

# Research on the Global PNG Trade Community Analysis and The Current Situation of Our Country's PNG Imports

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## ABSTRACT

Against the backdrop of global energy green and low-carbon transition and the "Dual Carbon" target, PNG, as a low-carbon clean energy source, has become increasingly prominent in the global energy consumption market. Research on the global PNG trade network contributes to an in-depth understanding of the current PNG trade pattern, clarifies China's position in the global PNG system, and provides strategic support for China's PNG supply security and energy security. This study employs social network analysis to classify countries involved in the global PNG trade into different communities. It investigates the agglomeration degree of supply and receiving stations within the same community and the formation mechanism of communities, and analyzes the community characteristics where China is located. The current situation of China's PNG import trade is examined from two dimensions: trade dependence index and import channels. The results demonstrate that: Firstly, community analysis reveals that geographical proximity constitutes the dominant factor influencing the global PNG trade. China acts as a leader in the Asia-Pacific community and holds a leading position in imports. Nevertheless, potential risks including geopolitical tensions, price volatility, and transportation security warrant vigilance. Secondly, the analysis of PMI and import channels indicates that China's PNG imports maintain a steady growth trend, and the structure of import channels is gradually moving toward diversification. Accordingly, policy recommendations are proposed to stabilize China's PNG supply and enhance the security capacity of national energy supply by adhering to the dual principles of expanding supply sources and controlling demand.

## KEYWORDS

PNG trade; Community analysis; Point-wise mutual information (PMI)

## 1. INTRODUCTION

Guided by the global energy transition towards green and low-carbon development and the goals of "carbon peaking and carbon neutrality", the energy structure is accelerating its evolution towards cleanliness, low-carbonization and diversification. The consumption of traditional fossil fuels such as coal and oil is gradually declining, and non-fossil energy is playing an increasingly dominant role in energy supply [1]. As a clean, efficient and high-quality energy source, natural gas not only meets the needs of low-carbon transition but also effectively connects traditional energy and renewable energy, playing a pivotal role in the restructure of the global energy pattern [2]. Natural gas trade is mainly realized through two modes: pipeline natural gas (PNG) and liquefied natural gas (LNG) [3]. PNG, with the advantages of stable transportation costs and continuous supply, has become the mainstream trade mode among geographically adjacent countries, while LNG provides a flexible solution for long-distance cross-regional trade.

In recent years, the global natural gas market has seen a tight supply-demand balance and a robust growth in trade scale [4]. However, the turbulent international political situation and frequent geopolitical conflicts have brought significant uncertainty to the natural gas trade pattern. The outbreak of the Russia-Ukraine conflict in February 2022 has become a key node reshaping the global energy trade order. As the world's largest natural gas exporter, Russia accounted for about one-fifth of the global natural gas export volume in 2025. After the outbreak of the conflict, the United States and Europe imposed multiple rounds of energy sanctions on Russia, leading to a sharp drop in Russia's PNG export capacity and a huge supply gap of natural gas in Europe. This not only triggered violent fluctuations in global natural gas prices but also promoted a structural adjustment in the global PNG trade network structure [5].

As an important participant in the global energy transition and one of the markets with the fastest growth in natural gas consumption, China's external dependence on natural gas has been rising continuously. As an important component of imported natural gas, the supply security of PNG is directly related to national energy security and the stable development of the economy and society. Against the backdrop of the reshaping of the global PNG trade pattern, China's PNG imports are facing multiple challenges such as changes in the supply stability of source countries, intensified regional resource competition, and the transmission of geopolitical risks. This paper uses social network analysis to systematically explore the community distribution and formation causes of the global PNG trade network, deeply analyze the current situation of China's PNG imports, and provide theoretical support and practical reference for China to optimize the layout of PNG imports and enhance the capacity of energy supply security guarantee.

## 2. LITERATURE REVIEW

For a long time, numerous scholars at home and abroad have carried out extensive research on natural gas trade, and most of the relevant research scopes focus on a single country or a specific region [6]. Zhang Jun et al. analyzed the evolution process of the PNG and LNG trade networks among countries along the "Belt and Road", pointing out that geographical location and energy consumption factors are more conducive to the expansion of natural gas trade scale along the route [7]. Liu Chang constructed a natural gas trade network between China and Middle Eastern countries to explore the structural characteristics and evolution trend of the network, and found that the network density and reciprocity index of natural gas trade between China and the Middle East have become increasingly close [8]. Xing Wenting et al. constructed a complex global PNG trade network, selected multiple indicators from the dimensions of static network structural characteristics and dynamic network functions, and evaluated the importance of nodes in the global PNG trade [9]. Wu Tao used social network analysis to analyze indicators such as network density and centrality of international PNG and LNG trade, and the results showed that the density of the world natural gas trade network is low, and the network density of LNG is much higher than that of PNG [10]. Tu Miao studied the evolution of the complex trade network pattern of global PNG and LNG under the goal of "carbon neutrality" through several key years, and found that the global PNG trade structure is relatively scattered and the network evolution speed is slow [11]. Wen Xin et al., based on the complex network theory and using the PNG trade data of countries along the "Belt and Road" from 2011 to 2018, analyzed the characteristics of the PNG trade network in this region and the changes in China's position by using indicators such as weighted degree centrality, network density, betweenness centrality and network community structure of the complex network.

With the geopolitical game and energy structure adjustment in recent years, the evolutionary characteristics of the PNG trade network have attracted extensive attention from scholars [12]. Dang Niu et al. argued that the changes in the geopolitical situation caused by the Russia-Ukraine conflict have brought huge challenges to the European energy security pattern [13]. Zhao Pengjun et al. explored the impact of international geopolitics on the transportation network pattern by studying the

changes in the structural characteristics of the crude oil maritime transportation network along the "Belt and Road" under the background of the Russia-Ukraine conflict, and found that the changes in the maritime transportation network have a significant and heterogeneous impact on the stability of China's crude oil imports, pointing out that China can cope with the risk of instability in the crude oil import network under the background of the Russia-Ukraine conflict by adjusting the proportion of imports from different sources and ports [14]. Li Jing et al. believed that the Russia-Ukraine conflict has intensified the tension of global geopolitics and brought unrest to the energy market, and at the same time, the conflict has increased Russia's dependence on the Chinese market [15].

Scholars have also left rich research results on the methods of exploring the natural gas trade network. Liu Jinsong used social network analysis to study the structure and evolutionary characteristics of the world or regional natural gas trade networks [16]. Peng Peng analyzed the global LNG trade pattern and its evolutionary characteristics by using complex network indicators [17]; Chen et al. constructed an LNG trade competition network and comprehensively analyzed the characteristics of the growth of competitive relations and the globalization of competition in LNG trade [18]. Aiming at the current situation of natural gas flow and trade pattern in China, Gao Zhenyu introduced social network analysis to study the evolution of China's natural gas market network, providing reference for the selection of key regions for the cultivation of China's natural gas market in the future [19]; Xiao Jianzhong et al. used social network analysis to deeply study the empirical characteristics of the trade relations in China's natural gas market and the laws of its development and changes [20]; Zhang Hong et al. based on the complex network model, explored the overall characteristics and pattern evolution of the global natural gas trade network, and deeply analyzed the evolution of China's natural gas import sources and paths [21]; Li et al. comprehensively used social network analysis to reasonably divide China's five regional natural gas markets and clarify the overall spatial pattern of the natural gas market [22]; Tu Miao, based on the natural gas trade data of 70 key countries in the world from 2001 to 2020 and combined with the weighted directed network model, explored the evolution of the complex trade network pattern of global PNG and LNG under the goal of "carbon neutrality" in key years, and put forward the optimization strategies for China's import paths under the goal of "carbon neutrality" [11].

To sum up, although the research on natural gas by scholars at home and abroad has become increasingly in-depth and extensive, there are still several deficiencies. First, scholars' attention is often focused on the overall level of global natural gas trade, discussing LNG and PNG as an inseparable whole. However, independent research on LNG and PNG is relatively scarce. In particular, the number of studies on LNG in the existing literature is far more than that on PNG, and the in-depth discussion on the global PNG trade relations is seriously insufficient. Second, against the background of geopolitical games and energy structure adjustment, there is a lack of special research on the impact of China's PNG and its future development direction. Third, in terms of research methods, relevant research on the analysis of the global PNG trade network using social network analysis is also relatively scarce.

Based on this, this study adopts social network analysis, starting from the community distribution of the PNG trade network, combining with the impacts such as geopolitics, deeply analyzes the current situation of China's PNG imports, provides practical significance for ensuring China's PNG supply security, and helps China to better understand and respond to the trend of global energy changes.

### **3. DATA SOURCES AND RESEARCH METHODS**

#### **3.1. Research Method**

Social network analysis is a research method for the quantitative analysis of the relationships between social actors as nodes and a series of network characteristics resulting therefrom, which can reflect the network structural characteristics among multiple participants. Social network analysis was first

applied in the field of psychology, and gradually extended to social science fields such as economics, management and political science [23]. The global trade network is a network system with trading countries as "nodes" and multilateral trade relations as "links". By constructing the trade network, the status of each country in the PNG trade market and their trade links can be clearly reflected, thus revealing the structural characteristics of the global PNG trade pattern more intuitively [24].

### 3.2. Data Sources and Network Construction

This study adopts the data from the Statistical Review of World Energy, covering the PNG importing and exporting countries and their corresponding import and export volumes from 2010 to 2023. The study takes the supplying and receiving countries of each country's PNG trade as nodes in the trade network, the trade activities between countries as links in the trade network, and constructs the global PNG trade network on an annual basis. The total volume of PNG shipped between two nodes is counted as the edge weight between these nodes, thus constructing the global PNG trade network.

### 3.3. Community Division

A community is a group phenomenon composed of actors with a specific relationship. Global PNG trade includes supply and receiving nodes with trade relations, which belongs to a group with a specific relationship. According to the degree of cooperation between PNG trading partner countries, different communities can be divided to explore the agglomeration status of relevant supply and receiving nodes and the corresponding causes of community formation.

### 3.4. Point-wise mutual information(PMI)

The Point-wise mutual information (PMI) is an indicator used to quantify the interdependence between nodes in the PNG trade network, whose core is to analyze the transaction scale of each node in the trade network so as to evaluate the trade preference between nodes. By capturing the dynamic changes of trade flows, this index can effectively depict the dependence balance state between trade relations, and thus reflect the evolution trend of the trade network [25]. When the PMI between trade nodes is 0, the trade network is in a neutral dependence state; when the PMI is greater than 0, it indicates that the actual trade flow is higher than the expected value and the trade volume is showing a growth trend; when the PMI is less than 0, it indicates that the actual trade flow is lower than the expected value and the trade volume is showing a decline trend. For the global PNG trade, this study uses the PMI algorithm proposed by Wanyan Ze to calculate the index between node  $i$  and node  $j$  [25], with the formula as follows:

$$PMI_{ij} = \log \left( \frac{P_{ij}P_{..}}{P_{i.}P_{.j}} \right) \quad (1)$$

Where:  $P_{ij}$  is the PNG trade volume from node  $i$  to node  $j$ ;  $P_{i.}$  is the total trade volume from  $i$  to all other nodes;  $P_{.j}$  is the total trade volume to  $j$  from all other nodes;  $P_{..}$  is the total trade volume of the entire network.

## 4. ANALYSIS OF GLOBAL PIPELINE NATURAL GAS TRADE COMMUNITIES

In the process of social network analysis, in addition to studying the overall attribute characteristics and node distribution characteristics of the network, "subgraphs" can be extracted from the network to further analyze the structural characteristics of the social network. At present, domestic scholars have different views on the description of national groups with common characteristics or interrelationships. Chen Qiao defined the group formed by some closely connected actors in the

network with the concept of "cohesive subgroup", pointing out that the higher the density of the cohesive subgroup, the more stable its internal members [26]; Wang Peiyu et al. believed that the "cohesive subgroup" mainly reveals the substructure within the group and is used to divide closely connected small groups in the social network [27]; Han Mengwei et al. used "network community" to represent a node subset composed of several nodes with a specific relationship in the network [28]; Wanyan Ze et al. also divided the nodes in the LNG trade network with "community" [25]; Wei Jingfu et al. defined different groups divided according to the degree of cooperation between LNG trading partner countries with "network clump" [29].

This study holds that it is more appropriate to define such groups with similar characteristics or links as "communities" in the field of PNG. In the global PNG trade relationship network, community analysis is different from the macro analysis of the overall network attributes and the micro analysis of node distribution. Community analysis from a meso perspective can effectively identify closely connected subgroups, i.e., small groups, in the network, thus depicting the complete structural characteristics of the network. The PNG trade between countries within a community is closer, while the PNG cooperation between different communities is relatively distant. For the global PNG trade network in 2023, this study uses the Ucinet software for community division, and obtains four major communities: the American Community, the European Community, the Asia-Pacific Community and the Middle East-Africa Community. Among them, icons of the same color represent countries in the same community, circular icons represent import nodes, square icons represent export nodes, arrow directions indicate the source of trade, and the thickness of the lines represents the degree of trade closeness between two nodes.

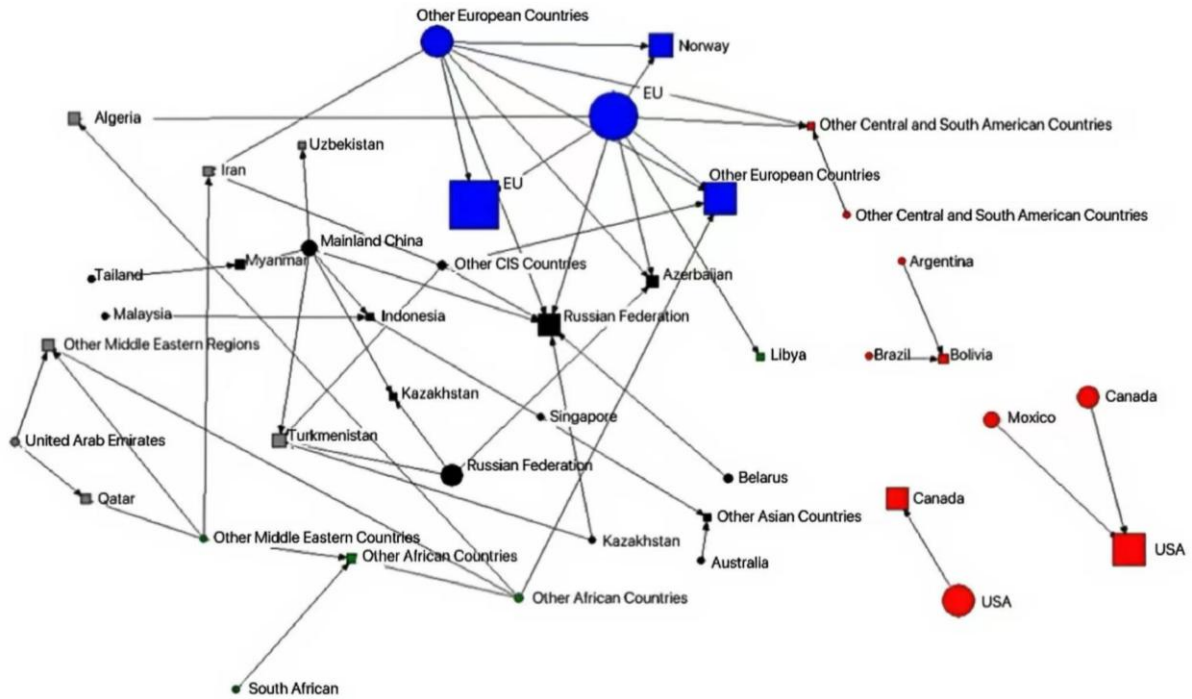
It can be seen from the global PNG trade network structure diagram in 2023 that the largest community is the European Community, which is mainly formed by the interaction between European natural gas exporting countries such as Norway and PNG importing blocs such as the European Union (EU). Norway and other countries are major natural gas producers in Europe, with abundant natural gas reserves and stable production capacity, and a mature and complete natural gas pipeline system. EU countries such as France, Germany and Italy import a large amount of PNG, and export the excess beyond their domestic demand to neighboring countries to obtain transit trade profits and promote the flow of PNG trade [9]. However, restricted by transportation costs and conditions, the transit scope mostly follows the proximity principle, and large-scale and wide-ranging transit is rare. In addition, Russia's PNG exports to the EU were huge before 2021, accounting for 45% of the EU's natural gas imports in 2021. After the outbreak of the Russia-Ukraine conflict in March 2022, the EU formulated a plan to get rid of its energy dependence on Russia and imposed sanctions on Russia's natural gas exports, leading to a significant decline in Russia's PNG supply. Importing a large amount of LNG from the United States has become an important source for Europe to make up for the gap in Russian PNG[30]. Therefore, geographical location and political factors are the main reasons for the formation of this community.

The second largest community is the American Community, which is mainly centered on the trade relations among major PNG importing and exporting countries such as the United States, Canada and Mexico. Taking the PNG trade between the United States and Canada as an example, the PNG imported by the United States from Canada is mainly used to balance the domestic natural gas market, especially playing an important role in peak shaving for heating demand in the Midwest of the United States. Due to the end of natural gas production in eastern Canada and the growth of natural gas production in the Appalachian region of the United States, the natural gas exported by the United States to eastern Canada through pipelines has exceeded the natural gas imported from eastern Canada. Geographical adjacency makes the construction of natural gas pipelines between the two countries relatively easy and the transportation cost relatively low, and resource complementarity also gives the natural gas trade between the two countries a natural advantage. Therefore, the formation of this community is mainly due to geographical location and resource complementarity.

The Asia-Pacific Community forms trade links through the trade between PNG exporting countries represented by Russia and Turkmenistan and PNG importing countries represented by China. From the direction of the arrows, Russia mainly exports PNG to the EU and other European countries, China, Belarus and other countries. Affected by the Russia-Ukraine conflict, Russia's export volume to Europe has decreased significantly, but the export volume to Europe is still the largest due to the large original export base. In addition, Europe was the primary target consumer market before the Russia-Ukraine conflict, and the crowding-out effect mostly occurred in the Asia-Pacific region. Correspondingly, the price was mostly based on the European regional natural gas price, and Asia followed its price changes and fluctuations. However, with the shift of the focus of competition, the Asia-Pacific region is expected to become a more important "bellwether" for the global natural gas market in terms of prices and demand changes [31]. China mainly imports PNG from Russia, Turkmenistan and other countries. On the one hand, these exporting countries have abundant natural gas production and stable supply; on the other hand, they are geographically adjacent to China and have a long history of cooperation. Therefore, the main reasons for the formation of this community are political factors and geographical location.

The overall PNG trade volume of the Middle East-Africa Community is not prominent, mainly consisting of importing countries such as the United Arab Emirates and exporting countries such as Algeria and Qatar. In terms of natural gas reserves and distribution, the distribution of natural gas resources in these regions is uneven, and the conditions for natural gas exploitation and transportation are relatively complex, which limits the PNG trade volume to a certain extent. Affected by geopolitics, some Middle Eastern and North African countries may be subject to international economic sanctions, which largely restricts their natural gas export capacity. At present, the escalation of the Russia-Ukraine conflict has made Europe face the risk of natural gas supply disruption, and at the same time, emerging Asian economies are accelerating the "coal-to-gas" transformation, so the global supply and demand of natural gas will enter a stage of rapid growth. Against this background, the natural gas in the Middle East will usher in a golden age of development [32]. For example, Middle Eastern countries with abundant natural gas such as the United Arab Emirates, Qatar and Algeria will further enhance their voice in the global energy supply chain due to the prominent strategic value of natural gas [32]. Therefore, the formation of this community is mostly affected by political factors.

The results of community analysis show that political factors and geographical location are the two main reasons for community formation. On the one hand, since the Ukraine crisis, Russia's PNG transportation capacity has dropped sharply, the natural gas gap in Europe has surged, the US LNG exports have increased significantly, the competition for resources in the Asian and European markets has become increasingly fierce, and global natural gas prices have risen rapidly [4]. The Russia-Ukraine conflict has brought a major reshuffle of global natural gas trade, which has greatly affected the formation and development of communities. On the other hand, the construction of natural gas pipelines is strictly restricted by geographical location and geological conditions, so PNG trade mainly occurs between geographically adjacent countries. Geographical proximity promotes the development of PNG trade, and the geographical distribution of trade core areas reflects the geographical characteristics of natural gas resources and the geographical distribution of demand markets, such as the Asia-Pacific Community with Russia as the exporter and China as the importer, and the European Community with Norway as the exporter and the EU as the importer.



**Figure 1.** Global PNG Trade Network Structure Diagram (2023)

**Table 1.** Spatial Scope Division of the Studied Communities

Community	Main Countries
American Community	Canada, Mexico, USA, Argentina, Brazil, etc.
European Community	EU, Norway, etc.
Asia-Pacific Community	China, Australia, Malaysia, Singapore, Thailand, Kazakhstan, Uzbekistan, Turkmenistan, the Russian Federation, Indonesia, Myanmar, etc.
Middle East-Africa Community	the United Arab Emirates, South Africa, other Middle East regions, other African countries, etc.

## 5. ANALYSIS OF THE CURRENT SITUATION OF CHINA'S PIPELINE NATURAL GAS IMPORTS

### 5.1. Analysis of PMI

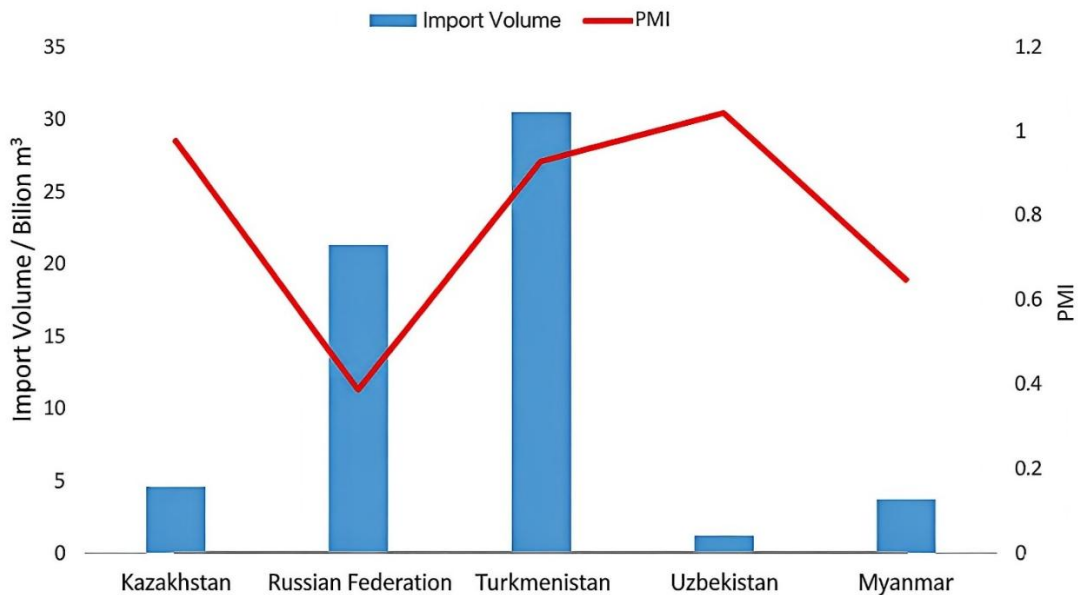
The evolution of the global PNG trade pattern has been stable since 2000, and the PNG market has gradually matured. China began to import PNG in 2010, realizing a synchronous mode of PNG and LNG import trade [21], which enriched the natural gas import channels.

At present, China has built three major natural gas import pipeline routes including the China-Central Asia, China-Myanmar and China-Russia pipelines, sourced from Central Asia (Kazakhstan, Turkmenistan, Uzbekistan), Myanmar and Russia respectively. The detailed transportation routes are shown in the following table.

**Table 2.** Main Transportation Routes of China's Imported PNG

Main Pipeline	Source Countries	Main Transportation Routes
China-Central Asia Natural Gas Pipeline	Uzbekistan	Line A, Line B: Uzbekistan - Alashankou - Khorgos
	Kazakhstan	Line C: Kazakhstan - Khorgos
	Turkmenistan	Line D: Tajikistan - Kyrgyzstan - Wuqia, Xinjiang
China-Myanmar Natural Gas Pipeline	Myanmar	Kyaukpyu Port, Myanmar - Ruili, Yunnan
China-Russia Natural Gas Pipeline	Russia	West Siberian Gas Field - Heihe, Heilongjiang

China's total PNG imports in 2023 reached 61.3 billion cubic meters, among which the import volume from Turkmenistan was the largest, up to 30.5 billion cubic meters, 4.6 billion cubic meters from Kazakhstan, 1.2 billion cubic meters from Uzbekistan, 3.7 billion cubic meters from Myanmar, and 21.3 billion cubic meters from Russia.



**Figure 2.** Distribution of China's PNG Import Trade Volume and PMI (2023)

Figure 2 shows the import volume and PMI distribution of China's PNG in 2023. It can be seen from the figure that the PMIs between China and the five major supply nodes including Turkmenistan, Uzbekistan, Kazakhstan, Russia and Myanmar are all positive, indicating that China has a trade advantage in PNG with these nodes. China should maintain good trade cooperation relations with these major nodes to ensure the source security and import stability of PNG. These nodes can be roughly divided into three categories: the first category is Central Asian nodes represented by Turkmenistan, Uzbekistan and Kazakhstan. These nodes have abundant natural gas reserves and have maintained close energy cooperation with China for a long time, which is a key link to ensure China's natural gas import security. Among them, Turkmenistan is the most important source of China's PNG. A complete natural gas pipeline has been built and put into use between the two countries, and the advantage of geographical proximity reduces the trade transportation cost and the risks of national geopolitics and maritime transportation. Therefore, China's PNG import volume from Turkmenistan is large and the PMI is high. Kazakhstan and Uzbekistan also have the advantage of abundant natural gas resources. China's import volume from these two nodes is low but shows a high PMI, indicating that China hopes to increase imports from these nodes to ensure the diversification of import channels. The second category is the Russian node. Russia began to supply natural gas to China in 2018. At present, the China-Russia Eastern Route Natural Gas Pipeline Project, an important energy artery of China, has been fully completed and entered the final preparation stage before commissioning. The

trade link between China and Russia has effectively promoted the formation of an integrated Eurasian market for PNG trade and reduced China's dependence on the Malacca Strait for natural gas imports [21]. The third category is the Myanmar node. Myanmar connects South Asia and East Asia, with abundant natural gas reserves, and has signed a 30-year long-term natural gas supply agreement with China, which is of great significance for meeting China's energy demand. However, Myanmar's unstable political environment and complex situation have greatly affected the safety and stability of PNG transportation through the China-Myanmar pipeline. Therefore, China's PNG import volume from Myanmar is relatively small and the PMI is relatively low.

## 5.2. Analysis of Import Channels

In terms of the main sources of PNG imports, China's import sources are concentrated in five countries: Turkmenistan, the Russian Federation, Kazakhstan, Myanmar and Uzbekistan, as shown in the table. To better understand China's current dependence on each PNG exporting country and the concentration degree of the entire market import structure, this study compiles the distribution table of China's PNG import concentration in 2010, in which the concentration of the top one importing country is recorded as CR<sub>1</sub>, and the concentration of the top three importing countries is recorded as CR<sub>3</sub>.

**Table 3.** Structure of Main Import Sources of China's PNG (2010-2023)

Unit: %

Import Source Countries	2010	2011	2012	2013	2014	2015	2016
Turkmenistan	100	100	100	99.6	90.1	82.7	77.4
Russian Federation	—	—	—	—	—	—	—
Kazakhstan	—	—	—	0.4	1.4	1.2	1.1
Myanmar	—	—	—	—	—	11.6	10.3
Uzbekistan	—	—	—	—	8.5	4.5	11.3
Import Source Countries	2017	2018	2019	2020	2021	2022	2023
Turkmenistan	80.3	69.5	66.2	60.3	59.2	56.2	49.8
Russian Federation	—	—	0.6	8.6	14.3	25.1	34.7
Kazakhstan	2.8	11.3	13.6	15.1	11.1	7.5	7.5
Myanmar	8.4	6.1	9.2	8.6	7.3	6.8	6.0
Uzbekistan	8.6	13.2	10.3	7.3	8.1	4.3	2.0

**Table 4.** Import Concentration Distribution of China's PNG (2010-2023)

Unit: %

Concentration	2010	2011	2012	2013	2014	2015	2016
CR <sub>1</sub>	100.0	100.0	100.0	99.6	90.1	82.7	77.4
CR <sub>3</sub>	—	—	—	100.0	100.0	98.8	98.9
Concentration	2017	2018	2019	2020	2021	2022	2023
CR <sub>1</sub>	80.3	69.5	66.2	60.3	59.2	56.2	49.8
CR <sub>3</sub>	97.2	93.9	90.1	84.0	84.6	88.9	92.0

In terms of import source countries, China's PNG imports are highly dependent on several major PNG exporting countries, but also show a trend of changing from an absolutely single import source to a relatively diversified one. Specifically, China began to import PNG from Turkmenistan in 2010, with the concentration CR<sub>1</sub> as high as 100%. In 2013, China began to import from Kazakhstan, which

opened the door for China to import PNG from multiple countries, but the gas source from Turkmenistan still accounted for an absolute proportion. China began to import PNG from Uzbekistan, Myanmar and the Russian Federation in 2014, 2015 and 2019 respectively, indicating that China has also realized the importance of diversified import sources. On the whole, the proportion of Turkmenistan in China's total PNG imports dropped from 100% to 49.8% from 2010 to 2023. With the normal operation of the China-Russia pipeline, the proportion of PNG imports from different countries has been adjusted. The volume of PNG imports from the Russian Federation showed a substantial increase from 2019 to 2023, rising from 0.6% to 34.7%, which helps to consolidate the security of China's PNG supply[9], while the proportions of imports from the other three countries have fluctuated around 10% in recent years.

In terms of the number of import source countries, China's PNG import sources have increased from 2010 to 2023, rising from 1 to 5, with a small increase, and the proportion of PNG imports from newly added source countries in the total import volume is extremely small. The pattern of extreme dependence on the supply of Turkmenistan and the Russian Federation has not fundamentally changed. The concentration  $CR_3$  of the top three importing countries has been as high as over 84% for a long time, even reaching 92% in 2023. This poses severe challenges to the current situation of China's PNG imports and also warns China to formulate corresponding countermeasures to prevent a huge import gap caused by the suspension of supply from major import channels.

## **6. CONCLUSIONS AND RECOMMENDATIONS**

### **6.1. Conclusions**

From the perspective of community analysis, geographical location is the primary reason for the formation of communities. In the global PNG trade network, transportation costs and safety risks increase with the increase of transportation distance between nodes. Therefore, the low transportation costs and high safety factor brought by geographical proximity make the import nodes relatively fixed and single in the choice of their trading partners. This selection tendency based on geographical factors has greatly promoted the formation and development of most existing trade communities. Political factors are the secondary reason for the formation of communities. Geographical proximity is conducive to the formation and development of trade communities, but political factors may restrict the exertion of this geographical advantage. Community analysis shows that China is a leader in the Asia-Pacific Community and holds a dominant position in imports, yet potential risks such as geopolitics, price fluctuations and transportation security still need to be vigilantly addressed.

Based on the analysis of PMI and the consideration of import channels, China's PNG import volume is currently showing a steady growth trend, and the import channels are gradually moving towards diversification, forming a PNG import source pattern of "taking Turkmenistan and the Russian Federation as the main sources, and Kazakhstan, Myanmar and Uzbekistan as the supplementary sources". This pattern is the result of the combined influence of multiple factors such as transportation costs, geographical location and national relations. In terms of natural gas reserves, output and export volume to China, Turkmenistan has an inherent guarantee advantage for China-Turkmenistan PNG cooperation, but Turkmenistan also faces risks such as domestic market problems and international competition [34]; the Russian Federation, with its abundant natural gas resources, has become a major natural gas importing country of China, but with the outbreak of the Russia-Ukraine conflict, the international political situation has changed rapidly, and China needs to consider the corresponding political risks and the natural gas import security risks brought by geopolitical frictions [35].

## 6.2. Recommendations

### (1) Expanding Supply Sources: Actively Carry Out Energy Cooperation and Diversify Import Channels

Firstly, deepen cooperative relations with traditional energy partners. Consolidate the cooperation foundation with traditional PNG supplying countries such as Central Asian countries and Russia, and improve the stability and reliability of PNG transmission by signing long-term purchase and sales agreements and promoting the upgrading and transformation of cross-border pipeline infrastructure. For example, accelerate the construction of the subsequent sections of the China-Russia Eastern Route Natural Gas Pipeline, optimize the gas transmission dispatching mechanism of the China-Central Asia Natural Gas Pipeline, and ensure the stable supply of the established gas sources.

Secondly, explore emerging gas source import markets[36]. Actively lay out emerging natural gas producing areas such as Southeast Asia and Africa, and explore cooperative development models with resource-rich countries. On the one hand, participate in overseas natural gas field exploration and development projects to obtain resource rights and interests; on the other hand, promote the feasibility study of pipeline interconnection with relevant countries, and gradually build a diversified cross-border pipeline network.

Thirdly, develop diversified natural gas import methods. While stabilizing PNG imports, vigorously enhance LNG import capacity to make up for the shortage of pipeline gas sources. Accelerate the construction and expansion of coastal LNG receiving terminals, optimize the layout of receiving terminals, and improve the storage, transshipment and peak-shaving capacity of LNG; encourage domestic enterprises to participate in international LNG trade, and enhance the flexibility of gas source allocation through a combination of long-term contracts and spot procurement.

Fourthly, strengthen the construction of regional energy cooperation mechanisms. Relying on multilateral cooperation platforms such as the Shanghai Cooperation Organization and the China-ASEAN Free Trade Area, promote the coordination of energy policies and trade facilitation within the region. Explore the establishment of a regional natural gas supply and demand linkage mechanism, promote the optimal allocation of natural gas resources within the region, and reduce the risks caused by the interruption of a single pipeline trade.

### (2) Reducing Energy Consumption: Effectively Manage Energy Consumption and Optimize the Low-Carbon Energy Structure

Firstly, strengthen the control of energy consumption in key fields. Formulate strict energy efficiency standards and energy consumption quotas for high energy-consuming fields such as industry, construction and transportation, and promote advanced energy-saving technologies and equipment. For example, promote the recovery of waste heat and pressure and the energy-saving transformation of motor systems in the industrial field; promote green building standards in the construction field, and popularize energy-saving products such as energy-saving doors and windows and heat pumps; accelerate the replacement of new energy vehicles and optimize the freight structure in the transportation field to reduce the intensity of energy consumption.

Secondly, promote the efficient and intensive utilization of natural gas. Clarify the consumption positioning of natural gas, give priority to ensuring the demand for civil gas, reasonably regulate industrial fuel gas, and guide natural gas to tilt towards efficient utilization fields such as urban gas, distributed energy and chemical raw materials. Establish a natural gas demand-side response mechanism, and encourage users to cut loads during gas consumption peak periods through price leverage and incentive policies to improve the allocation efficiency of natural gas resources.

Thirdly, accelerate the green transformation of the energy structure. Vigorously develop renewable energy, gradually increase the proportion of clean energy such as wind power, photovoltaic power and hydropower in energy consumption, and reduce the dependence on fossil energy such as natural

gas. Promote the complementary integration of renewable energy and natural gas power generation, build an integrated energy system of "wind, solar, storage and gas", and improve the stability and flexibility of the energy system.

### (3) Build an Energy Security Guarantee System Integrating Expanding Supply Sources and Reducing Energy Consumption

To ensure China's energy security, it is necessary to organically combine the strategies of expanding supply sources and reducing energy consumption, and at the same time strengthen the construction of supporting systems. On the one hand, strengthen the interconnection of energy infrastructure, build a national integrated natural gas transmission system [37], and improve the capacity of overall resource allocation; on the other hand, accelerate energy technological innovation and break through key technical bottlenecks such as natural gas storage and transportation and renewable energy substitution. In addition, improve the energy emergency reserve mechanism and risk early warning system, enhance the ability to respond to trade fluctuations and supply interruptions, and build a solid energy security barrier for the high-quality development of China's economy and society.

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