The Potential of Sino–Russian Energy Cooperation in the Arctic Region and Its Impact on China’s Energy Security

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The Sino–Russian Arctic energy cooperation is a successful example based on the comprehensive strategic partnership between the two countries. In order to analyze the impact of Sino–Russian oil and gas resources cooperation in the Arctic on China’s energy security, this paper selects 11 influencing factors such as energy self-sufficiency rate and uses the energy security index method to evaluate the three dimensions of energy supply, demand, and environmental security. The assessment results show that China’s energy security is mainly affected by the over concentration of energy import sources. At the same time, energy demand and environmental security will also have an important impact on China’s energy security. However, relative to energy demand, environmental security factors such as the proportion of clean energy consumption and channel safety factor have a greater impact on China’s energy security. After China and Russia strengthen cooperation in oil and gas resources in the Arctic, China’s energy security index is expected to increase from 0.4419 in 2020 to 0.5412 in 2025. Therefore, China can use technology, funds, scientific research, and other support to carry out all-round cooperation with Russia in the Arctic waterway, oil and gas exploration and development, and Arctic scientific research.

1. Introduction

With the climate warming and the “Arctic amplification” phenomenon [1], the development and utilization of Arctic energy have attracted more and more attention. As a “major stakeholder in the Arctic,” the Chinese government released the first white paper on China’s Arctic policy in 2018, which clearly supports Chinese enterprises to actively participate in the development of Arctic oil and gas resources. The Arctic region is rich in oil and gas resources. According to the estimation of the United States Geological Survey (USGS), the total technically exploitable oil and natural gas resources in the Arctic region are 412 billion barrels of oil equivalent, of which 78% are expected to be natural gas and liquid natural gas. However, China has no geographical advantage in participating in the development of Arctic oil and gas resources. According to the Arctic energy and gas resources. The Arctic region is rich in oil and gas resources. According to the estimation of the United States Geological Survey (USGS), the total technically exploitable oil and natural gas resources in the Arctic region are 412 billion barrels of oil equivalent, of which 78% are expected to be natural gas and liquid natural gas. However, China has no geographical advantage in participating in the development of Arctic energy, and the United States and other countries have restricted China’s influence in Arctic affairs for a long time, which has hindered China’s in-depth participation in Arctic affairs. In recent years, the scale of Russia’s development of oil and gas resources in the Arctic has been expanding, and its financial and technical support has also increased, which provides an opportunity for China to participate in the cooperative development of Arctic energy. At present, the Yamal natural gas project, in which China and Russia have cooperated in the Arctic region, has been put into operation since 2017, with a total output of 45.8 million tons by 2020. The project plays a leading role in China’s further participation in the development of Arctic energy. Meanwhile, the Sino–Russian Arctic 2 liquid natural gas project under construction will further deepen the cooperation between the two countries in oil and gas resources. The Sino–Russian Arctic oil and gas cooperation not only provides China with the opportunity to jointly develop the Arctic waterway but also on the energy level, the Arctic oil and gas projects have greatly alleviated the need for China’s energy structure adjustment. Therefore, the main research content of this paper is to analyze the potential of energy cooperation...
between China and Russia in the Arctic region and evaluate the impact of Sino–Russian Arctic energy development on China’s energy security.

At present, the research on Arctic energy security is not rare at home and abroad. The existing research is mainly carried out from the perspective of energy policy and the environment. In terms of Arctic energy security policy, Zhang and Xing [2] assessed the political and economic role of the Arctic in international relations from the perspective of China’s energy policy strategy. Luo and Li [3] combed the Arctic energy policies of Arctic countries, the European Union, Britain, Germany, Japan, and South Korea and analyzed the game of major powers in the Arctic region and its impact on China’s energy security. Korkmaz (2021) [4] studied the characteristics of China’s Arctic policy and its links with the “Belt and Road” initiative through the white paper on China’s Arctic policy. In terms of the impact of Arctic climate change on China’s energy security, Yang et al. [5] analyzed the possibility of Arctic energy development from the perspective of climate change. Pan [6] analyzed the uncertainties and risks faced by the development of oil and gas resources in the Arctic region and put forward countermeasures for China’s energy security according to the changes in the Arctic climate and environment. However, there is a lack of research on the specific measurement system and evaluation methods of Arctic energy security in the existing literature.

Based on this, this paper studies the current situation of energy cooperation between China and Russia predicts the potential of energy cooperation between China and Russia in the Arctic region and uses the energy security index method to evaluate the impact of Arctic energy development on China’s energy security.

2. Current Situation of Energy Development Cooperation between China and Russia

Among the eight Arctic countries, Russia has the most abundant oil and gas reserves in the Arctic region. According to the USGS assessment, there are 61 large oil and gas fields in the Arctic region, of which 43 are located in the Russian Arctic region, with an oil and gas volume of about 247.4 billion barrels of oil equivalent. In 2017, China and Russia reached an agreement on the construction of the northern waterway and the “ice silk road”. In 2016 and 2018, China and Russia formed two joint investigation teams to complete the scientific investigation of the key waters of the “northeast channel”. In 2019, China–Russia relations will become “strategic cooperative partners,” and China has increased its investment in Russia’s Arctic region.

At present, the oil and gas cooperation projects between China and Russia in the Arctic region mainly include Yamal liquid natural gas project and the Arctic 2 natural gas project. Yamal project, integrating natural gas development, processing, liquefaction, and maritime transportation, is a major oil and gas project in the world. The project is jointly operated by CNPC, China Silk Road Fund, Novatec of Russia, and a total of France, holding 20%, 9.9%, 50.1%, and 20% of the shares of the project, respectively. By 2021, all four production lines of the project will be put into production, and the annual production capacity of natural gas will reach 19.75 million tons.

The Arctic 2 liquid natural gas project is the second liquid natural gas project developed by Novatec in the Arctic region after the Yamal project. Novatec of Russia holds 60% of the shares in the project, and CNOOC PetroChina exploration and Development Corporation, a total of France, and Mitsui property-jogmec consortium of Japan holds 10% of the shares respectively. The project is expected to build three natural gas production lines, with a single production line capacity of 6.6 million tons/year and a total annual output of 19.8 million tons. Novatec plans to put the first natural gas production line into production in 2023 and put all three production lines into production in 2025.

According to the data of the world energy network, the actual output of energy cooperation projects between China and Russia in the Arctic region from 2017 to 2020 is shown in Table 1.

3. Analysis of the Potential of Energy Cooperation between China and Russia in the Arctic Region

According to the USGS assessment results, about 30% of the crude oil, 69.3% of the liquid natural gas, and natural gas in the Arctic region are located in Russia. Table 2 shows the technically recoverable oil and gas resources not found in the Arctic region of Russia. From the perspective of resources, the East Barents basin and Timan bochaola basin, which are rich in oil and gas resources, have a low degree of exploration and have broad exploration and production prospects. China and Russia still have much room for cooperation in the Arctic region. From the perspective of Russia’s natural gas exports, Russia’s natural gas exports to Japan, South Korea, and other countries in Asia are decreasing in 2020, but its natural gas exports to China have increased by about 35%. As an important oil and gas exporter of Russia in Asia, Russia is bound to strengthen its energy cooperation with China. At the same time, with the smooth progress of the Yamal project, Russia will strengthen the development of Arctic oil and gas resources. In October 2020, the Russian government approved the national security strategy for developing the Arctic region by 2035. The strategy points out that Russia is expected to significantly increase the Arctic natural gas production from 8.6 million tons in 2018 to 43 million tons, 64 million tons, and finally, to 91 million tons in 2024, 2030, and 2035. At the same time, the strategy also plans to increase the proportion of Russian Arctic oil production in the total oil production, from 17.3% in 2018 to 23% in 2030.

The factors that affect the potential of energy cooperation among countries mainly include the scale of energy cooperation, i.e., energy output, import and export volume, investment in energy technology, equipment, and funds, and the closeness of political and diplomatic relations among countries. However, considering the measurability and availability of data, this paper takes the scale of energy
cooperation as the analysis index of the potential of China and Russia oil and gas resources cooperation in the Arctic region.

As the actual annual output of the Yamal project is higher than the estimated annual output, and the annual output has increased, relevant assumptions need to be made when predicting the annual natural gas production capacity of China and Russia in the Arctic region. Assumption: the annual growth rate of natural gas production in China and Russia in the Arctic region is 1.02, and the actual production capacity of the Arctic No. 2 single production line is 7.39 million tons. The reason is that by 2021, all four production lines of the Yamal project have been completed and put into production, and the estimated annual capacity of the first three production lines is 16.5 million tons. However, according to the report of energy world network Moscow, its actual output will be 18.4 million tons/year in 2019 and 18.8 million tons/year in 2020. Considering the actual production capacity of the mining technology, this paper assumes that the actual annual production capacity of a single production line of the Arctic 2 project is 1.12 times of the estimated annual production capacity. Meanwhile, the first three production lines of the Yamal project will be fully put into production in 2019 and 2020, but the capacity in 2020 is 1.02 times that in 2019, so it is assumed that the annual capacity growth rate of the two projects is 1.02.

Based on the above assumptions, this paper forecasts the output from 2021 to 2025, and the results are shown in Table 3.

### 4. Selection Basis of Energy Security Assessment Methods and Influencing Factors

#### 4.1. Basis for Selection of Energy Security Assessment Method

Energy security is the core content of a country’s national security system. China is relatively short of oil and gas natural resources and has long relied on imports. The long-term stable supply of energy and transportation security has

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**Table 1:** Actual total annual production of Yamal 2017–2020.

| Particular year | Yamal project | Estimated capacity of a single production line | Actual annual output |
|-----------------|---------------|----------------------------------|----------------------|
| 2017            | In December, the first line was put into operation | 5.5 million tons/year | —                    |
| 2018            | In July, the second line was put into operation | 5.5 million tons/year | 8.6 million tons     |
| 2019            | —             | —                                | 18.4 million tons     |
| 2020            | —             | —                                | 18.8 million tons     |

Source: World Energy Network.

**Table 2:** Undiscovered, technically recoverable oil and gas resources in the Russian Arctic (including shared resources with Norway).

| Basin                        | Crude oil (billion barrels) | Natural gas (ten thousand) | Crude oil (billion barrels) | Natural gas (ten thousand) |
|------------------------------|-------------------------------|-----------------------------|-------------------------------|-----------------------------|
| Siberian basin               | 3.66                          | 651.5                       | 20.33                         | 132.57                      |
| Yenisei–Khatanga basin       | 5.58                          | 99.96                       | 2.68                          | 24.92                       |
| Laptev Sea continental shelf | 3.12                          | 32.56                       | 0.87                          | 9.41                        |
| North Kara basin             | 1.81                          | 14.97                       | 0.39                          | 4.69                        |
| Timan bochaola basin         | 1.67                          | 9.06                        | 0.2                           | 3.38                        |
| Lena–Anabar basin            | 1.91                          | 2.11                        | 0.06                          | 2.32                        |
| Scintillation basin          | 0.10                          | 5.74                        | 0.10                          | 1.16                        |
| Northwest raodev shelf       | 0.17                          | 4.49                        | 0.12                          | 1.04                        |
| Lena–Vilyui basin            | 0.38                          | 1.34                        | 0.04                          | 0.64                        |
| Rilianga basin               | 0.05                          | 1.51                        | 0.04                          | 0.34                        |
| Eastern Siberian basin       | 0.02                          | 0.62                        | 0.01                          | 0.13                        |
| East Barents basin           | 7.41                          | 317.56                      | 1.42                          | 61.7                        |
| Eurasian basin               | 1.34                          | 19.48                       | 0.52                          | 5.11                        |
| Total                        | 27.22                         | 1160.9                      | 26.78                         | 247.47                      |

Source: USGS https://earthquake.usgs.gov/. Note: 6 trillion cubic feet of natural gas is equivalent to 1 billion barrels of crude oil.

**Table 3:** Total annual production from Yamal and arctic 2 2021–2025.

| Particular year | Yamal project | Arctic 2 project | Estimated capacity of a single production line | Estimated annual output |
|-----------------|---------------|------------------|----------------------------------|-------------------------|
| 2021            | Article 4 production line put into operation | — | 950000 T/a | 2018 million tons |
| 2022            | —             | —                | —                                | 20.62 million tons      |
| 2023            | —             | The first production line is put into operation | 6.6 million tons/year | 28.46 million tons |
| 2024            | —             | The second production line is put into operation | 6.6 million tons/year | 36.47 million tons |
| 2025            | —             | All three production lines are put into operation | 6.6 million tons/year | 44.65 million tons |
always been the focus of China’s attention. For China, energy security is not just an economic issue of energy supply and demand, but a strategic issue involving energy cooperation and national security among countries. The large-scale natural gas cooperation project between China and Russia in the Arctic region not only stabilizes the overseas supply of China’s oil and gas resources but also invests in the construction of the Arctic northeast channel to further expand China’s maritime transport channels. But how to quantify its impact on China’s energy security is a big challenge. In the existing research, scholars use different measurement methods to quantify energy security. Filipović et al. (2018) [7] used the energy security index (ESI) to analyze and rank the energy security index of EU Member States on the basis of principal component analysis (PCA). Wang et al. [8] proposed a dynamic analysis method of ESI within the framework of FDA (function data analysis), namely desic. The improved desic can dynamically analyze the change in energy security index over time. Ioannidis and Chalvatzis (2017) [9] for the first time, based on the Shannon Wiener diversity index and the Herfindal-Hirschman index, combined the diversity of fuel composition with the dependence on energy imports to assess the security of energy supply. Augustis et al. [10] used the ESL energy assessment method to analyze the energy security of the Baltic Sea. Among many energy security assessment methods, the energy security index (ESI) is a common method for quantitative analysis of energy security. It classifies the data related to energy security, calculates the information entropy, and then combines them into a total value. This method can integrate the information of the Russian Arctic region on China’s oil and gas resource supply, energy transport safety coefficient, and so on, summarize China’s entire energy system, and reflect the characteristics of energy security. And it has been widely studied in the application of assessing and measuring national energy security, and the research results are relatively reliable.

4.2. Basis for Selection of Factors Affecting Energy Security. On the one hand, the selection of factors affecting energy security in this paper can integrate the information of China Russia Arctic energy cooperation, on the other hand, the data should be easy to sort out and a weighted summary. In the existing literature, scholars use different influencing factors to evaluate energy security. Matsumoto et al. (2018) [11] assessed the energy security of EU countries, focusing on energy diversity, import dependence, and supply risks. Radovanovi et al. [12] proposed an energy security index covering environmental and social factors, which was applicable to EU countries from 1990 to 2012. Kruyt et al. [13] combed four dimensions such as the availability of energy security and selected influencing factors from the four dimensions. Song et al. [14] proposed China’s energy security index, which includes three dimensions: energy supply, energy consumption, and environment. This dimension can be divided from the supply of oil and gas resources, the proportion of China’s oil and gas resources consumption, the energy transportation environment, and other factors to specifically analyze the impact of China Russia Arctic energy cooperation and development on China’s energy security. In this paper, the selection of factors affecting energy security is mainly considered from three aspects: first, it can measure the impact of changes in the supply of oil and gas resources on energy security after China’s participation in the cooperative development of Arctic energy; Second, it can measure the impact of the utilization of the Northeast waterway on China’s energy security; The third is the availability, reliability, and integrity of data. According to the existing literature, this paper selects 11 influencing factors, including 5 energy supply dimensions, 3 energy demand dimensions, and 3 environmental dimensions.

5. Impact Assessment of China Russia Energy Cooperation on China’s Energy Security

5.1. Basic Assumptions. In 2018, the first batch of liquid natural gas of the Sino–Russian Yamal project was transported to Rudong terminal in Jiangsu, China, opening a new chapter in Sino–Russian Arctic oil and gas resources cooperation. At the same time, the construction and production of Sino–Russian Arctic No. 2 project will further increase the natural gas delivered to China. However, the specific data that China will import oil and gas resources from the Russian Arctic region after the Arctic 2 project is put into operation is not clear. Therefore, before assessing the impact of Arctic energy development on China’s energy security, this paper makes the following assumptions:

Assumption 1. Assumption that China imports oil and gas resources from the Russian Arctic region

China’s import of oil and gas resources from Russia’s Arctic region accounts for 21% of the total output of bilateral cooperation projects. The reason is that the actual output of liquid natural gas of the Yamal project in 2019 is 18.4 million tons, of which at least 4 million tons will be transported to China, accounting for about 21%. At present, the Sino–Russian Yamal project is progressing very smoothly, and it is also the foundation and important fulcrum for China to participate in the Arctic energy cooperation. The project can also be used as a reference for subsequent cooperation.

Assumption 2. Assumption of influencing factors of energy security

When assessing the impact of the Arctic oil and gas resources cooperation between China and Russia on China’s energy security, it is assumed that other factors affecting energy security, except the per capita supply of natural gas, per capita supply of oil and channel safety factors, and maintain the current upward or downward trend. The per capita supply of natural gas, per capita supply of oil and channel safety factors, is evaluated using the data predicted in this paper.

5.2. Accounting and Data Source of Influencing Factors of Energy Security. This paper sorts out the influencing factors of China’s energy security from the three dimensions of
energy supply, energy demand, and environment, mainly involving 11 influencing factors such as oil import concentration, energy consumption elasticity coefficient, and channel safety coefficient. It is used to reflect and predict China’s energy security from 2010 to 2025. The specific accounting methods and data sources are as follows:

5.2.1. Factors Affecting Energy Supply. The impact of Sino–Russian cooperation in oil and gas resources in the Arctic on China’s energy is mainly reflected in the energy supply. The stronger the country’s energy supply capacity and the higher the per capita supply, the more its energy security can be guaranteed. In view of this, five factors affecting energy supply security, such as the per capita supply of natural gas, are selected in terms of energy supply security.

(1) Dependence on foreign oil. The proportion of a country’s net oil imports in its domestic oil consumption. External dependence on oil = (total annual oil imports – total annual oil exports)/total annual oil consumption. The higher the dependence on foreign oil, the higher the risks of energy supply.

(2) Oil import concentration. The proportion of the total export volume of all China’s oil import source countries to China’s top five oil countries each year in China’s net oil import volume. The higher the value, the higher the concentration of China’s oil imports and the greater the risk of energy supply.

(3) Energy self-sufficiency rate. Percentage of domestic energy output to total energy consumption. Indicates the extent to which a country’s energy production meets its consumption. The higher the energy self-sufficiency rate, the stronger the domestic energy supply capacity and the higher the energy security.

(4) Per capita supply of natural gas. The average amount of natural gas per person in the country can be provided for use. Per capita natural gas supply = total annual natural gas supply of a country/total population of the country in this year. The total natural gas supply includes domestic production and foreign net import. Among them, the natural gas import volume of Russia’s Arctic region from 2020 to 2025 is predicted in this paper.

(5) Per capita oil supply. The amount of oil that can be provided for use per capita in the country. Per capita oil supply = annual oil supply of the country/population of the country in the current year. The total oil supply includes domestic production and foreign net import.

5.2.2. Factors Affecting Energy Demand. The energy security of a country is also affected by energy consumption and energy efficiency. High energy consumption means high energy demand, which means that more energy supply is needed to ensure social production and life. The Sino–Russian cooperation on oil and gas resources in the Arctic region has an impact on China’s energy efficiency to a certain extent. The increase in the use of natural gas will improve energy efficiency. Efficient energy consumption and a good energy demand structure can reduce energy waste and ensure the full utilization of energy. Therefore, three factors, such as the proportion of oil consumption, are used to measure the security of energy demand.

(1) Elasticity coefficient of energy consumption. In China, this indicator is the ratio of the average growth rate of energy consumption in a certain period to the average growth rate of agricultural GDP in the same period. The elasticity coefficient of energy consumption is affected by energy efficiency, economic structure, and other factors. With the improvement of energy efficiency and the optimization of economic structure, the elasticity of energy consumption will decline.

(2) Energy consumption per unit of GDP. The ratio of total primary energy consumption to domestic GDP. This indicator can reflect the national energy demand level and energy efficiency. Energy consumption per unit GDP = domestic primary energy consumption (ten thousand megajoules)/domestic GDP (ten thousand yuan).

(3) Proportion of oil consumption. The proportion of domestic oil consumption in primary energy consumption. Oil security is particularly important in energy security. The stability of the oil market has an impact on China’s energy security, economic security, and even national security.

5.2.3. Environmental Factors. The stable natural gas supply from the Arctic region to China every year can alleviate environmental pressure and contribute to China’s realization of “carbon peak” and “carbon neutrality.” At the same time, with the further deepening of energy cooperation between China and Russia in the Arctic region, the commercial and economic value of the Northeast passage of the Arctic is becoming greater and greater. The Strait of Malacca has always been responsible for China’s energy transport. The full opening of the Northeast passage of the Arctic can reduce the dependence of energy transport on the traditional passage. Assessing the safety of China’s energy maritime transport channels, especially the safety factors of the Malacca Strait and the Northeast channel, can further clarify China’s energy security situation. In view of this, China’s energy and environmental security is measured by the proportion of coal consumption, the proportion of clean energy, and the channel safety factor.

(1) Proportion of coal consumption. The proportion of domestic coal consumption in primary energy consumption. This indicator can reflect the energy consumption structure of a country. Reducing the proportion of coal consumption is conducive to the country’s optimization of energy structure and improvement of energy efficiency. It is also a practical need to promote China’s clean and low-carbon energy transformation.
(2) Proportion of clean energy. The proportion of domestic clean energy consumption in primary energy consumption. The higher the proportion of clean energy consumption in a country, the more friendly its energy consumption is to the environment and the more conducive it is to the long-term stable development of the social economy.

(3) Channel safety coefficient. Channel safety is an important guarantee for energy maritime transportation. The higher the channel safety coefficient, the higher the overseas supply security of energy. The channel safety factors of ships in the Strait of Malacca and the Northeast channel of the Arctic mainly include hydrological conditions (current and tide, sea ice conditions), meteorological conditions (wind speed, temperature, visibility), channel conditions (navigation width, water depth), traffic conditions (annual traffic accidents, international navigation law), and other conditions (port construction, piracy, navigation facilities). Because the navigation conditions of the channel are fuzzy and complex, the fuzzy analytic hierarchy process is used to measure the channel safety factor. In this paper, five classification conditions are used to form a judgment matrix, and 13 influencing factors are used to form five judgment matrices. The factors in each matrix are compared in pairs, the scaling method is used to assign values, and the weights of each influencing factor are calculated. At the same time, comparing the advantages and disadvantages of various factors in the Arctic channel and the Malacca Strait, the more advantageous one gets a score of 1 and the other 0. The specific weights and scoring results are shown in Table 4.

From the above assessment, the safety factor score of the Arctic channel is 0.2942 and that of the Malacca Strait is 0.7058. The Malacca Strait is superior to the Northeast Arctic channel in sea ice, meteorological conditions, and water conditions, so its final safety factor is also higher than the Northeast Arctic channel. In this paper, the overall safety factor of the channel = the safety factor of the channel of the Malacca Strait, the proportion of the energy freight volume of the Malacca Strait + the safety factor of the Arctic channel, the proportion of the energy freight volume of the Arctic channel. The energy freight volume data of Malacca Strait is from EIA, and the energy freight volume data of the Arctic channel is from the Norwegian ship owners’ Association.

The influencing factors and relevant information used in the energy security assessment are as follows:

5.3. Energy Security Assessment and Result Analysis

5.3.1. Introduction of Energy Security Assessment Method. Among many energy security assessment methods, the energy security index method is more objective and interpretable, and its application is the most. This paper will use this method to evaluate energy security. As shown in Table 5 in 4.2, the measurement of China’s energy security is divided into three dimensions. Each dimension contains the influencing factors related to this dimension, but the influencing factors of each dimension are quite different. Therefore, assuming that the importance of each influencing factor is not distinguished in the same dimension, the subindicators of each dimension are objectively evaluated through information entropy, and then a comprehensive index is aggregated by assigning weights to each dimension. As each influencing factor has different directions for China’s energy security, it is necessary to standardize the data of each influencing factor. The specific steps are as follows:

The first step is to standardize the influencing factors of different attributes or scales into a common scale. Generally, the standardized data is between 0 and 1.

Factors that have a positive impact on China’s energy security, such as channel safety factors, $x_i(t) = \frac{y(t) - \min[y(t)]}{\max[y(t)] - \min[y(t)]} (t_1 \leq t \leq t_{10}); \quad i = 1, \ldots, m,$

where $t$ is the statistical year, $m$ is the number of influencing factors in each dimension, and $y(t)$ is the original value of each influencing factor; $\min[y(t)]$ and $\max[y(t)]$ respectively...
represent the minimum and maximum values of influencing factor \(i\) in each dimension.

Factors that have a negative impact on China’s energy security, such as energy consumption elasticity,

\[
x_i(t) = \frac{y(t) - \max[y(t)]}{\min[y(t)] - \max[y(t)]} \quad (t_1 \leq t \leq t_{10}) \quad i = 1, \ldots, m.
\]  
(2)

The second step is to use the function information entropy to measure the proportion of each influencing factor of the operator dimension

\[
P_i = \frac{x_i(t)}{\sum_{k=1}^{m} x_k(t)} \quad (t_1 \leq t \leq t_{10}).
\]  
(3)

The third step is to calculate the information entropy of the influencing factors included in each dimension

\[
E_i = [\ln(t_{10} - t_1 + 1)]^{-1} \cdot \sum_{k=1}^{m} P_i \cdot \ln(P_i).
\]  
(4)

The fourth step is to calculate the weight of influencing factors included in each dimension

\[
\omega_i = \frac{1 - E_i}{m - \sum_{k=1}^{m} E_k} \quad (0 \leq \omega_i \leq 1).
\]  
(5)

The fifth step is the energy security index of each dimension

\[
ESI(t) = \sum_{k=1}^{m} \omega_i(t) \cdot x_i(t) \cdot (t_1 \leq t \leq t_{10}) \quad (0 \leq \omega_i \leq 1).
\]  
(6)

Finally, reasonably allocate weights to each dimension, summarize the security indexes of each dimension, and form a comprehensive China energy security index

\[
TESI(t) = \sum_{d=1}^{D} \alpha_d \cdot \left[ \sum_{k=1}^{m} \omega_i(t) \cdot x_i(t) \right].
\]  
(7)

where \(d\) represents different dimensions, \(D\) represents the total number of dimensions, and \(\alpha_d\) represents the weight of different dimensions. According to the research of Ang et al. [15], the weights of energy supply, energy demand, and environment are 50%, 25%, and 25%, respectively. Giving a higher weight to the dimension of energy supply is to emphasize the importance of uninterrupted energy supply. Since all influencing factors have been subject to positive standardization, a larger Tesi \((T)\) means a safer level of energy security.

5.3.2. Energy Security Assessment Results

(1) Evaluation Results of Three Dimensions of Energy Security. According to the above calculation method, the energy security assessment [16–22] results of three dimensions are calculated respectively, as shown in Figures 1–3 below. Obviously, the fluctuation of the evaluation results of each dimension is different. The assessment results of China’s energy supply security are shown in Figure 1, which shows a downward trend before 2020. This downward trend also reflects that China has always been highly dependent on energy imports, with concentrated sources of energy imports, and a low per capita supply of oil and natural gas. In fact, limited by domestic energy resources, China’s dependence on oil imports has reached 73% in 2020, and the
concentration of oil imports is 57%. China’s energy supply faces great risks. After considering the long-term oil and gas resources cooperation projects between China and Russia in the Arctic region, it can be seen from Figure 1 that the energy supply security index has rebounded significantly after 2020 because China’s oil and gas resources, especially the import of natural gas, have been protected to a great extent.

The energy demand security assessment index is shown in Figure 2, which fluctuates from 2011 to 2025 and reaches a trough in 2020. After 2014, the energy demand security index has decreased significantly. The possible reason is that in the past, the proportion of oil consumption increased by an average of about 0.2% every year. From 2014 to 2015, the proportion of oil consumption in primary energy consumption increased from 17.3% to 18.4%. Since 2015, the proportion of oil consumption has been relatively stable, and the fluctuation of the energy demand security index is mainly due to the increase of the energy consumption elasticity coefficient (the value in 2020 is 0.96). After 2020, with the further deepening of natural gas cooperation between China and Russia, the proportion of clean energy consumption such as natural gas has increased, and the energy structure has been optimized, which has played a significant role in improving the security of energy demand. But at the same time, the increase in the proportion of oil consumption makes the energy consumption elasticity index unable to rise all the time, so the security of energy demand fluctuates.

The energy and environmental security assessment index is shown in Figure 3, which shows an overall upward trend from 2011 to 2025. Among the three environmental factors, the proportion of coal consumption has a negative impact on the environmental index, and the proportion of clean energy and channel safety factor have a positive impact on it. With the further deepening of oil and gas resources cooperation between China and Russia in the Arctic region, the Northeast passage of the Arctic has been more utilized, and China’s energy transportation has become less dependent on the Malacca Strait. At the same time, the increased use of natural gas has reduced the pressure of energy consumption on the ecological environment. Under the joint action of the two aspects, the growth rate of the energy and environmental security index will increase after 2020.

(2) Overall Assessment Results of China’s Energy Security. With reference to the predetermined weights, the evaluation results of China’s energy security index are obtained by using the final summary formula in 3.3.1, as shown in Figure 4 below. In fact, in 2011, China put forward many favorable energy policies, such as promoting diversified and clean energy development and closing small coal mines, which improved the level of energy security. However, China’s domestic energy resources have long been more coal and less oil and gas. In 2019, China’s oil import concentration reached 62%, posing challenges to the security of the energy supply, which led to a sharp decline in the energy security factor. With China actively expanding energy channels, strengthening cooperation with Russia on oil and gas resources projects in the Arctic region, and improving energy efficiency, China’s overall energy security level has maintained a steady rise. After considering the Arctic energy cooperation with Russia, China’s energy security level is expected to rise from 0.4381 in 2019 to 0.5412 in 2025. The continuous promotion of China–Russia Arctic energy cooperation and the construction of the Arctic waterway has reduced China’s dependence on energy imports from the Middle East, reduced the constraints of the Malacca Strait, increased the proportion of clean energy imports, optimized the energy structure, improved energy efficiency, and improved the level of energy security.

6. Conclusion

This study uses the energy security index method to evaluate the impact of oil and gas development cooperation between
China and Arctic countries, especially Russia, on China’s energy security. From the final results of the evaluation, it has an impact on China’s energy supply security, energy demand security, and environmental security. The specific conclusions are as follows:

(1) China’s energy security risks are mainly affected by the over concentration of energy import sources. Therefore, diversifying energy imports and reducing energy imports from volatile regions such as the Middle East can effectively disperse China’s energy supply risks.

(2) Energy demand and environmental security will also have an important impact on China’s energy security. However, compared with energy demand, environmental security factors such as the proportion of clean energy consumption and channel safety factor have a greater impact on China’s energy security. Therefore, increasing the proportion of clean energy consumption, reducing the dependence on energy import channels in the Malacca Strait, and diversifying energy import transport channels can effectively ensure China’s energy security.

(3) Strengthening energy cooperation with Russia in the Arctic region can greatly enhance China’s energy security. Therefore, with the support of technology, funds, and scientific research, China can carry out all-round and multifield cooperation with Russia in the construction of Arctic waterway, port infrastructure, icebreaker technology, oil and gas exploration and exploitation technology, and Arctic scientific research.

Data Availability

The dataset can be accessed upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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