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A Conceptual Model for the Sustainable Development of the Arctic's Mineral Resources Considering Current Global Trends: Future Scenarios, Key Actors, and Recommendations

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Abstract: Today, the issues of sustainable development are among the most pressing ones. They are particularly relevant in the context of mineral resource development as operations in this sector always have an impact on the environment and socioeconomic development. Developing the mineral resource base of the Arctic presents a difficult task, as it requires finding a balance between the growing demand in resources and the acute climatic and geopolitical challenges. In view of both the specific features of the region and the pressure caused by various trends and challenges, ensuring the sustainable development of the Arctic's mineral resource base is highly important. In 2022, the global landscape that consists of sustainable development trends, ESG agendas, and environmental awareness was supplemented by national import substitution policies introduced in many strategic industries, which led to an inevitable increase in demand for mineral resources. This substantiates the importance of the research goal—developing a model for the sustainable development of the Arctic's mineral resource base that will produce quantitative results and provide key actors with reasonable recommendations for restructuring the priority areas of development.

Keywords: sustainable development; Arctic region; mineral resources; scenarios; trends and tendencies; actors

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1. Introduction

When considering options for the development of the national economy of Russia, it should be borne in mind that the Russian Arctic, its mineral resource base, and the Northern Sea Route are considered to be national strategic resources [1]. Despite the fact that a diversified economy of the Arctic has already been shaped by now, with industries and sectors of the national economy such as maritime transport, fisheries, shipbuilding and ship repair, marine engineering, marine construction, marine tourism, etc. [1], mineral resource development is the key direction for the development of the Russian Arctic and an element of ensuring national security. This is confirmed by the statistics on the gross regional product (GRP) for the key Arctic regions (Figure 1).

Resource exploration and extraction in the Arctic territories have been ongoing for more than a decade, with Russia being one of the first countries to study and exploit mineral resources north of the Arctic Circle. In the past decade, the Russian Arctic has witnessed large-scale infrastructure and mining projects, as well as intensified investment and business activities. Today, it is considered essential to develop both the unique mineral resource base of the region and the economic potential of the Arctic to ensure growth of the national economy.

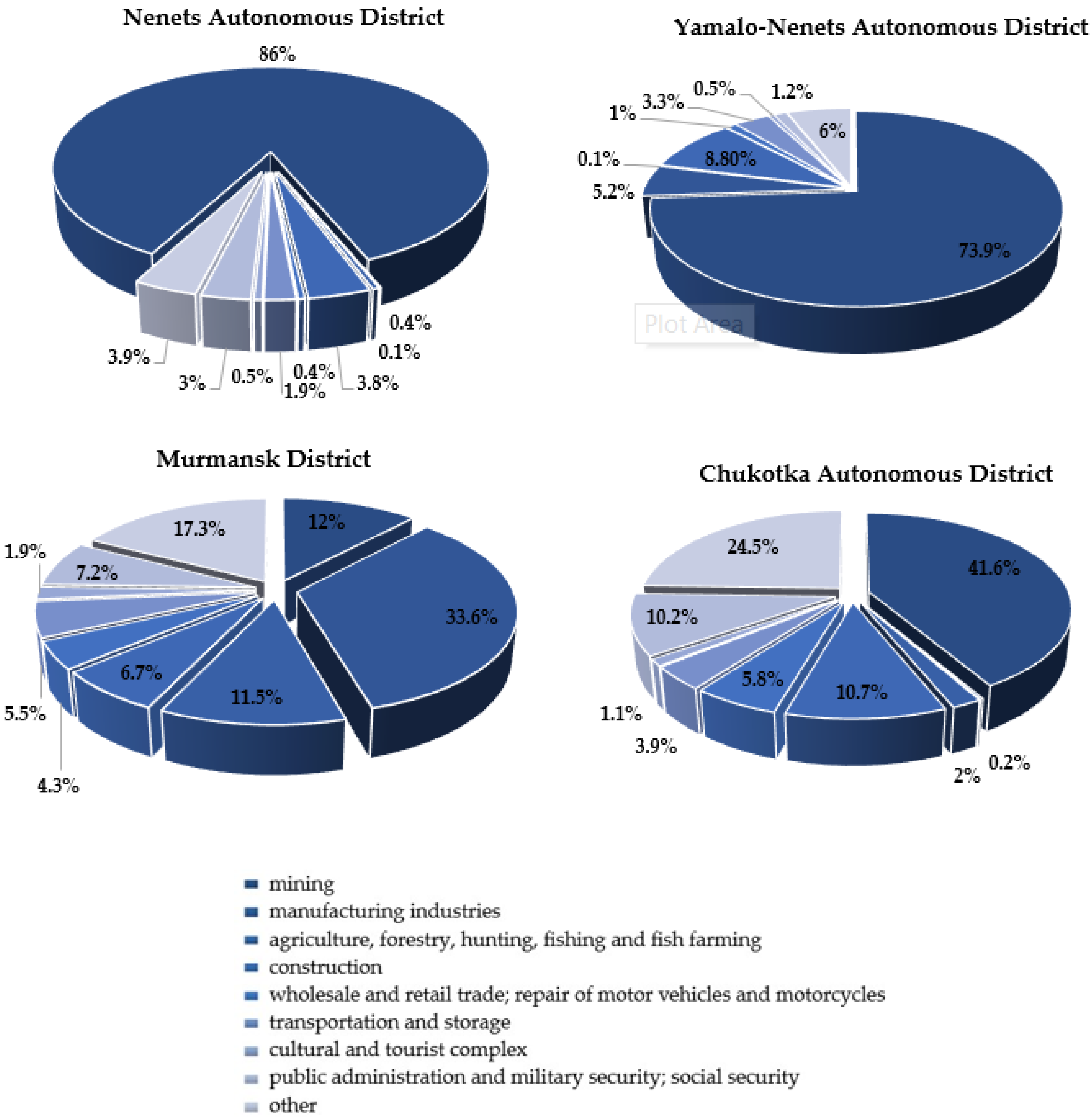

Figure 1. The structure of the GRP in the key Arctic regions in 2021. Source: compiled by the authors based on [2].

Mineral resource development in the Arctic is characterized by specific challenges. The diversification of the regional economy is hindered by high production costs resulting from the long heating season, high energy consumption during the extended polar night, isolation from power supply, and poor transport links with energy generation hubs and production centers for consumer and industrial goods [3]. Moreover, as the regional economy is focused on raw materials, it is vulnerable to fluctuations in international and domestic prices for hydrocarbons, as well as to the volume of demand for the current and future periods. Such fluctuations affect the profitability of the regional budget, holding back the development of social and transport infrastructure during crisis periods, as this activity is mainly supported by investments from the federal budget.

Another great challenge facing the region is the underutilization of its vast natural reserves, which require additional exploration for industrial development [3]. The Strategy for the Development of the Mineral Resource Base of the Russian Federation and the Strategy for the Development of the Arctic Zone of the Russian Federation highlight the rational development of Arctic mineral resources and the search for new deposits as key areas. This is particularly important in the current geopolitical climate, where national security concerns are of paramount importance. Hence, the role of geological exploration, particularly in the Arctic, is growing.

In addition to national priorities, global concerns regarding Arctic issues are becoming increasingly important. Resource extraction in the Arctic is associated with significant energy costs [4], which is especially important given the sensitivity of Arctic ecosystems [5]. In addition to other environmental problems, the issue of greenhouse gas emissions, caused by both the development of deposits and the melting of ice, is particularly pressing [6].

The problems and difficulties identified earlier are compounded by new challenges. The level of uncertainty in the functioning of the mineral markets is increasing. There is a gradual shift in focus from traditional to green energy sources. The demand for various types of minerals is changing, and the level of environmental and social requirements is increasing. Moreover, new approaches to project financing are emerging due to the current ESG (environmental, social, and governance) agenda [5,7–11].

The latest challenges arising from geopolitical and energy crises are also changing the nature of resource exploration in the Arctic [12,13]. The role of the region in providing national security is becoming more and more significant.

In the context of today's turbulent external environment, the challenges of achieving sustainable development (SD) are extremely complex for mining companies and regions, as well as the country as a whole. It is becoming increasingly evident that it is ineffective for regions or companies to follow established patterns of behavior. Achieving balance in the face of conflicting and pressing external circumstances requires a flexible approach and restructuring of activities at all levels to ensure sustainable development. Identifying the key actors that the sustainable development of mineral resources depends on is an important aspect of this endeavor [14].

Actors' identities and interests are shaped by the broader institutional environment and should not be considered as fixed or exogenous. According to Jackson (2010) [14], actors may be 'rule makers', but they take existing rules as a starting point for defining their own identities and interests. Conversely, actors may also be 'rule takers', yet they modify or even overturn those rules from time to time. Currently, literature on the topic does not consider which actors influence the sustainable development of mineral resources or how they do so. Additionally, there are no indicators or methods for assessing the degree of sustainability of the Arctic's mineral resource base.

Given these issues, the main goal of this paper is to design a model for the sustainable development of Arctic's mineral resources that can determine priority areas for their development and identify the role of key actors in achieving it. These issues are particularly relevant in the current economic and geopolitical climate, given the concentration of large reserves of various minerals in the Russian Arctic.

To achieve this goal, we aim to answer the following research questions:

1. How can the sustainable development of the mineral resource base contribute to the sustainable development of the Arctic?
2. How can the sustainable development of the mineral resource base be assessed?
3. What is the role of key actors in the sustainable development of the mineral resource base?

In order to answer these research questions, we organized the paper as follows: we conducted a desk study that involved a comprehensive review of academic literature on the development of mineral resources, the SD of Arctic regions, and mining companies in the Arctic. We defined the concept of the SD of the mineral resource base in the Arctic regions and identified related challenges. We also explored existing indicator systems and tools used to assess the level of sustainable development in the Arctic and the balanced development of mineral resources. We also investigated the rational use of mineral resources in these regions. Finally, we identified four key directions for the development of the mineral resource base in the Arctic and developed recommendations for the key actors.

2. Literature Review

2.1. Sustainable Development of the Arctic Regions and Companies

A lot of Russian and international literature has been dedicated to the issues surrounding the sustainable development of the Arctic regions and mining companies [15–17]. This subject is becoming particularly relevant due to the climate change agenda and the global energy transition [18–23]. Crépin et al. (2017) discuss the climate issues from the position of the social and economic impact on the Arctic development [24]. Tiller et al. (2022) determine an effect of the climate change on the Arctic shipping focusing on sustainable development goals [18]. Therefore, the transformation of the current Arctic policies and strategies is needed to ensure the sustainable development of the Northern territories.

Scientists [5,25–27] have discussed the problems associated with transforming the economy of the Russian Arctic, identifying priority tasks for the development of the Arctic regions against the background of global challenges.

The authors of [28] explore the staffing process in the Arctic and its role in achieving sustainable regional development. They examine the sociocultural situation in the Russian Arctic and emphasize the importance of national efforts towards the development of the region. Novoselov et al. (2022) assess the contribution of social projects to the SD of the Arctic region [29]. In the study conducted by Teslya et al. (2022), the authors investigate the role of digitalization in promoting SD in the Arctic region [30]. They propose the use of a new system of balanced indicators and a strategic map for regional development, which considers the digital transformation of socioeconomic processes.

The SD of Arctic companies has a significant impact on the SD of the Arctic region. Pronin et al. (2011) argue that the mining sector is a cornerstone of industrial regions as it creates conditions for the development of other industries and shapes the economic activity of the region in the long term [31]. Given the abundance of mineral resources, including oil, gas, and solid minerals, the mining industry plays a dominant role in the development of northern territories. Gutman et al. (2022) explore the relationship between the SD of the Arctic region and its backbone business, offering strategic development maps for both the business and the region and proposing a new system of balanced indicators to assess the degree of achievement of sustainable development goals (SDG) [32]. The authors also present a diagram of the relationships between the SD indicators at two levels—corporate and regional. Yakusheva and Sinitskaya (2019) suggest a methodology for assessing the contribution of mining companies to the SD of the Arctic regions [33].

Kosolapov (2012) argues that mineral resources serve as the foundation for the development of modern industries and some areas of scientific and technological progress [34]. As science advances and technology progresses, their role becomes increasingly significant. The pace of development of the Arctic regions is greatly influenced by the discovery of new mineral deposits in the north, both on land and on the continental shelf, as well as by the creation of sea transport routes [29]. Ilinova et al. (2018) also note the important role of implementing offshore oil and gas projects in the Russian Arctic for the development of northern territories [35]. Cherepovitsyn et al. (2020) assess the strategic sustainability of such projects using a specific system of indicators [36].

Any economy largely depends on the stability of the mineral resource base and the availability of fuel and energy resources. One of the primary economic security factors for countries worldwide is resource provision. In this regard, Sekerin V. et al. (2019) have studied the relationship between mineral resources and national economic security and developed an integrated index for estimating national mineral and raw material security (MRMS) and a methodology to measure it [37]. The authors have tested their methodology by applying it to the iron-ore industry as a case study.

The active development of mineral resources in the Arctic has a downside, which is the impact on the environment. Due to its delicate ecosystem, the Arctic region is highly vulnerable to environmental disasters [38–40]. Many scientific articles have been published on the subject of developing the mineral resources of the Arctic in conditions of high environmental risks for the entire planet [41–44]. In particular, Romasheva et al. (2022) delve into the adverse impact of several mining companies on the Arctic environment and suggest solutions to tackle the environmental issues, aiming at environmentally responsible nature management [11]. Li et al. (2022) investigate the effects of green innovations, natural resource rent, and GDP on environmental sustainability in Arctic regions of various countries including Russia, the USA, Canada, Denmark, Finland, and Sweden [45]. Garbiz et al. (2023) discuss the governing of the green economy in the Arctic taking into consideration the importance of sustainability and the roles of key actors and stakeholders [46].

2.2. Sustainable Development of the Mineral Resources

The SD of the mineral resources in the Arctic is currently a significant agenda for the global scientific community [47–50]. This issue is widely discussed at the state level by the Arctic Council, the USA, Canada, the European countries, and others [51–53]. Thus, the Study on Arctic Mining in Greenland (2020) stresses the importance of the SD of mining by the greater involvement of the business community [54].

The Strategy for the Development of the Mineral Resource Base of the Russian Federation until 2035 [55] defines the mineral resource base as a combination of explored, estimated, localized, and predicted mineral resources. It is the foundation of the Russian mineral resource sector. Kaplunov et al. (2014) argue that the SD of mineral resources and mining businesses is a development that meets the needs of the present generation without compromising the opportunities of future generations in resource use [56].

Kaplunov and Rachenko (2017) propose a definition of the SD of mines, which is achieved by the rapid adaptation of geotechnologies to changing conditions [57]. In their article, the authors outline a new technological paradigm designed to ensure the sustainable development of underground mines and highlight its key objectives. They suggest that the target functions of the mining system should be optimized according to the required technical, economic, environmental, and social criteria.

Kosolapov (2012) identifies problems associated with the development of the mineral resource base entailing a violation of its stability [34]. These include a decrease in the rate of growth of reserves and exploration, a disproportion between explored and estimated reserves, a shortage of particular minerals, including strategic ones, a low level of intensity in the use of developed deposits, and insufficient involvement in the processing of production waste. Busyrev (2020) believes that the ongoing disruption of the balance between consumption and replenishment of the mineral resource base may lead to serious consequences for the Russian economy in the future [58]. To prevent them, it will be necessary to increase expenditures for all stages of geological prospecting and exploration.

Kaplunov (2014) also asserts that as the global reserves of solid minerals become depleted, Russia's budget and national raw material security will increasingly depend on the timely reproduction of the mineral resource base and its efficient industrial exploitation [56]. The Strategy for the Development of the Mineral Resource Base of the Russian Federation until 2035 emphasizes that in the long term, sustainable operation of the extractive industries is only possible if the development of the mineral resource base is continuous, and newly discovered reserves compensate for those depleted during production. It is undesirable to violate the optimal balance between the localization of forecast resources, the growth of reserves, and the extraction of minerals in any direction [55]. To ensure the stability of the mineral resource base, more geological data is needed, which implies the demand for geological exploration [59].

Polyanskaya and Yurak (2018) propose definitions for the concepts of balanced nature management and balanced resource use and identify their key principles. They also give methodological recommendations for assessing the level of balance between the region's nature management and resource use as its component [60]. Alekseev (2015) studies the geological and economic indicators of the balance of the mineral resource base, developing spatial and territorial balance models and long-term development forecasts [61].

Smol et al. (2020) propose a holistic approach to sustainable management of mineral raw materials including the three main pillars of SD—environmental, economic, and social [62]. The authors identify key indicators presenting sustainable mineral resources management. They are the following: domestic material consumption (DMC), raw material consumption (RMC), and the level of resource productivity.

Deb and Sarkar (2017) argue that to achieve the sustainable development of the mineral resource base, three guiding principles should be taken into account: reduce, replace, and recycle [63]. The main challenge of sustainable mining in this case is to ensure environmental responsibility.

Busyrev (2020) argues that achieving a rational development of mineral resources requires a balance between the economic interests of the state and the mining industry [58]. He notes that the rational development of deposits is difficult due to an imperfect mechanism for regulating financial relations between the state and mine operators, particularly during the exploitation and replenishment of the mineral resource base. Additionally, he believes that insufficient knowledge and understanding of the role of mineral reserves can further complicate this process.

According to Rylnikova (2022), the SD of Russia's mineral resource base can be achieved through a rational combination of geotechnological processes and their implementation on a suitable scale. She further emphasizes the importance of activating innovative processes and utilizing natural and man-made georesources [64]. The principles of SD of mining systems, such as profitability, resource and energy conservation, the use of environmentally balanced geotechnologies, and enhancing the material well-being of the population, are also discussed by the author [64]. Additionally, the importance of transparency in corporate governance systems and the integration of digital technologies are highlighted, all of which align with the modern concept of ESG ranking. Dmitrieva et al. also discuss importance of ESG issue during hydrocarbon reserves exploitation in the Russian Arctic, emphasizing the importance of innovation in achieving SD [5].

Many contemporary studies aim to assess the level of sustainable development in territories ranging from cities to regions. Several studies are of interest for evaluating the influence of the mineral resources industry on sustainable development.

Jing and Wang (2020) propose a comprehensive and systematic evaluation indicator system to reflect the SD of the "society–economy–environment" system of resource-based cities [65]. The authors mention several studies devoted to the SD of a city, the design of theoretical indicator frameworks for SD, and major indicator systems to evaluate SD. Yang et al. (2019) use a system of indicators to assess the level of green development in Chinese cities whose economies are based on mineral resources [66].

There are numerous modern studies focused on assessing the sustainability of the Arctic regions [67]. One of the most popular methodologies is the Polar Index project, which was launched in 2018 with the aim of promoting the principles of SD throughout the Arctic [68]. Peshkova et al. (2008) propose a system of indicators for assessing the accessibility of the regional mineral resource base, which takes into account the meso-economic effects of the mutual influence of economic entities, as well as the impact of many socioeconomic factors, including those that are difficult to formalize [69]. These factors include, first of all, the expectation of a high level of profitability from investing in mining, the fiscal system of taxation and the lack of differentiation of taxation depending on the quality of reserves and development conditions, low availability of investment and labor resources, and various risks. The essence of the proposed approach to assessing the mineral resource potential of the region is to utilize economic information obtained from the analysis of the state of the mineral resource base of the region represented by deposits grouped by industrial or genetic types.

The study by Rumyantsev et al. (2022) focuses on prioritizing the structural transformation of the region's economy in response to external turbulence by identifying promising economic activities [70]. The authors highlight the indicators used in their calculations to determine the prospective economic specialization of the region and describe the proposed methodology. Nilsson and Larsen (2020) provide an exploratory assessment of the global sustainable development goals (SDGs) and indicators from an Arctic perspective [71].

Public governance in the field of mineral resources is considered to be one of the most important aspects of the SD concept. In order to increase transparency and accountability in the extractive sector, the Natural Resource Governance Institute (NRGI) has introduced the Resource Governance Index (RGI), which reflects the state of resource governance in countries around the world. It can be used by stakeholders as a benchmark, a diagnostic tool, and a roadmap for reforms at the global, regional, and national levels [72].

The paper [73] provides an overview of various indicators, indicator systems, and integrated assessments of SD. The author suggests using a balanced scorecard as a mechanism that will streamline the set of existing indicators and bring the system in line with the goals and SD strategy of the territories of the Russian Arctic.

Based on the literature review, it can be concluded that little attention has been paid to defining the concept of sustainable development of the mineral resource base of regions and developing indicators and methodologies to assess it. Additionally, there is limited literature on achieving balanced development of mineral resources in the regions which considers the replenishment of mineral reserves, rational exploitation of deposits, and national security concerns, while also taking into account the unique challenges of the Arctic region, such as difficult development conditions and the vulnerability of ecosystems. This paper aims at filling this research gap.

3. Materials and Methods

This study aimed to develop a conceptual model for the SD of the mineral resource base in the Russian Arctic. The model included three stages: (i) choosing the scenario; (ii) assessing the development of the Arctic mineral resource base; (iii) recommendations for key actors. The first stage was devoted to identifying the present global trends and challenges in Arctic resource development and selecting an appropriate scenario. For that we used such methods as desk studies, content analysis, PESTLE analysis, and event analysis that helped us to develop three scenarios of the development of the mineral resource industry, highlight the current macroeconomic and geopolitical trends and choose the most appropriate scenario in these conditions.

The second stage was focused on assessing the development of the Arctic mineral resource base. For that, we applied the following methods: (i) systematization of the factors which are then grouped by four key directions of the mineral resource base development. As an additional instrument, we compared different approaches to sustainable development, i.e., matching six aspects of SD and four directions of the mineral resource base development, which we used as an auxiliary analytical tool and information base for highlighting the SD factors for the mineral resource base; (ii) clustering of indicators according to the identified factors, which is presented in a separate table; (iii) a checklist which accumulates information on the real and desired dynamics of each indicator; (iv) mathematical calculations of the shares of coincidences of the real and desired dynamics. The algorithm for assessing the development of the mineral resource base is presented in Figure 2.

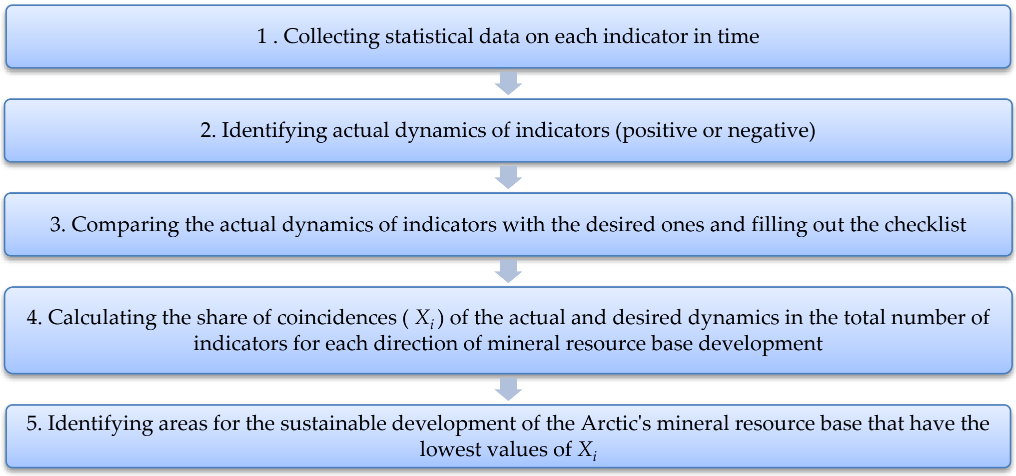

Figure 2. The algorithm for assessing the level of the development of the Arctic mineral recourse base in each direction. Source: compiled by the authors.

The third stage was aimed at developing possible recommendations for key actors whose influence on the development of mineral resources is significant. Here, we used induction and systematization methods, trying to accumulate in a structured way all potential initiatives that could be implemented by the state, region, and companies in order to comply with the concept of sustainable development of the Arctic mineral resource base and contribute to all four directions of its development.

Throughout the research we also applied general scientific methods—analysis, synthesis, generalization, systematization, classification, induction, and deduction. We tried to support statistical and analytical information using visualization methods, namely circle diagrams, author's infographics, visual description of the research algorithm and the evaluation algorithm, organizational schemes, and charts.

Thus, we can illustrate our research design as follows (Figure 3).

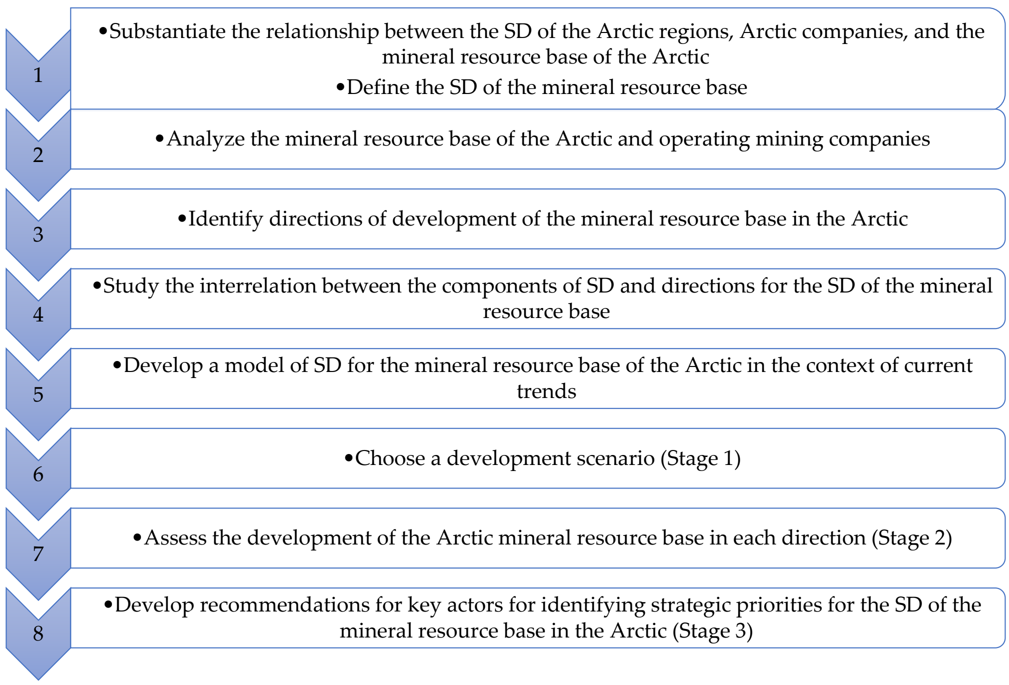

Figure 3. Research design. Source: compiled by the authors.

The proposed model had some limitations, particularly related to the availability of data on the proposed indicators. It can be challenging to access the necessary information from companies and government sources.

4. Results and Discussion

4.1. The Arctic's Sustainable Development: The Role of the Mineral Resource Base

As demonstrated earlier, the sustainability of the Arctic regions, encompassing economic, environmental, and social dimensions, is closely linked to the sustainable development of the companies that operate within these regions. Considering the Russian Arctic's wealth of mineral resources and harsh living conditions, it can be asserted that mining forms the foundation of all industrial development within these territories.

The SD of Arctic mining companies, in turn, is dependent on the condition of the Arctic mineral resource base. When analyzing the latter, it is crucial to consider factors such as the types of minerals, the number of deposits, the rate of replenishment of the mineral resource base, investments in geological exploration, mining infrastructure, and technologies, and the availability of qualified personnel, among others. These factors and indicators pertain to various aspects of the mining industry, and most of them must be studied over time to reflect national and corporate policies in developing the Arctic mineral resources that are vitally important for the country.

One more factor is that the global mining industry is currently functioning under the pressure and within the concept of social SD, which was shown in the literature review section. Thus, the authors studied Arctic mineral resources from the SD perspective.

The SD of the mineral resource base differs from that of the mining companies. The key reasons for this are as follows:

1. There is a mismatch of SDG. While 17 SDG have been formulated for companies, including mining businesses, there are no specific SDG for the mineral resource base, and it is evident that they should differ.
2. The SD of companies depends primarily on the companies themselves. Political or macroeconomic factors act as external conditions in which the company operates and top management makes decisions.
3. Among the key actors who influence the development of the mineral resource base, the state and regional structures play significant roles. Their participation and support are vital for the SD of mineral deposits in the Arctic.
4. The SD of the Arctic's mineral resource base is of strategic importance for the country's economy. In this regard, an important direction of the SD of mineral resources is to ensure the national security of the country.
5. The systems of indicators for assessing the level of SD of mining companies and that of the Arctic's mineral resource base differ significantly.

Lastly, we posit that the SD of the Arctic region is inextricably linked to the progress of its mineral resource base, which is propelled by mining businesses. For instance, the miners' salaries enhance the average regional salary and influence the standard of living of the population in the region and its education [32]. In turn, the SD of the Arctic stimulates the further development of the local mineral resources. This is due to the amplification of human potential, the upskilling of workers and locals, and the availability of well-developed mining, transport, and social infrastructure, among other factors. This interdependence is illustrated in Figure 4.

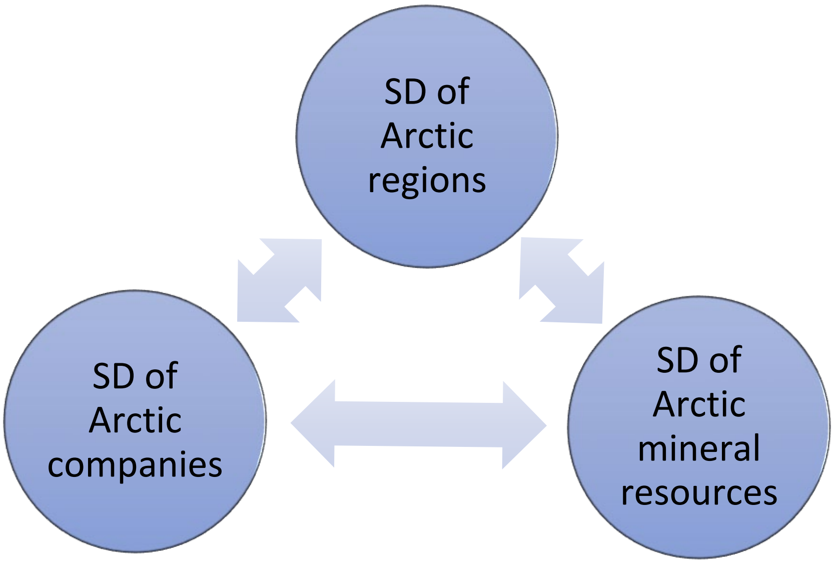

Figure 4. The circular relationship between the types of SD. Source: compiled by the authors.

The circular relationship can be illustrated using the example of the Murmansk Region. It ranked the highest among all Russian Arctic regions in the Polar Index 2022 [68]. The Kola Peninsula, with its abundant deposits of various minerals, milder climate conditions, and proximity to the central part of Russia, serves as a driving force for the active development of mining companies in the region (Figure 4). Mining companies, as discussed in the literature review section, play a key role in the SD of the region, contributing to its infrastructure, social and economic development, and attracting qualified workers and investment [65,74]. The region, in turn, invests in the SD of its mineral resource base using labor, material resources, and financial resources.

To illustrate the types of mineral resources, the number of deposits, and the mining companies operating in the Russian Arctic, we have created an infographic (Figure 4) based on official statistics [2,3]. The infographic shows that the Russian Arctic is rich in various types of minerals, including critical ones, although not all types of minerals are being extracted. The distribution of minerals across the Arctic regions is not uniform, and neither is the location of corporate mining assets. Additionally, the infographic demonstrates that the largest mining companies operating in the Arctic are actively pursuing SDG, as evidenced by their participation in ESG rankings.

Many researchers have emphasized the significance of geological exploration for the development of the mineral resource base. To accelerate the economic development of energy resources in the Arctic, the Russian Federation needs substantial investments in geological exploration and the production of specialized equipment. Hence, we analyzed geological exploration in the Russian Arctic by types and groups of minerals in four Arctic regions (Appendix A). Figure 5 presents the results of our analysis, showing dynamics of exploration funding and investment sources.

The analysis highlights the crucial role of the mineral resource base in the development of the entire Russian Arctic. This underscores the importance of exploring the main directions for the sustainable development of this resource base. Further research is needed to develop a comprehensive concept of sustainable development that can guide policy-making and investment decisions.

4.2. Development of the Mineral Resource Base

The exploitation of mineral reserves involves the creation and operation of a technical system for the extraction and processing of mineral resources [75]. Therefore, in this study, we define the exploitation of the mineral resource base as the development of a deposit. This activity of mining companies is characterized by the types of minerals extracted in a particular territory, the technologies and profitability of their extraction, the degree of involvement of small and medium-sized enterprises in deposit development, and other factors. However, any exploitation of reserves should be carried out rationally, without waste and with maximum return on funds invested. This means that resource use should be rational, allowing the country to utilize its resources and account for the needs of future generations for minerals [17].

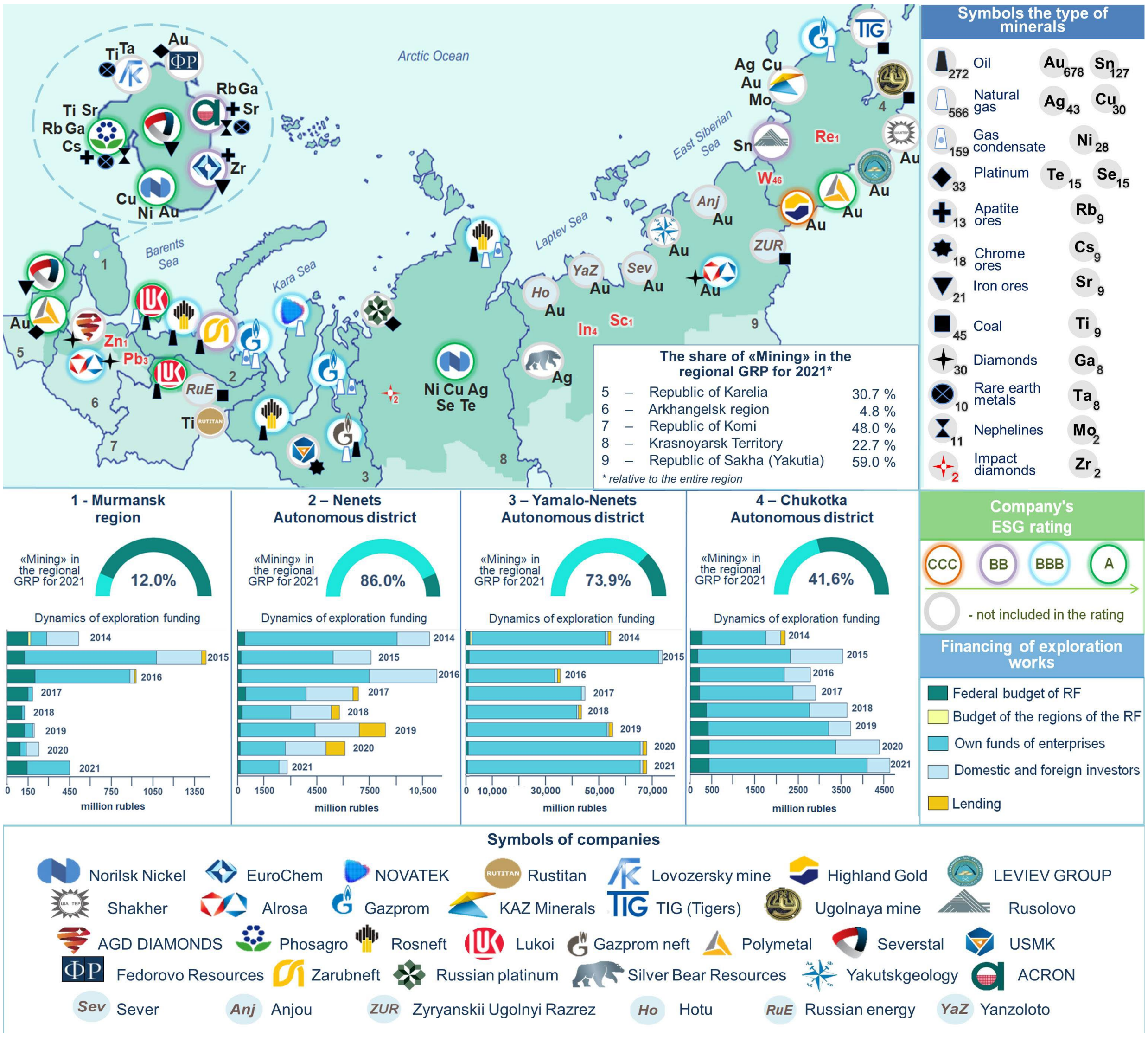

Figure 5. Mineral resource development in the Russian Arctic (infographics). Source: compiled by the authors based on [2,3].

We have combined these two areas into a block, referred to as the sustainable exploitation of the mineral resource base. One of the current global issues is the potential shortage of mineral resources. As a result, given the continued reliance on hydrocarbons in economies, as well as the necessity for the use of solid minerals (particularly rare-earth metals [76]), it is crucial to actively replenish the mineral resource base by searching for and exploring new deposits. Additionally, the reproduction of the national mineral resource base, its supply with various types of minerals, and the high level of processing of raw materials directly influence national security. Therefore, such directions as geological prospecting and exploration and national security are also essential and, in the authors' view, are integral to the concept of the development of the mineral resource base (Figure 6).

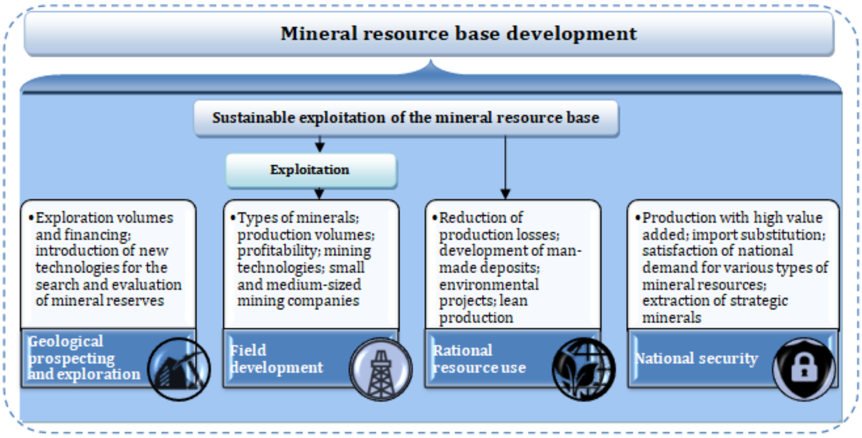

Figure 6. Directions for the development of mineral resource base. Source: compiled by the authors.

It is important to note that sustainable development of the mineral resource base encompasses more than just rational resource use and conservation of Arctic ecosystems. It cannot be achieved without taking into account the key modern trends. Every year, global trends and priorities change; some of them are moving in the same direction, while others diverge. For instance, not long ago, the low-carbon development path, the climate agenda, and the ESG transition used to be at the forefront, but they are gradually being overtaken by macroeconomic and national security risks, as well as geopolitical tensions. The energy crisis of 2022 has affected not only industrial development but also the global economy as a whole.

All these changes influence the structure of the mineral resource base (traditional energy sources, strategically important types of resources, critical materials) used to ensure industrial needs [77]. Figure 7 illustrates the dominant global trends observed in recent years.

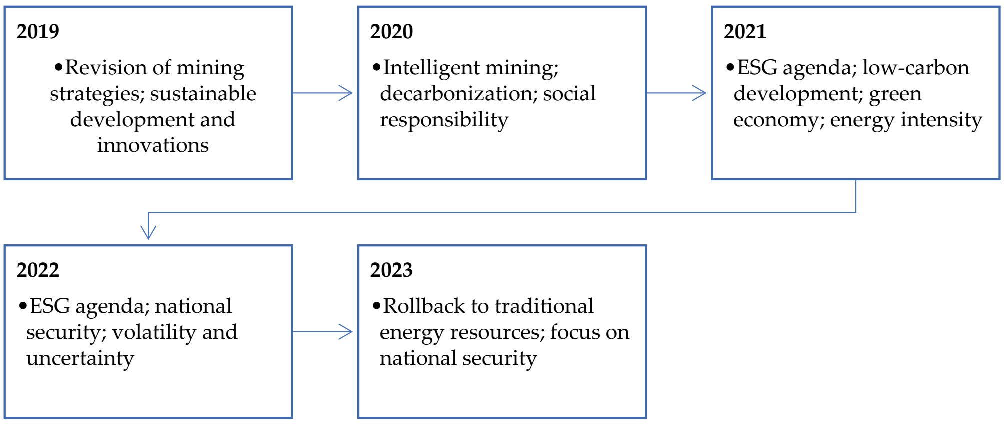

Figure 7. Dominant global trends in the mining industry. Source: compiled by the authors based on [77].

Based on global trends, in addition to the traditional three components of sustainability (macroeconomics, social factors, and ecological factors), sustainable development should include novel elements reflecting modern trends, namely governance, technology, and geopolitics. Therefore, in order to ensure the sustainable development of the mineral resource base, it is necessary to bring to accordance the four directions and six aspects of sustainability, which will form the basis for the model.

Table 1 shows the way the main directions of mineral resource base exploration contribute to the key aspects of sustainable development pointed out before.

The analysis carried out makes it possible to determine the factors for the sustainable development of the mineral resource base and identify indicators for a reasonable assessment. Based on these results, the authors developed a comprehensive model for the sustainable development of the mineral resource base in the Arctic that comprises a series of stages.

4.3. Stage 1. Choosing Scenarios

The first stage proceeds from the necessity of strategic forecasting and planning. It is essential to determine prospective goals, as well as the ways to achieve them.

Currently, this stage is becoming increasingly challenging due to the high level of macroeconomic uncertainty and turbulence. Every year, global trends and directions are in constant flux. Some of them are unidirectional while others are divergent. As geopolitical, macroeconomic, and national security risks increase, the low-carbon development path, the climate agenda, and the ESG transition are gradually taking a backseat. These changes have a significant impact on the structure of the mineral resource base required to meet industrial needs, including traditional energy sources, strategically important resources, and critical materials [77].

Table 1. Interrelation between the key components of SD and the directions for the sustainable development of the mineral resource base.

<table>
<tr><th rowspan="2"></th><th colspan="6">Aspects of Sustainable Development</th></tr>
<tr><th>Society</th><th>Environment</th><th>Governance</th><th>Technology</th><th>Macroeconomics</th><th>Geopolitics</th></tr>
<tr><td>Geological prospecting and exploration</td><td rowspan="2">Growth in the number of people employed in geological prospecting, exploration, and resource development in the Arctic; creating new jobs; improving the quality of life of the locals</td><td rowspan="2">Negative interrelation; it is required to prevent potential threats and ensure the conservation of unstable and fragile ecosystems</td><td rowspan="3">Achievement of the priority goals at all levels (corporate, regional, and federal)</td><td rowspan="2">Development of the technological infrastructure; scientific and technological advance; technological import substitution</td><td>No direct interrelation</td><td rowspan="4">Provision of the country with strategic types of minerals; increase in exports and imports</td></tr>
<tr><td>Field exploitation</td><td>Effective development of small and medium-sized businesses; infrastructure development</td></tr>
<tr><td>Rational resource use</td><td>Improving the quality of life of the locals</td><td>Ensuring resource and energy efficiency; ensuring a balanced development of the resource potential (exploration of man-made deposits; curbing CO_2 emission levels)</td><td>Development of technologies for the comprehensive use of raw materials</td><td>Expansion of the range of products; maintaining a high level of resource endowment</td></tr>
<tr><td>National security</td><td>Better social infrastructure in the region</td><td>No direct interrelation</td><td>Decrease in the level of import dependence</td><td>No direct interrelation</td><td>Increasing the investment attractiveness of the Arctic region; GRP</td></tr>
</table>

Source: compiled by the authors.

Prior research provides an overview of the controversies surrounding the development of the Arctic's mineral resources based on key global trends. There are three main scenarios that differ in terms of energy and resource intensity, CO_2 emissions, investment directions, and other factors [78,79]. These scenarios are as follows:

"Scenario 1—green transformation" based on ESG and climate agenda principles, low-carbon development, and the implementation of the Paris agreement. The main ways to achieve this scenario include funding green assets, implementing new low-carbon technologies, and exploring critical materials.

"Scenario 2—traditional energy sources" is built on geopolitics and macroeconomic trends, with a focus on energy and resource safety. The key directions for this scenario are the growth in oil and coal production, commissioning offshore fields to achieve energy security, and opening new production facilities.

"Scenario 3—keeping balance" suggests a moderate combination of modern trends, with a focus on adaptation to current conditions. This scenario includes maintaining current assets, gradual exploration of critical materials, sustainable development of infrastructure, and using the best available technologies (BAT).

The third scenario (keeping balance) is presently the most appropriate approach. It is essential to strike a balance that avoids repeating past controversies and takes into account the current and future trends. Rather than ignoring modern trends, the approach should adapt to the new reality, considering factors such as resource endowment, import dependence, and priority projects. The third scenario reflects a well-founded approach, which is why it is used as the key one in this study.

4.4. Stage 2. Assessing the Development of the Arctic Mineral Resource Base

In the context of the proposed model of sustainable development, we assume that each of the four directions for the development of the Arctic's mineral resource base (Figure 5) can be assessed using indicators. To do this, the authors have developed a system of indicators (Table 2) based on six SD aspects described above (Table 1). Normally, each indicator demonstrates the desired dynamics in terms of the development of the mineral resource base. In addition, the table shows the key actors whose influence on the dynamics of a particular indicator is critical.

The evaluation procedure involves collecting statistical data for the indicators under study for at least the past five years. Using the system of indicators proposed by the authors, a checklist is created to compare the desired and actual dynamics in the development of the mineral resource base. The actual dynamics is traced by analyzing annual changes in values for each indicator and identifying positive or negative dynamics. The share of indicators with coinciding dynamics in the total number of indicators is then calculated for each direction. These shares are denoted by X_i, $i = \overline{1,4}$. The values of variables X_i vary in the range from 0 to 100%:

$$0 \leq X_i \leq 100\%, i = \overline{1,4}.$$

Then, the values of X_i are compared with each other, and weak points in the development of the Arctic mineral resource base are identified. The lowest value of X_i indicates the direction for the development of the Arctic's mineral resource base that requires the most attention and effort from key actors. The highest value of X_i indicates that development in that direction does not need to be forced, and it is necessary to divert activity towards those directions where the values of X_i are lower.

As one of the results of our study, we developed a system of indicators which are used within our model for the SD of the Arctic mineral resource base. The table of indicators grouped by factors is presented below (Table 2).

As an example, Figures 8–11 demonstrate dynamics for the past 7 years of four indicators for the Murmansk region. Some of them ("region's GRP" and "R&D costs in the field of rational resource use") meet the desired dynamics, while "exploration volumes in the region per capita" had declined and did not correspond to the desired dynamics.

Table 2. Indicators of the sustainable development of the Arctic's mineral resource base.

	Factors	Indicators of the Sustainable Development of the Arctic's Mineral Resource Base	Desired Dynamics	Key Actors: Companies	Key Actors: Region	Key Actors: State
Geological prospecting and exploration	Structure of the mineral resource base	Number of types of minerals with a low content of valuable components in the ore of the deposits located in the Russian Arctic;	growth	–	–	–
		Number of types of minerals not presented in the Russian Arctic;	decline	–	–	–
		Number of deposits in the Russian Arctic.	growth	+	–	+
	Geological exploration	Number of workers employed in the field of geological prospecting and exploration in the Arctic;	growth	+	+	+
		The number of deposits of solid minerals per unit of exploration costs;	growth	+	–	+
		The number of hydrocarbon deposits per unit of exploration costs;	growth	+	–	+
		Exploration volumes in the region per capita;	growth	+	–	+
		Share of investments in exploration in all investments of the company (on average for the companies of the Russian Arctic).	growth	+	–	–
	Technological development and import substitution	Government expenditures on R&D in the field of prospecting, exploration, and evaluation of mineral reserves;	growth	–	–	+
		Number of patents in the field of geological prospecting and exploration;	growth	+	+	+
		Corporate expenditures on technological innovations in the field of prospecting, exploration, and evaluation of mineral reserves;	growth	+	–	–
		Share of imported special equipment used for exploration;	decline	+	–	+
		Number of plants producing equipment for exploration in the Russian Federation;	growth	–	+	+
		Ratio between the rate of increase in reserves and the rate of extraction (for critical types of minerals).	growth	+	+	+
Field development	Development of the mineral resource base	Share of mineral deposits developed;	growth	+	–	–
		Number of undeveloped mineral deposits;	decline	+	–	–
		Number of suspended deposits;	decline	+	–	–
		Number of types of minerals that are not mined;	decline	+	+	+
		Share of profitable deposits in the total volume of deposits at the time of the assessment;	growth	+	–	–
		Number of workers employed in the development of deposits in the Russian Arctic;	growth	+	+	+
		Index of industrial production in the Russian Arctic.	growth	+	+	+
	Technological development	Share of inventions introduced into corporate business processes during mining in the Arctic;	growth	+	–	–
		Number of scientists engaged in the development of modern technologies for the extraction of mineral resources in the Arctic;	growth	–	+	+
		Number of research institutes engaged in the development of modern technologies for the extraction of mineral resources in the Arctic;	growth	–	+	+
		R&D costs in the development of new mining technologies, including mining hard-to-recover reserves;	growth	+	+	+
		Number of technologies reducing the impact on the Arctic ecosystem that are adopted by companies.	growth	+	–	–
	Small and medium sized businesses	Number of small and medium-sized mining companies in the region;	growth	+	+	–
		Number of government support measures for small and medium-sized companies developing Arctic deposits;	growth	–	+	+
		Number of small and medium-sized companies creating infrastructure elements in the Russian Arctic.	growth	–	+	–
	Infrastructure	Level of development of mining infrastructure in the Russian Arctic;	growth	+	–	–
		Level of development of transport infrastructure in the Russian Arctic.	growth	–	+	+

Table 2. *Cont.*

	Factors	Indicators of the Sustainable Development of the Arctic's Mineral Resource Base	Desired Dynamics	Key Actors: Companies	Key Actors: Region	Key Actors: State
Rational resource use	Economic production and extraction	Average level of mineral losses during extraction (by types of minerals);	decline	+	−	−
		Number of patents on technologies that reduce the loss of a useful component during mining;	growth	+	+	+
		The degree of use of the deposits being developed;	growth	+	−	−
		Volumes of dumps and waste created by extractive industries;	decline	+	−	−
		R&D costs in the field of rational resource use.	growth	+	+	+
	Ecology	The number of man-made deposits exploited in the Russian Arctic;	growth	+	+	+
		Indicator of the degree of involvement of waste in production;	growth	+	−	−
		Wastewater emissions from the development of the Arctic's deposits;	decline	+	+	−
		Wastewater purification levels;	growth	+	+	−
		Levels of emissions avoided;	growth	+	+	−
		CO_2 emissions from companies operating in the Arctic;	decline	+	−	+
		Total corporate investments in environmental projects in the Russian Arctic;	growth	+	−	−
		R&D costs in the field of protection of the Arctic's ecosystem;	growth	+	+	+
		The number of technological solutions implemented in the field of protecting the Arctic's ecosystem;	growth	+	+	+
		Contributions to insurance funds for preventing possible environmental damage.	growth	+	+	+
	Managementin Arctic companies	The share of mining companies that have implemented lean manufacturing;	growth	+	−	+
		Average ESG indicators among companies operating in the Arctic;	growth	+	−	−
		The quality of operational management in the field;	growth	+	−	−
		The share of workers with specialized education in the total number of workers in the field.	growth	+	+	+
National security	Export and import of minerals	Number of types of minerals with reserves in the Arctic that are not mined;	decline	+	+	+
		Number of types of imported minerals;	decline	−	−	+
		Number of types of strategic minerals that are imported;	decline	−	−	+
		Number of types of exported minerals.	growth	−	−	+
	Strategic minerals	Provision of the country with strategic types of minerals;	growth	+	+	+
		Number of exploited deposits of strategic mineral resources in the region;	growth	+	+	+
		Share of the Arctic region in the production of strategic mineral resources among all regions;	growth	+	+	−
		Share of imports in the volume of consumption of strategic minerals within the country.	decline	+	−	+
	Creating value added	The Arctic's GRP;	growth	+	+	+
		The share of income from the export of value-added products produced by the mining industry of the Arctic in GDP;	growth	+	+	+
		The number of Arctic companies producing value-added products;	growth	+	+	+
		Investment attractiveness of the Arctic.	growth	+	+	+
	Infrastructure and society	The level of development of the social infrastructure of the region;	growth	+	+	+
		The level of development of the transport infrastructure of the region;	growth	−	+	+
		The availability of energy resources for the operation of mining companies;	growth	−	+	−
		The share of employees at mining companies with higher education;	growth	+	+	−
		Human Development Index of the Arctic.	growth	+	+	+

Source: compiled by the authors based on [5,34,58,60,68,70,73].

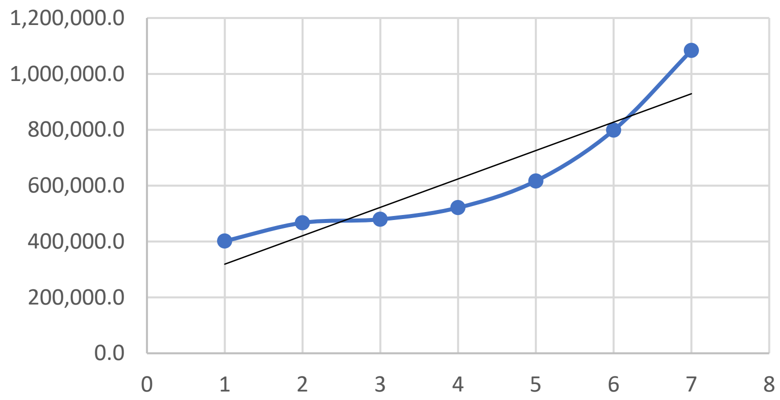

Figure 8. The region's GRP in Murmansk region, m. rub.

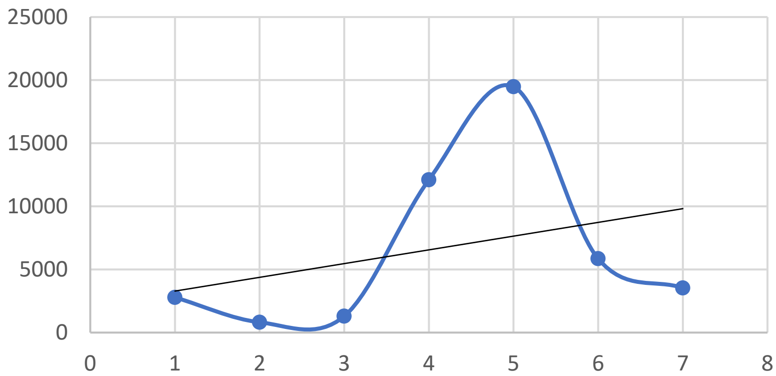

Figure 9. R&D costs in the field of rational resource use in Murmansk region, m. rub.

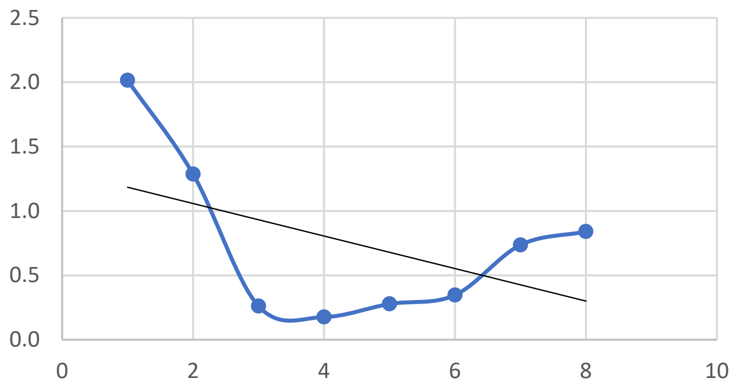

Figure 10. Exploration volumes in the region per capita in Murmansk region, thousand rub.

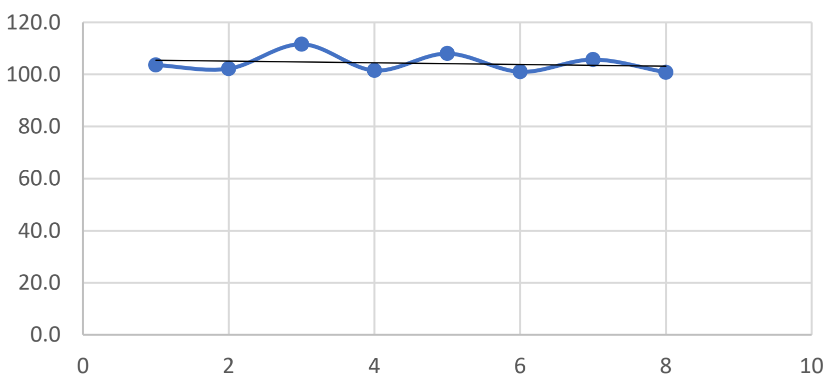

Figure 11. Growth rate for index of industrial production in Murmansk region, %.

The evaluation of the main directions for the development of the Arctic's mineral resource base was conducted for the entire Russian Arctic. This is because the distribution of minerals in the Arctic is not uniform. However, by analyzing the entire Arctic territory, it was possible to obtain a comprehensive understanding of the types of minerals and their reserves within the Russian Federation's borders. This also enabled an assessment of the structure and importance of the Arctic mineral resource base in meeting the country's needs for various types of mineral resources.

This method could also be used in the case of assessing the SD directions in individual Arctic regions, such as Murmansk Region or Chukotka Autonomous District. In this case, researchers could obtain an understanding of how the mineral resource base of the territory has been developing over the period under study. Additionally, a comparative analysis of the state of key directions of mineral resource development in various Russian Arctic regions could be conducted to draw relevant conclusions and develop appropriate recommendations.

It is important to note that the desired dynamics in the proposed indicators and the role of key actors may vary depending on the strategic priorities of the state's economic policy. For instance, a focus on innovative economic development would imply a decrease in the export of raw materials and an increase in domestic consumption. In addition, the development of knowledge-intensive industries would increase the demand for strategic minerals, and therefore the government may adjust the list accordingly. As a result, priority areas for the development of the country's mineral resource base, particularly in the Arctic, may need to be restructured. The proposed system of indicators was developed in line with current global trends and challenges and can be easily adapted to changing external conditions.

4.5. Stage 3. Development of Recommendations for Key Actors to Identify Strategic Priorities for the Sustainable Development of the Arctic Mineral Resource Base

In order to highlight the role of specific parties in the sustainable development of the mineral resource base, we will use the term "key actors". According to [62], "key actors" refers to various entities or stakeholders that are directly involved in the main activities.

Based on our literature review, we have identified three key actors involved in the development of the Arctic's mineral resource base: (i) the national government, (ii) the regional government and other institutions, and (iii) mining companies in the Arctic. Each of these actors has its own means and instruments that enables it to influence the sustainable development of the mineral resource base.

The state plays a crucial role in creating favorable conditions for the development of the mineral resource base in the Arctic. This involves improving the legislative framework, providing tax benefits, developing a comprehensive strategy and development programs, supporting small and medium-sized businesses, and investing in geological exploration, technology, and engineering projects [10]. Such active investments not only enhance the mineral resource base but also contribute to improving the country's national security level.

The role of the region lies in creating favorable conditions for the sustainable development of companies engaged in the development of mineral resources. Regional actors contribute to the development of regional infrastructure, support small and medium-sized businesses in the region, actively attract researchers and young professionals to the region, and invest in regional industrial development and the service sector.

The role of companies lies in ensuring the rational development of deposits. Additionally, companies explore and search for new deposits, invest in exploration activities, create mining infrastructure, develop production technologies in the Arctic, and preserve the Arctic ecosystem [10].

One important aspect of developing the mineral resource base in the Arctic is the search for and exploration of new deposits, as supported by our literature review. However, an analysis of statistical data from 2014 to 2020 for four regions within the Russian Arctic reveals that the largest investments in exploration were made by mining companies using their own funds, while the share of exploration funds provided by the state was negligible (Figure 4). Therefore, the primary recommendation for the government should be to increase the financing of exploration from the national budget [3]. Another recommendation presented in a book by Busyrev (2020) [58] involves improving the mechanism for mining companies to pay for the use of their reserves of exploited deposits. Additionally, developing regional development programs that focus on digital transformation, as suggested by Teslya (2022) [30], is also extremely important. Environmental protection in the Arctic, which is widely discussed in the scientific literature, highlights the need to address serious gaps in the liability systems of Arctic states. Johannsdottir and Cook (2019) [80] suggest that the Arctic Council should consider establishing an Arctic offshore oil spill compensation fund to manage environmental risks.

Recommendations for three key actors compiled by the authors are presented in Table 3. Color highlights indicate the roles of the key actors in the SD of the mineral resource base in the Arctic.

Table 3. The role of key actors and possible initiatives to stimulate the sustainable development of the mineral resource base.

Key Actors	**Planning**	**Sustainable Development of the Mineral Recourse Base**			
		Geological Prospecting and Exploration	**Field Development**	**Rational Resource Use**	**National Security**
State	• Improving and detailing the Strategy for the development of the mineral resource base of the Russian Federation. • Development of strategic maps for the sustainable development of the mineral resource base in the Arctic.	• Increase in the volume of exploration financing in the Russian Arctic. • Providing better salaries to professionals in the field of geology. • Simplification of the procedure for obtaining patents for prospecting and exploration technologies. • Stimulating import substitution in the field of technologies for geological prospecting and exploration.	• Investments in the latest mining technologies in the Arctic • Financing infrastructure development programs of the Russian Arctic. • State programs to attract specialists to work in the Russian Arctic. • Financing research institutes that focus on mining. • Programs for the development of small and medium-sized businesses in the field of mining in the Russian Arctic. • Improving legislation in the field of the development of mineral resource base in the Russian Arctic.	• Tax benefits for companies investing in the replenishment of the mineral resource base. • Financing of training and retraining programs for mining professionals. • Systems of fines and incentives for companies generating emissions into the environment. • Measures of economic stimulation for companies to increase the degree of resource development.	• Investments in R&D in the field of technologies for the extraction of strategic minerals in the Arctic. • Benefits for companies extracting scarce and strategic minerals for the country. • Investments in R&D in the Arctic. • Investments in the development of industrial production in the Russian Arctic. • Support for small and medium-sized businesses in the Russian Arctic. • Development of the Northern sea route

Table 3. *Cont.*

Key Actors	Planning	Sustainable Development of the Mineral Recourse Base: Geological Prospecting and Exploration	Field Development	Rational Resource Use	National Security
Region	Development of regional programs for the SD of the mineral resource base.	• Creation of geological research centers for the advanced training of geologists. • Development of social programs to attract geologists to work in the Russian Arctic. • Investments in the search for new mineral deposits.	• Improvement of sectoral mechanisms in mining regulation. • Investments in creation of transport infrastructure in mining regions. • Financing of regional research and development institutes in the field of mining. • Programs for the development of small and medium-sized businesses in the field of mining in the Russian Arctic	• Development of incentives for companies implementing technologies of rational resource use (reduction of production losses, etc.). • Financing regional research institutes and research in the field of rational resource use.	• Active participation in creation and development of transport and social infrastructure. • Investments in improving the human potential of the Russian Arctic (education, professional retraining, improving the standard of living). • Targeted use of funds allocated for territorial development programs and the fight against corruption.
Mining companies	Development of strategies for the SD of the mineral resource base taking into account the factors identified.	• Investments in modern technologies and equipment for exploration. • Increase in the volume of exploration financing in the Russian Arctic. • Creation of an effective corporate system for motivating geologists to work in the Russian Arctic.	• Commissioning of new deposits. • Investments in upgrading production facilities. • Investments in digital projects (Industry 4.0). • Social programs to attract professionals to work in the Russian Arctic.	• Systematic investments in environmental projects. • Minimization of emissions into the environment. • Bigger investments in R&D in the field of rational resource use. • Introduction of technologies that reduce losses during the extraction of minerals. • Increasing and maintaining the ESG rating.	• Creation of a system of incentives for qualified personnel to work in the Russian Arctic.
Color highlights:		[dark blue]	Critical influence; the development of the mineral resource base is impossible without the participation of this actor.		
		[grey]	The actor has one of the most important roles in the development of the mineral resource base.		
		[light blue]	The actor has an impact along with others.		

Source: compiled by the authors based on [3,14,30,34,58].

The highlighted colors in the table clear indicate entities with the greatest influence on each of the four development directions of the Arctic mineral resource base. The state holds the most significant role in areas such as geological prospecting and exploration and national security. Mining companies play a primary role in the development of deposits and rational resource use. The table serves to systematize recommendations for key actors in the development of the mineral resource base, indicating which should primarily exert managerial influence.

4.6. A Model of Sustainable Development for the Arctic Mineral Resource Base

The sustainable development of a mineral resource base is an approach to the strategic development of the mineral resource base of a territory that ensures the balance of its four key directions and dynamics (geological prospecting and exploration, field development, rational resource use, national security) in view of the current global trends.

The phrase "sustainable development of the Arctic mineral resource base" proposed by the authors, which identifies four key directions of sustainable development, was used as the basis for the model. Each of the four directions is characterized by the most important factors that have a significant impact on the sustainable development of the mineral resource base in the Russian Arctic (Figure 12).

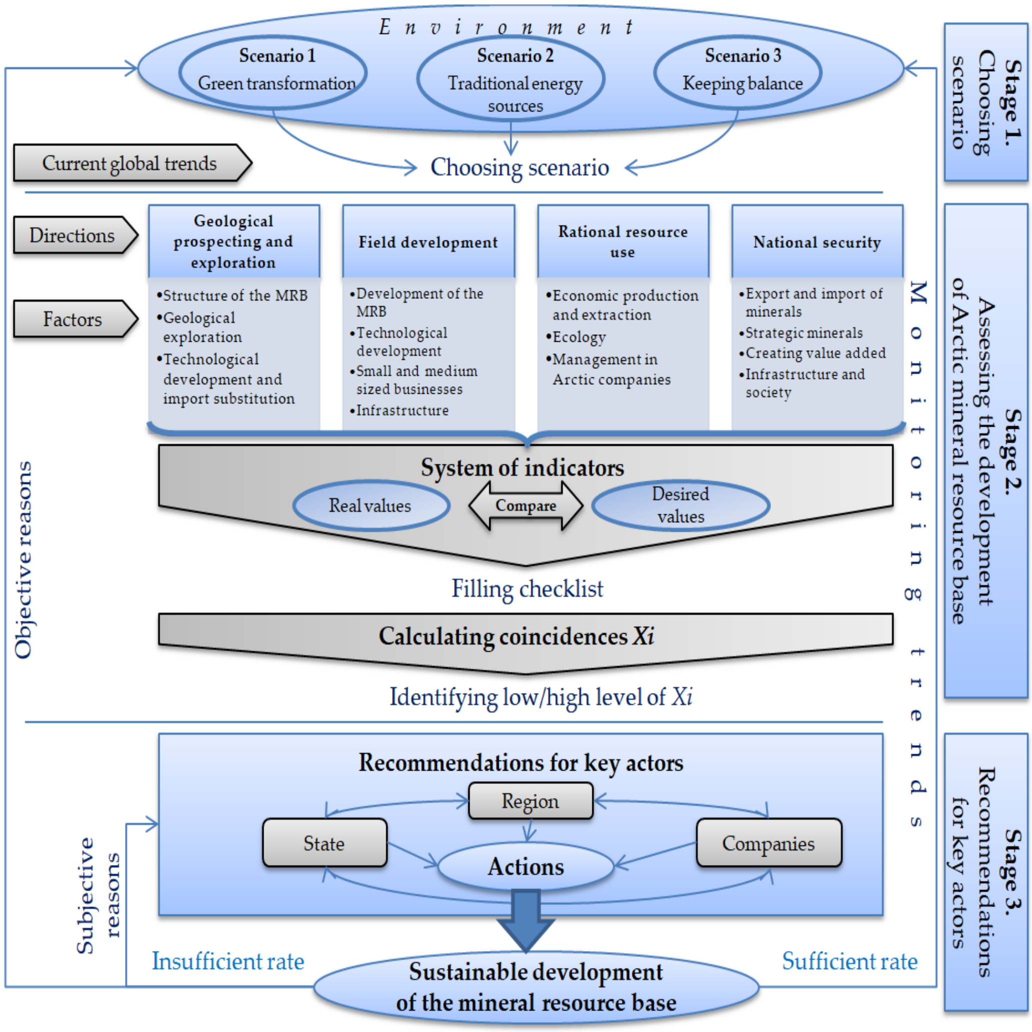

Figure 12. A model for the sustainable development of the Arctic's mineral resource base taking into account the current global trends. Source: compiled by the authors.

The model proposed by the authors provides a systematic approach to assessing the sustainable development of the Arctic's mineral resource base. It takes into account existing trends and the chosen path of economic and industrial development, key areas for resource potential development, and mechanisms of interaction between the main actors to achieve established target priorities.

5. Conclusions

As already noted, sustainable development issues remain relevant despite changes in the global situation. Geopolitical aspects and changes in national development paths in many countries have only expanded existing trends. However, mineral resources continue to serve as a critical source of socioeconomic development, particularly for Russia.

As a result of our research, we propose a model for the sustainable development of the mineral resource base. It provides an organizational mechanism for managing the development of the Arctic mineral resource base, considers current external environment, helps to analyze the current situation, and identifies "key actors": the state, the regional institutions, and the mining companies. It provides an assessment of the development of the Arctic mineral resource base in current macroeconomic and geopolitical conditions (so-called "global trends") and generates possible recommendations for these actors. Basing on this model, key actors can clearly delineate responsibilities and allocate efforts aimed at sustainable development of the Arctic mineral resources.

In the paper, we provide all the necessary tools for implementing this model: the table of specific indicators selected for the chosen global scenario called "keeping balance", and the list of possible recommendations and initiatives for the key actors that will lead to the sustainable development of mineral resource base.

Using this model, it is possible to determine the directions that require efforts to be redirected, such as investments, organizational and legal adjustments, towards those with lower values (i.e., promoting development in these directions). Meanwhile, areas where the value of X_i is close to 1 can be temporarily put on hold, allowing for the restructuring of priority areas for the development of the mineral resource base, while taking into account emerging global trends. The proposed assessment method enables the identification of the state of each of the four crucial areas for the development of the Arctic's mineral resource base, the formulation of recommendations for key actors, and the proper prioritization of mineral resource development in the Arctic while considering new trends and challenges.

It should be mentioned that the proposed mechanism should be implemented on a regular basis bearing in mind the constantly changing external environment and global trends, as well as actions of the key actors leading to a changing situation. The latter may not always lead to the desired results, while the pace of sustainable development should be satisfactory for key actors. Therefore, it is necessary to identify objective and subjective reasons for insufficient rates of sustainable development, eliminate them, and reactivate the proposed mechanism.

Further research will be devoted to the implementation of this model on a particular Arctic region and to the development of concrete recommendations for the actors.

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Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A Geological exploration by their types and groups of minerals, thousand rubles

Volumes of Geological Exploration, Thousand Rubles																															
Murmansk Region								**Nenets Autonomous District**								**Yamalo-Nenets Autonomous District**								**Chukotka Autonomous District**							
2014	2015	2016	2017	2018	2019	2020	2021	2014	2015	2016	2017	2018	2019	2020	2021	2014	2015	2016	2017	2018	2019	2020	2021	2014	2015	2016	2017	2018	2019	2020	2021
Hydrocarbon raw materials																															
2043	893	0	0	0	0	0	0	12,531,198.3	8,588,104.4	13,046,487.2	7,755,694.5	6,386,284.5	9,480,661.1	6,383,069.6	2,837,176	31,739,685.2	44,397,149.7	32,598,455.4	43,062,946.7	37,837,168.9	57,635,386	70,987,307.8	71,728,683.2	0	0	0	0	0	0	0	0
Ferrous metals																															
76,350	249,183.7	199,816.1	0	650	0	106,563.3	146,844.3	0	0	0	0	5197.6	0	0	0	311,464.2	201,503.2	328,099.4	177,313	714.6	69,971.6	154,630	153,304.9	0	0	0	0	0	0	0	0
Coal																															
0	0	0	0	0	0	0	0	0	0	11,218.4	5048.5	27,166.9	1289.2	8871.8	23,956.8	0	0	0	0	0	0	0	0	367,440.5	419,351	80,114.8	2252	19,013	17,106	761	13,935
Non-ferrous metals																															
89,219	61,736	1789	0	0	0	0	3000	0	0	0	0	0	0	0	0	1,209,166	0	0	0	0	0	0	0	184,754.5	1,154,579	615,218.1	473,945	997,089	601,547	1,067,405	510,014
Precious metals and diamonds																															
98,976	98,335	178,754	133,764	73,953	94,081	36,252	267,764	0	0	0	0	0	0	0	0	1608	3040	6388	2915	2113	920	1859	10,587	1,806,912.6	2,448,407	2,399,104.9	2,742,851	2,936,929	3,427,120	3,785,880	4,710,870
Nonmetals																															
240,344	208,860	9303	1730	7716	51,220	25,920	2154	0	0	0	0	0	0	0	44	12,454	1034	712	413	3352	69	5511	33,218	0	0	0	0	0	0	0	0

Regional geological study of subsurface																															
10,506	16,163	25,459	23,489	40,160	44,897	54,703	86,668	0	0	35,265.5	39,908.8	44,265.3	46,872.8	12,906.5	27,572.9	856,000	612,136	142,169	91,892	23,354	14,683	28,489	43,761	62,505	28,000	104,242.9	107,872	198,346	240,902	270,222	156,249
Research and development work																															
0	0	0	0	0	0	0	0	0	137,728	141,189.9	159,226.5	107,534.2	238,726.7	89,308	126,752	940,775	1,143,203	1,085,178	870,742	1,005,569	923,941	1,301,446	1,256,452	0	0	0	0	0	0	0	0
Thematic and experimental-methodical works related to the geological study of the subsoil and the reproduction of the mineral resource base																															
2830	0	0	0	0	307	381	373	342,761	191,527	42,438.3	112,394.4	91,929.9	142,835	92,325.1	97,434.1	1,430,182	2,907,381	2,376,390	2,561,301	1,246,733	2,069,934	3,226,911	2,937,473	0	0	0	0	0	0	76	106	62

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