas industry in the amount of $1.4–2.5 billion [79]. The development of the country's own system for monitoring the carbon intensity of production will create incentives for decarbonization and sustainable growth of the oil and gas sector and optimize costs to remain competitive in global markets. In the long term, the primary environmental initiative in the oil and gas industry will be carbon capture, utilization, and storage (CCUS) [61,80].

Thus, with a certain transformation, the development of oil and gas resources can meet the climate agenda. This is confirmed by the analysis of the industrial development of Russia's four Arctic regions, which demonstrates a downward trend in greenhouse gas emissions against the background of growing production volumes (Figure 1).

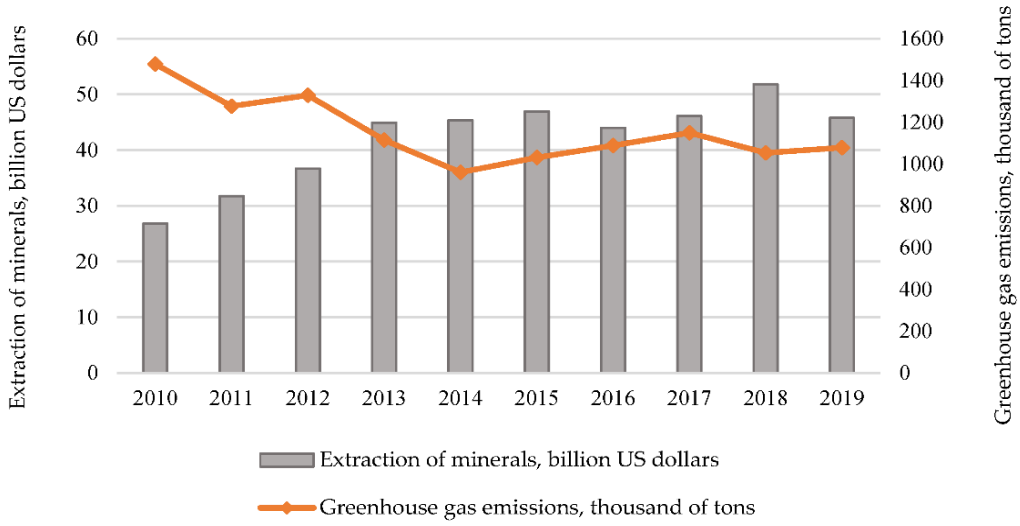

Figure 1. Changes in resource extraction and greenhouse gas emissions in the Russian Arctic. Source: created by the authors, data from [81,82].

Rodionova et al. note the important role of government policy in the use of natural resources and the growth in hydrocarbon reserves in the Arctic [83]. Improving legislation, developing infrastructure for monitoring the state and of the environment and pollution levels, developing uniform measures for making oil and gas production greener are important steps towards sustainable development of the oil and gas sector. The creation of specialized government and corporate environmental funds based on the use of "green" financial instruments seems promising. This will increase investments in environmental protection, including the mitigation of previously caused damage.

Fulfilling these conditions is a foundation for the environmental sustainability of the development of the Arctic's oil and gas fields. Environmental sustainability can be defined as protecting and preserving the natural environment and ensuring the quality of life and human health while deriving benefits from the use of hydrocarbon resources. This concept implies coordinating actions associated with designing oil and gas facilities, scientific and technological development, and institutional changes.

3.2. Socio-Economic Sustainability of the Development of Oil and Gas Resources in the Arctic

It is without doubt that socio-economic sustainability is an important component in the sustainable development of the oil and gas sector. However, there are different opinions regarding its essence.

Economic development of the industry is associated with deriving profits while sustainable growth is associated with creating economic value and an increase in production. A.O. Nedosekin, E.I. Rejshahrit, and A.N. Kozlovskij define economic sustainability as a property of economic systems to achieve strategic goals set by the strategy period in terms of external and internal challenges of negative and positive direction [84]. Consequently, it can be assumed that the economic sustainability of the development of hydrocarbon resources can be determined by the stability of the income of both oil and gas companies and the country in conditions of high turbulence in the industry.

Today, oil and gas projects are being implemented against the background of high instability and rapid changes in the global energy system (Figure 2). The situation worsened in 2020 when the COVID-19 pandemic exacerbated the imbalance in the market. Global consumption of oil decreased by almost 9%, and that of natural gas fell by 2% [85]. Energy prices hit historic lows. It is predicted that price and demand volatility are here to stay as there is no confidence in the scenario of the global economic recovery [86].

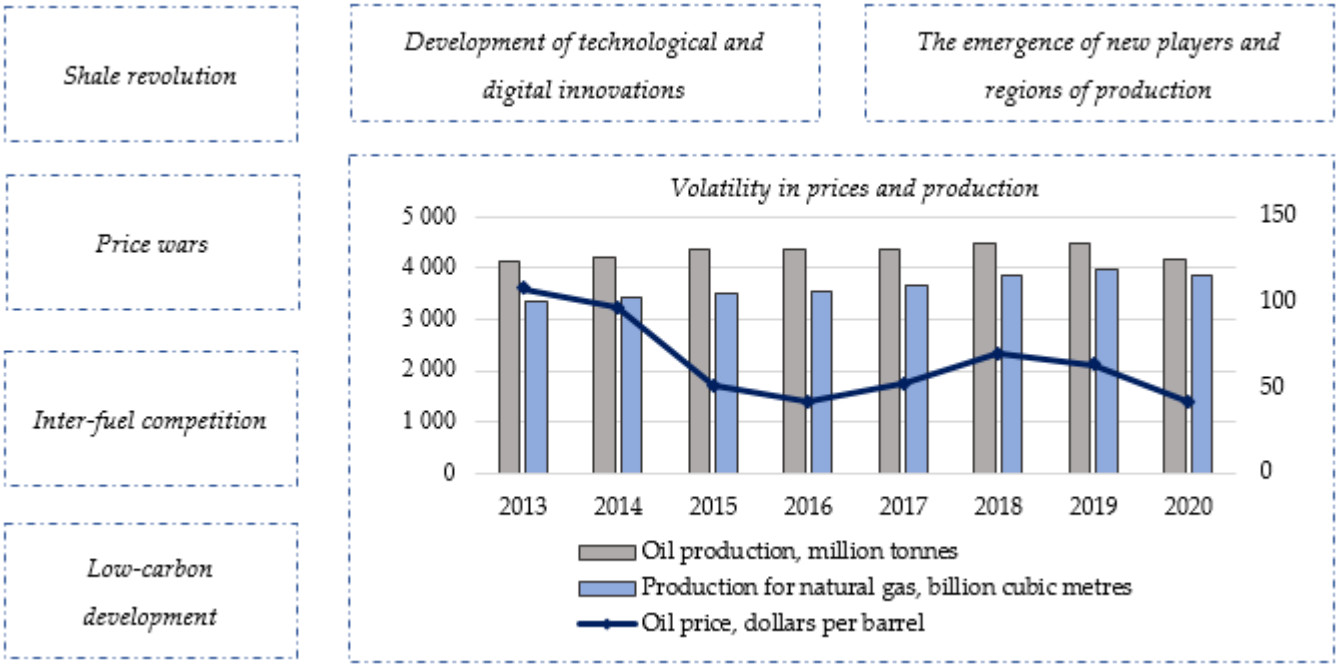

Figure 2. Factors of global instability and changes in the key indicators of the global oil and gas market. Source: created by the authors with the use of [87].

At the end of 2020, Russia's oil and gas revenues fell by more than 33% compared to the previous year, with the share of the oil and gas sector in the country's GDP decreasing by 4%. Experts note that these trends are associated with a collapse in prices and a decrease in the volume of hydrocarbon exports caused by a drop in demand in traditional markets [88]. Russian oil and gas companies, despite the fact that their financial results were positive in 2020, showed a significant decrease in net profit and production volumes.

The turbulence of the oil and gas sector and current trends in its development affect the economic sustainability of capital-intensive and high-risk Arctic oil and gas projects the most. The cost of oil production in the Arctic ranges from $50 to $100 per barrel, the lower values being relevant only for projects either on land or in the western Arctic where the waters do not freeze [4]. Therefore, in the current conditions of market development, the prospects for the study and development of the Arctic are associated primarily with

onshore fields and the most promising projects in coastal and transit zones near production areas with well-developed infrastructure.

Researchers believe that the development of deep-water hydrocarbon reserves will be expedient only if the conditions in the global energy market are favorable [89]. However, improving the economic sustainability of the development of the Arctic oil and gas resources is possible not only when prices for energy resources are high. Introducing innovative technologies and solutions, creating production infrastructure, and overcoming logistics communication challenges can result in a significant reduction in production costs. Ensuring that the taxation system is flexible and creating a set of measures to stimulate investment in the Arctic oil and gas sector are of no small importance.

There is another approach which states that economic sustainability is not only an increase in wealth. It argues that the intensification of production activities should contribute to the socio-cultural development of society [90]. With regard to the Arctic region, experts note that in addition to the direct economic benefits from the implementation of oil and gas projects, a pronounced multiplier effect is created [43]. It manifests itself in growing research and technology potential associated with innovative technologies, infrastructural development of the northern territories, demand for products created in related industries, new jobs for highly qualified staff, and better indicators of socio-economic development of the northern regions.

As the economy of the Russian Arctic heavily relies on resource extraction, the socio-economic development of northern regions is highly dependent on how well the resources sector functions [91]. The focus on raw materials is reflected in the high share of hydrocarbon production in both the gross regional product (GRP) and tax revenues and has a significant impact on the living standards and employment indicators in the region. It is predicted that the priorities for the long-term development of the Russian Arctic will continue to be associated with creating opportunities for growth in the oil and gas sector. In the government policy, the development of the oil and gas sector is considered primarily in the context of its expediency and contribution to the socio-economic development of the macroregion [34,35].

Thus, the sustainable development of the Arctic's resource potential seems to be the foundation of a stable regional economy that has the ability to adapt to challenges. In this regard, the socio-economic sustainability of the development of hydrocarbon resources in the Arctic correlates with quantitative indicators of regional development, such as GRP, employment, and household income.

At present, the Arctic regions vary greatly in their socio-economic indicators, which goes against the strategic objectives of government policy and the needs of the population. Large-scale development of hydrocarbon resources will lead to an increase in the economic indicators of regional development, such as GRP, tax revenues, and investment in fixed assets. In addition, the exploitation of the hydrocarbon fields will give impetus to the development of related industrial sectors, such as the petrochemical industry, shipbuilding, and mechanical engineering. It will also stimulate the development of small and medium-sized businesses and give a sour to entrepreneurial activity in the region.

Human resources are recognized as one of the most important factors in the development of the Arctic. Today, the Russian Arctic is characterized by a difficult demographic situation with a high population decline rate, significant unemployment figures, limited and low-quality social services, and a mismatch between the qualifications of the local population and the needs of the market in the absence of a specialized vocational education system [92]. The income level of the population does not compensate for the costs of living in the Arctic. The ranking of regions by quality of life reflects the Arctic's low position, which is exacerbated by uncomfortable living conditions. Table 1 shows the key socio-economic development indicators of the Artic regions.

Table 1. Indicators of social development of the Arctic regions in 2019.

Region	Migration Rate	Unemployment Rate, %	Population Income Rank (of All Russian Regions)	Quality of Life Rank
Murmansk Oblast	−6.5	5.4	12	36
Republic of Karelia	−13.8	7.4	28	73
Arkhangelsk Oblast	−0.9	6.2	19	74
Nenets Autonomous Okrug	1.8	7.9	3	66
Komi Republic	−20.9	6.8	18	69
Yamalo-Nenets Autonomous Okrug	−2.4	1.9	2	12
Krasnoyarsk Krai	−3.9	4.5	26	38
The Republic of Sakha (Yakutia)	−3.4	6.9	11	70
Chukotka Autonomous Okrug	11.1	3.8	1	68

Source: Created by the authors, data from [82,93]).

In view of the above, a number of experts highlight that intensifying oil and gas production in the macroregion will bring benefits in terms of socio-economic consequences for the population [94]. This is reflected in improving the quality of life and well-being of residents of the Arctic regions, ensuring positive demographic processes, creating conditions for the effective use of highly qualified labor and developing competencies, building an effective social infrastructure, and reducing the stratification of society in terms of income. The increase in employment in high-tech industries, in turn, will intensify the development of the education system and research activities.

The socio-economic sustainability of the development of oil and gas resources in the Arctic covers a wide range of interests, from economic benefits for oil and gas producers and the state to new incentives for the socio-economic development or regions to improved well-being of the population. As there are several stakeholders, it leads to goal conflicts [95]. The biggest conflict between the interests of the state and those of the regions lies in the distribution of oil and gas revenues. The key issue is how to preserve the habitat and traditional forms of economic activity of the indigenous population of the Arctic regions while boosting industrial activity. At the levels of the state and the population, the importance is emphasized of providing the indigenous peoples of the North with access to energy sources, respecting the right to a healthy environment, and giving the local population the opportunity to participate in decision-making. Experts note that it is necessary to improve the legal regulation of interaction between indigenous peoples and industries in Russia, and it is important for oil and gas companies to pay greater attention to social responsibility [96].

3.3. Innovative Sustainability of the Development of Oil and Gas Resources in the Arctic

The relationship between the widespread use of innovation and SD has been confirmed in many studies [97,98]. Technological innovations are recognized as the most important tool for sustainable development [99,100], especially in the field of resource extraction [101]. The role of innovation is significant for the sustainable development of the oil and gas potential of the Arctic and its offshore hydrocarbon fields [102].

For the effective development of oil and gas resources in extreme northern conditions, it is necessary to ensure that a number of complex technological and managerial problems are solved in such fields as geological exploration, oil and gas production, and transportation. The oil and gas sector is one of the drivers of innovations and one of the leaders in their implementation. The Arctic zone is a promising testing ground for creating new scientific knowledge and testing knowledge-intensive hydrocarbon production and transportation methods and environmentally friendly production technologies.

The innovative sustainability of the oil and gas sector implies a continuous accumulation of organizational, technological, and marketing changes aimed at improving the efficiency of business processes, reducing losses and costs, using resources rationally, and minimizing negative impact on the environment. Of particular importance are innovations for the development of the Arctic's offshore hydrocarbon fields, for which it is impossible to use technical solutions tested on land. The development of the offshore reserves requires introducing innovative technologies for offshore engineering and geological surveys, creating high-tech offshore structures, applying modern methods of conceptual design, and using advanced oilfield services.

Effective tools for the innovative development of the oil and gas sector include implementing joint projects with foreign partners, localization of production, and transfer of technologies to Russia. Also, innovative upgrading implies creating favorable conditions for science and research. Integration of the experience and competencies of oil and gas companies, universities, and research centers can ensure the creation of scientific and technical developments that are novel and breakthrough in nature. As experts note, only those entities in the oil and gas sector have prospects for sustainable development that are able not only to adopt in a timely manner global innovations in science and technology but also to create their own innovations [103,104].

The growing role of digitalization has a particular impact on the development of the oil and gas sector [105,106]. The largest oil and gas companies are highlighting digitalization as a strategic priority and are expanding the practice of using modern digital tools to solve applied problems in the Arctic. Introducing digital initiatives and technologies, optimizing information flows, and developing effective digital transformation management systems are becoming the foundation for the sustainable development of the oil and gas industry in the Arctic. Offshore projects need digitalization the most, which is due to the remoteness of the offshore fields from the mainland, high construction and operation costs, special requirements regarding occupational and environmental safety, and the growing complexity of drilling technologies. In such conditions, operations should be as efficient as possible, and decisions should be made promptly.

Currently, Russian oil and gas companies have a shortage of environmentally and commercially efficient technological solutions and engineering surveys for exploration and development. The US and EU sanctions that were introduced in 2014 greatly limit Russia's access to technologies and investments from other countries [107]. In addition, the problem often lies not in replacing foreign equipment with domestic alternatives, but in creating technologies from scratch to suit the Arctic's specific conditions. This requires significant financial and time resources.

Nevertheless, it is worth noting that the sanctions have also brought obvious advantages for the development of Russian high-tech oil and gas equipment and services. Over the past few years, the implementation of a new scientific and technological policy in the oil and gas industry has intensified cooperation between oil and gas producers, federal authorities, research institutes, and machine-building companies on the design and testing of technical systems for hydrocarbon production. For oil and gas companies, technological challenges present new opportunities for improving their professional competencies and future development [104].

The importance of innovative sustainability in the development of oil and gas resources in the Arctic can hardly be overestimated. Making the development of the Arctic territories knowledge-intensive will significantly reduce oil and gas production costs, ensure that production processes are environmentally friendly, expand the exports of high-tech products and services, and create great demand for scientific knowledge and products created by related industries.

3.4. The Relationship between Environmental, Socio-Economic, and Innovative Sustainability of the Development of Oil and Gas Resources in the Arctic

Based on the above analysis, it can be concluded that the rich resource potential of the Arctic regions is not a factor of sustainability in itself. Sustainable development of

oil and gas resources is a complex system in which all elements are interconnected and have mutual influence. Thus, making oil and gas production greener contributes to the realization of the right of the Arctic population to a favorable environment. In addition, improving the environmental performance of economic activities will allow oil and gas companies to save significant amounts of money on cross-border hydrocarbon regulation, improve their image in the global energy market, and attract investment. There is no doubt that the awareness of the necessity to preserve the unique Arctic ecosystems and reduce climate risks is a driver for innovative upgrading in the oil and gas sector and the development of the relevant research sector. Introducing more innovations in the oil and gas industry will result in economic growth and sustainable economic development of the Arctic regions due to the increase in GRP, fixed assets and employed figures. In turn, economic growth creates effects for the social sphere in the form of improving the quality of life and well-being of the population (Figure 3).

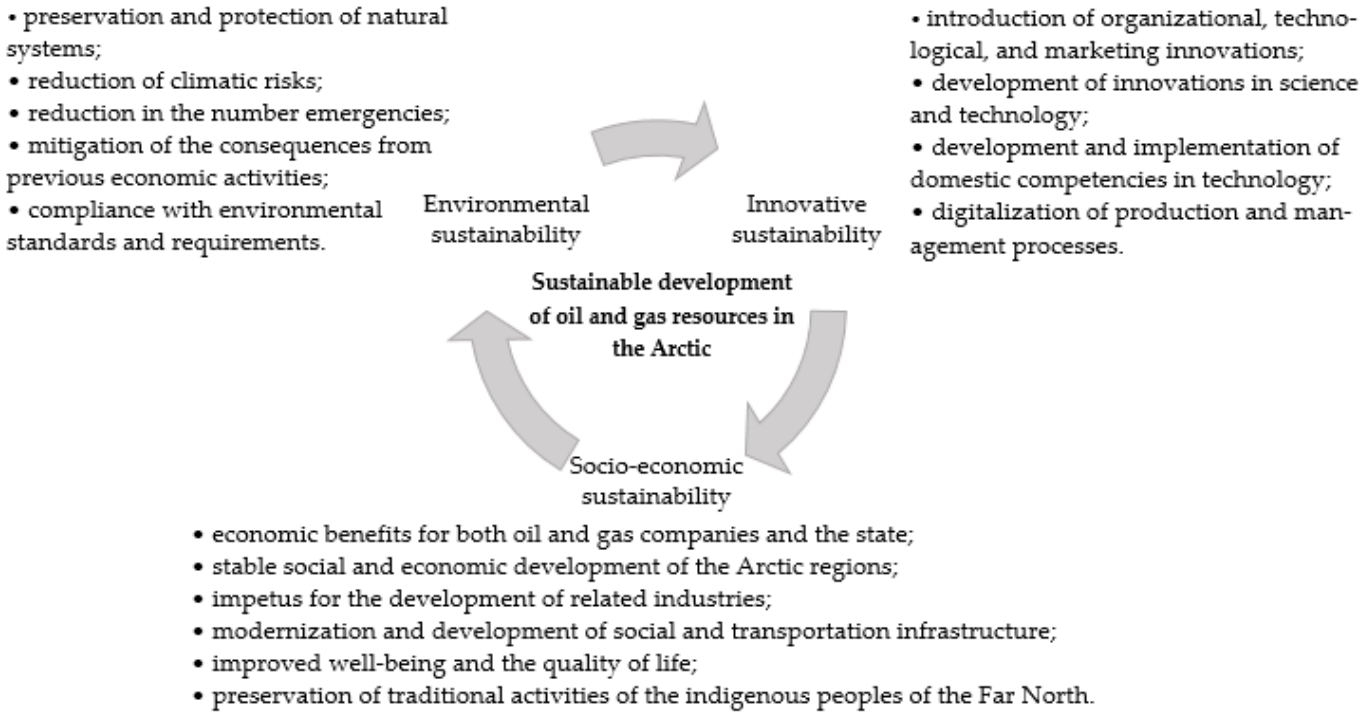

Figure 3. Environmental, socio-economic, and innovative sustainability of the development of oil and gas resources in the Arctic. Source: created by the authors.

Thus, in our opinion, the sustainable development of oil and gas resources can be defines as follows: it is rational and cost-effective production and transportation of hydrocarbons that ensures high environmental safety standards and has a beneficial effect on socio-economic processes.

4. Results

Most Russian onshore oil and gas reserves are located in the Yamalo-Nenets Autonomous Okrug. As a lot of geological surveys have already been conducted there and the region is located close to the existing transportation infrastructure, it produces almost 6% of Russian oil, 77% of NGLs, 81% of and natural gas (20% of the global production) [108]. The active growth in production in the region was caused by the launch of a number of large infrastructure projects (the Arctic Gates oil-loading terminal, the Zapolyarye-Purpe oil pipeline, and the Bovanenkovo-Ukhta gas pipeline). As the region has access to the Northern Sea Route, it creates conditions for supplying both western and eastern markets with oil and gas products. In addition to the Yamalo-Nenets Autonomous Okrug, big

hydrocarbon reserves are located in the Nenets Autonomous Okrug (oil), Krasnoyarsk Krai, and the Republic of Sakha, or Yakutia (gas).

However, Russia sees its main long-term prospects in the development of offshore oil and gas resources in the Arctic, where the total recoverable reserves are estimated at 120 billion tons of oil equivalent. Experts predict that by 2050 the Arctic shelf, whose reserves are estimated at more than $20 trillion, will account for about 20–30% of Russian hydrocarbon production [109]. Due to the high complexity of the implementation of offshore projects, production volumes in the northern waters are currently not very big. Commercial offshore oil production in the Arctic is carried out by Gazprom Neft at the Prirazlomnoye field in the Pechora Sea; gas is not produced. The development of the Prirazlomnoye field is the first Russian project for the offshore production of hydrocarbons in the Arctic.

Gazprom holds the largest number of licenses for the development of Russia's Arctic shelf. The company, using an integrated cluster approach, is actively conducting exploration surveys in all its license areas in the Arctic. The cluster method will make it possible to form a unified approach to the arrangement of facilities within each of the clusters, eliminate unreasonable economic costs, prioritize the implementation of priority projects and, in the future, will make it possible to set a standard for the industrial development of offshore resources.

In the next three years, Gazprom plans to complete geological exploration on the Priyamal shelf of the Kara Sea. It also plans to prepare the Leningradskoye gas condensate field for the commercial development gas reserves, where it is supposed to test deep-water production equipment developed in Russia. The Rusanovskoye gas condensate field is located 70 km north of the Leningradskoye field. Proximity to the already developed onshore areas will allow the company to optimize the costs for the development of the Leningradskoye and Rusanovskoye fields through the use of the existing onshore gas production infrastructure. Another promising offshore project implemented by Gazprom in the Kara Sea is the Kamennomysskoe-Sea field. Its key facility will be a special ice-resistant offshore platform, the construction of which began in June 2020. Gas production is planned to start after 2025 [110].

According to the Strategy for the Development of the Arctic Zone of Russia and Ensuring National Security until 2035, which was approved in 2020 [35], it is predicted that by 2035 the share of oil produced in the Arctic in the total volume of oil production in Russia will grow and reach 26%, there will be a tenfold increase in the volume of LNG production, and the level of gas production will remain high. To achieve these targets, huge steps are being taken by the government. New mechanisms are being developed to support the investment attractiveness of Arctic projects, a system of tax preferences has been created, a logistics infrastructure is being developed, projects are being implemented to create and localize equipment and production technologies, including those for offshore operations, and research in the development of Arctic resources is being stimulated.

At the same time, in addition to expanding the resource base and assessing the economic effect of the development of the Arctic, it is necessary to answer equally important questions. Is it possible to extract Arctic oil and gas resources, especially on the continental shelf, without damaging the environment? How will oil and gas production affect the socio-economic development of the Arctic regions and the well-being of the local population? Will the experience in the development of the Arctic's hydrocarbon reserves contribute to the transition of the Russian economy to a path of innovative development? That is, will the development of the oil and gas potential of the Arctic be in harmony with the concept of sustainable development and sustainable in the long term?

To answer these questions, we have compiled a list of key tasks for the sustainable development of Arctic oil and gas resources, identified their relationship with the global SDGs, and calculated the corresponding indicators (Table 2). The proposed indicators reflect changes in the environmental safety of resource extraction, the socio-economic

efficiency of oil and gas production for regional systems, and the innovative activity of the Arctic oil and gas sector.

Table 2. Indicators of environmental, socio-economic, and innovative sustainability of the development of oil and gas resources in the Arctic.

Sustainable Development Challenges	SDG Goals	Indicators
Environmental sustainability		
Environmentally safe and resource-efficient use of the unique oil and gas potential of the Arctic zone.	SDG 6 Clean water and sanitation; SDG 7: Affordable and clean energy; SDG 13: Climate action; SDG 14: Life below water; SDG 15: Life on land.	1. The share of recycled and neutralized industrial waste in the total volume of waste, %; 2. The share of contaminated wastewater in the total volume of discharge into surface water bodies, %; 3. Energy intensity of GRP, kg of oil equivalent/10 thousand rubles.
Socio-economic sustainability		
Comprehensive socio-economic development of the region aimed at improving the well-being of the population and the development of regional economies.	SDG 1: No poverty; SDG 4: Quality education; SDG 8: Decent work and economic growth.	1. Volume index of GRP; 2. The share of the employed population in the average annual population, %; 3. Real population income, % of the previous year.
Innovative sustainability		
Creation and development of domestic oil and gas innovations based on fundamental and applied research and development.	SDG 9: Industry, innovation and infrastructure; SDG 12: Responsible consumption and production.	1. The number of advanced production technologies used; 2. The share of organizations implementing technological innovations; 3. The number of personnel engaged in research and development.

Source: created by the authors.

To assess environmental sustainability, in particular on the continental shelf, it is most important to analyze changes in the volumes of recycled and neutralized waste and contaminated wastewater discharge. Drilling fluids, drill cuttings, and huge volumes of wastewater with high concentrations of toxic substances can cause irreparable damage to surface and ground waters and other objects. In addition, we propose using the energy intensity indicator as an important aspect in the framework of the new climate agenda aimed at reducing air pollution by combustion products from carbon-containing fuels. The socio-economic sustainability of oil and gas production can be most objectively reflected by such important characteristics of the development of regional economic systems as the volume index of GRP, employment figures, and population income. Innovative sustainability, in our opinion, is reflected by the level of adopting advanced technologies and the development of innovations and research in the companies operating in the region.

According to forecasts of the development of the global energy market, it is expected that by 2035 the demand for oil and the share of oil in the global energy mix will decline [111]. At the same time, it is predicted that natural gas will remain competitive, especially in the face of growing demand in developing countries. In addition, technologies for the exploration, production, and transportation of gas are more environmentally friendly than the production of oil and solid minerals, ensuring the sustainability of the gas industry against the background of growing environmental awareness. This opens up great opportunities for natural gas and its products. Russian oil and gas companies are following the global trend of low-carbon development, implementing projects to increase the efficiency of natural gas use, diversifying directions and expanding the possibilities of using natural gas, including through the development of efficient technologies and the search for new niches in the market.

As of today, the hydrocarbon resource base of the Russian Arctic shelf consists mainly of natural gas. Oil accounts for just over 10%. Most of the gas resources are predicted to be located in the Kara Sea (60.6%) and in the Barents Sea (33.3%) [89]. Therefore, to verify the

indicator system, we are considering the prospects for the development of gas fields in the Russian Arctic, in particular offshore.

A major part of offshore gas fields are concentrated in the Yamalo-Nenets Autonomous Okrug. The development of the resource base plays a decisive role in the economy of the region. At the end of 2020, the extraction of resources accounted for more than 70% of the GRP, 97% of the total volume of industrial production, and 27% of the total employment [112]. Thus, the region's economy is predominantly focused on the production and transportation of hydrocarbons, which makes it vulnerable to transformations in the oil and gas sector and the instability of the global energy market.

Using data from open sources provided by Russian official statistics services, we studied the quantitative indicators of the development of the Yamalo-Nenets Autonomous Okrug for the 2014–2019 period within the framework of the proposed sustainability indicators (Table 3).

Table 3. Indicators of the development of the Yamalo-Nenets Autonomous Okrug within the framework of the proposed sustainability indicators.

	2014	2015	2016	2017	2018	2019	Correlation Coefficient
Natural gas production, bcm	516.2	507.8	509.3	560.1	601.5	607.7	
Environmental sustainability							
1	58.1	-	41.5	-	91.7	-	
2	57.0	-	85.2	-	78.6	-	
3	85.8	78.4	74.4	58.6	57.6	58.4	−0.9
Socio-economic sustainability							
1	105.7	98.1	105.6	107.8	114.8	105.9	0.7
3	73.2	73.7	75.2	78.2	77.2	77.8	0.8
4	98.3	98.4	99.8	102.5	102.0	103.5	0.9
Innovative sustainability							
1	3930	4052	3627	4354	4242	5178	0.8
2	7.3	6.3	6.8	16.0	15.0	13.2	0.9
3	98	109	112	116	134	129	0.9

Source: created by the authors using the data from [81,82,112].

To identify the relationship between the quantitative indicators and the volume of gas production in the region, we used the Pearson correlation coefficient, which reflects the cause-and-effect relationship between the parameters under study. The results confirmed the high dependence of socio-economic and innovative development on the intensification of gas production. The GRP energy intensity indicator decreases despite the increase in production (inverse correlation). This indicates positive trends in increasing the energy efficiency of production processes. The results of the correlation analysis for environmental sustainability indicators No. 1 and 2 seem to be incorrect due to the lack of data. The volume of contaminated wastewater discharge is quite high, but it does not increase with an increase in gas production. The significant amount of industrial waste is a major problem.

In recent years, a number of effective measures have been taken in the Yamalo-Nenets Autonomous Okrug within the framework of the government policy in the field of ensuring environmental safety. Among them are the establishment of special regimes for the use of natural resources and the protection of the environment, including pollution monitoring, land reclamation programs, and toxic waste disposal programs. As a result, by the end of 2020, the share of recycled and neutralized industrial waste in the total volume of waste in the region exceeded 105% (that is, the environmental damage previously

carried out was mitigated). Oil and gas companies operating in the region are introducing the best available technologies (i.e., economically affordable and environmentally sound solutions and methods aimed at laying the innovative and technological foundations for the sustainable development of the industrial sector).

Oil and gas producers also pay a lot of attention to solving environmental problems in the Arctic. The environmental safety and energy efficiency of the operating oil and gas facilities are being improved through the introduction of innovative technical and technological solutions.

In 2020, Gazprom reduced its gross emissions of pollutants into the air from stationary sources by 14.6%, and improved its associated petroleum utilization (98.2%). The total capacity of wastewater treatment plants is growing annually. By the end of 2020, the level of contaminated wastewater in the total volume of discharge decreased to 3%. In addition, energy efficiency of production processes was improved, which led to savings of 3.78 million tons of oil equivalent in 2020 [113].

The company has an effective environmental management system; there is a liability insurance contract for causing harm to the environment; industrial environmental control and monitoring is carried out; an open-ended biodiversity conservation program is being implemented to support the natural parameters of the unique ecosystem of the Arctic.

Environmentally sound disposal of drilling waste during the operation of wells is one of the main tasks of oil and gas companies implementing projects in the Arctic. To this end, design solutions are actively introduced into practice during the development of fields, which helps to minimize the impact on ecosystems in the process of drilling. Russian companies use pitless drilling technologies, technologies for processing drilling waste in sludge accumulators, and environmentally friendly drilling fluids.

The Prirazlomnaya offshore ice-resistant oil platform is an example of environmentally friendly oil and gas resource development on the Arctic shelf. The platform operates in accordance with the principle of zero discharge: after being used, drilling mud, cuttings, and other kinds of waste are pumped into a special absorption well. Water intake structures are equipped with fish protection devices. Oil or gas wells are equipped with blowout preventers.

In view of the above, one can argue that the importance of the environmentally sustainable development of oil and gas resources is recognized by both the government and Russian companies. They coordinate their efforts in making extraction and transportation process more environmentally friendly and ensuring the rational use of natural resources in accordance with the government priority for the innovative environmental development of the Arctic oil and gas sector.

To forecast gas production in the Yamalo-Nenets Autonomous Okrug until 2035 after three large offshore gas fields (Leningradskoye, Rusanovskoye, and Kamennomysskoe-Sea) have been commissioned, we used:

- Data from Gazprom's open sources on the development of offshore hydrocarbon production in the Kara Sea [110];
- Information from official documents on strategic planning in the Arctic regarding prospects for the development of the resource base of the Arctic waters [34,35];
- Data on the development of the fuel and energy sector of the Yamalo-Nenets Autonomous Okrug until 2035 [112].

Using regression analysis, we calculated the predicted values of the development of the Yamal-Nenets Autonomous Okrug in accordance with the proposed system of indicators of environmental, socio-economic, and innovative sustainability. Environmental sustainability indicators No. 1 and 2 were calculated using the information from strategic documents for the development of the Yamalo-Nenets Autonomous Okrug and data on the commissioning of production facilities and the upgrading of treatment facilities in the region, and the development of new methods of sludge waste disposal [81,112,113] (Table 4).

Table 4. Estimated values of the indicators reflecting the development of the Yamalo-Nenets Autonomous Okrug within the framework of the proposed sustainability indicators.

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Natural gas production, bcm	615	620	618	613	670	682	690	695	750	755	764	778	789	790	880
Environmental sustainability															
1	87.5	83.8	79.2	85.4	69.5	80.1	83.4	82.9	86.7	78.5	88.2	91.6	92.3	95.4	91.7
2	80.5	82.3	78.5	69.4	75.3	68.9	57.8	55.3	49.7	50.4	38.9	35.2	37.7	32.8	29.9
3	100.2	99.8	100.0	100.3	96.5	95.7	95.2	94.9	91.3	90.9	90.3	89.4	88.7	88.6	82.7
Socio-economic sustainability															
1	112.9	113.3	113.1	112.7	117.3	118.3	118.9	119.3	123.7	124.1	124.8	125.9	126.8	126.9	134.1
3	78.0	78.2	78.1	77.9	80.1	80.5	80.8	81.0	83.1	83.3	83.6	84.2	84.6	84.6	88.0
4	103.3	103.6	103.5	103.3	105.7	106.2	106.6	106.8	109.2	109.4	109.8	110.4	110.8	110.9	114.7
Innovative sustainability															
1	4827	4873	4855	4808	5336	5447	5521	5568	6077	6123	6207	6336	6438	6447	7281
2	14.6	15.0	14.9	14.5	19.0	20.0	20.6	21.0	25.4	25.8	26.6	27.7	28.6	28.6	35.8
3	135	136	135	134	149	152	154	155	170	171	173	177	180	180	204

Source: created by the authors based on the data from [34,35,81,110,112,113].

Figure 4 presents a graph reflecting the dependency of socio-economic development in the region on gas production, which is accompanied by the regression equations that were used.

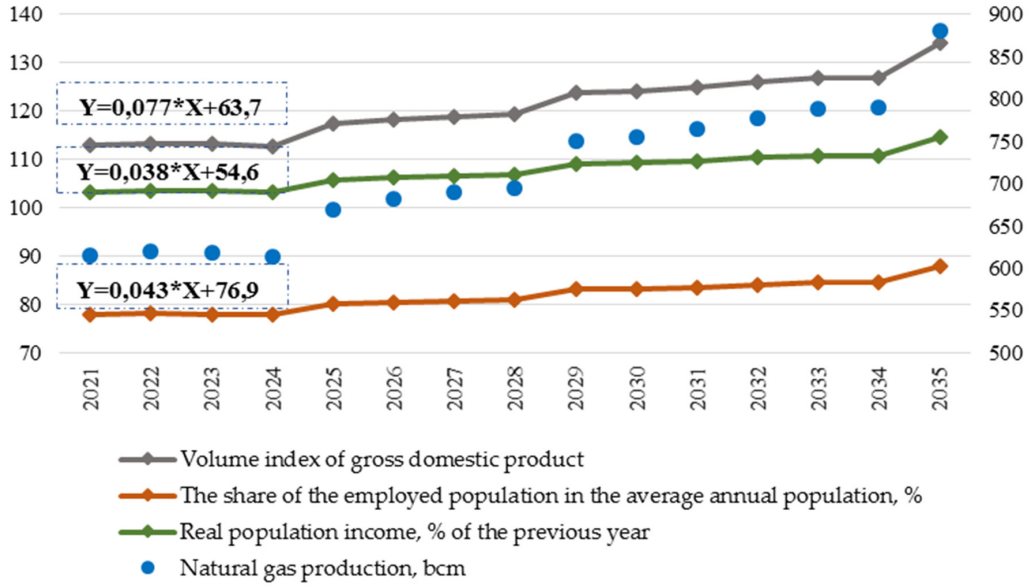

Figure 4. Forecast of changes in the indicators of socio-economic sustainability of the development of oil and gas resources in the Yamalo-Nenets Autonomous Okrug taking into account changes in gas production. Source: created by the authors.

5. Discussion

The development of oil and gas resources in the Arctic has long been a controversial issue. In addition to doubts about the economic feasibility of capital-intensive Arctic projects in the context of the unstable energy market and a decrease in both demand and prices for energy sources, primarily oil, the environmental and social aspects of resource extraction in the Arctic Circle are widely discussed. Finding a balance between the development of resource potential, preservation of the natural environment, and the stability of the socio-economic systems of the Far North is a truly global challenge. The sustainability of oil and gas production in the Arctic covers a wide range of issues: ensuring

domestic needs for hydrocarbons and stable exports, minimizing environmental damage, creating knowledge-intensive technologies and facilities, using production capacities to the fullest, developing transport and social infrastructure, creating new high-tech jobs.

The central place is occupied by the problem of environmentally safe extraction and transportation of resources. Today, there are still high environmental risks associated with the implementation of oil and gas projects, especially on the continental shelf, and with the expansion of trans-Arctic transportation. Oil spills and gas leaks during transportation can lead to catastrophic consequences for the northern seas. Large-scale production of hydrocarbons intensifies the process of global warming. Solving these problems is more important than obtaining economic and geopolitical benefits from the development of the Arctic.

The proposed system of environmental, socio-economic, and innovation indicators of the sustainable development of oil and gas resources in the Arctic reflects environmental safety priorities in resource extraction, targets for the development of regional economic systems, and ways of innovative development for the oil and gas sector. The system was developed taking into account the specific features of both offshore oil and gas project implementation and the regional development of the northern territories of Russia.

Ongoing analysis of the proposed indicators will make it possible to:

- Make conclusions about the possibility of developing the Arctic's hydrocarbon reserves in a sustainable manner;
- Identify problematic areas of development that limit the implementation of SD principles in developing the resource potential of the Arctic;
- Attract the attention of decision-makers at the national and regional levels;
- Adjust the priorities of oil and gas companies in the development of the Arctic's hydrocarbon fields, including offshore ones.

As follows from the analysis of the indicators reflecting the situation in the Yamalo-Nenets Autonomous Okrug, which is one of the top hydrocarbon producers, growth in production positively affects the social and economic state of the northern territories (by improving the economic activity in the region, the level of employment, and the well-being of the local population). Furthermore, it can be argued that the implementation of large-scale production projects is able to bring the Russian oil and gas industry to a high level of innovative and technological development, to ensure the development of demand for Russian research and production.

To test the proposed system of indicators, we analyzed the exploitation of gas fields located on the Arctic shelf, which can be successfully combined with the paradigm of sustainable development. However, the presented model cannot reliably predict the environmental sustainability of hydrocarbon production in the Arctic's deep waters. Therefore, in order to improve the system of indicators and make the assessment more relevant, the proposed criteria should be supplemented with environmental sustainability indicators, such as the level of renewable energy and hydrogen technology use in production processes, the share of extra payments in the total amount of payments for negative impact on the environment, the level of marine and biodiversity conservation measures, etc.

Socio-economic development parameters can also be supplemented. A more effective assessment of the sustainability of production in the Arctic will be obtained by taking into account the indicators of the development of competencies in the field of offshore oil and gas production, measures for preserving the habitat and traditional forms of economic activity of the indigenous peoples of the Far North, and progress in developing social and transportation in the region. Innovative sustainability can also be measured by adding such indicators as the development of fundamentally new Russian technologies for offshore production and the development of digital tools for solving production and management problems in the Arctic.

The authors suggest that the proposed system of indicators of environmental, socio-economic, and innovation sustainability can be used in making strategic decisions regarding the prospects for the development of offshore hydrocarbon resources in the Arctic.

6. Conclusions

The great importance of developing the resource and economic potential of the Arctic for the Russian economy makes both the government and oil and gas companies interested in the exploitation of the Arctic's resources. At the same time, the integration of the concept of sustainable development into the global energy system changes the principles and approaches to the development of oil and gas resources. Today, the key priorities include: (1) environmentally friendly production and transportation of hydrocarbons; (2) a high level of social responsibility and contribution to the socio-economic development of the regions where oil and gas companies operate; (3) economic efficiency of oil and gas projects. The authors also take into account the criteria for the innovative and technological development of the oil and gas sector as an important component of the sustainability of resource extraction in the Arctic.

For the purpose of the study, the authors analyzed the theoretical aspects of the sustainable development paradigm in the context of developing the Arctic oil and gas sector, as well as methodological approaches sustainability assessment. Within the framework of the study, we identified conditions for ensuring the environmental sustainability of the development of hydrocarbon resources in the Arctic, the specific features of social and economic development in the Arctic, and prospects for innovative upgrading in the Russian oil and gas sector.

The study made it possible to propose specific indicators for assessing the sustainability of the development of oil and gas resources in the Arctic. These indicators take into account the specific nature of the hydrocarbon potential of the Far North and individual offshore projects, the special aspects of developing regional economic systems, and the impact that the transformation of the global energy system has on the sector.

To analyze and assess the sustainability of large-scale offshore gas production in the Arctic and to test the proposed system of indicators, quantitative indicators of regional development over the past periods were analyzed. The use of regression analysis made it possible to develop forecasts for each of the indicators for the long term. The results of the study allow us to draw reasonable conclusions about the possibility of developing Arctic offshore resources based on the principles of sustainable development.

The primary recommendation for widening the scope of application of the proposed system is to expand the list of environmental sustainability criteria. The high environmental risks of Arctic oil and gas projects, the vulnerability of the northern ecosystems, and growing environmental awareness require special approaches to ensuring environmentally safe production and transportation of hydrocarbons in Arctic conditions. It is necessary to continuously monitor changes in the values of environmental sustainability indicator and set new goals in accordance with the development trends witnessed in the Arctic oil and gas sector.

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