WEP Warwick Evans Publishing

International Journal of Global Economics and Management

ISSN: 3005-9690 (Print), ISSN: 3005-8090 (Online) | Volume 4, Number 1, Year 2024
DOI: https://doi.org/10.62051/ijgem.v4n1.65
Journal homepage: https://wepub.org/index.php/IJGEM/index

Challenges and Countermeasures of Natural Gas Supply Chain Management in China

Bingqing Sun *

School of Economics and Management, Southwest Petroleum University, Chengdu, 610500, China
*Corresponding Author: Bingqing Sun

ABSTRACT

The natural gas supply chain is roughly divided into four parts: production, supply, storage, and sales. China is committed to building a high-quality natural gas production, supply, storage, and sales system, strengthening the management of the natural gas supply chain, and improving the stability and systematicness of the natural gas production, supply, storage, and sales system. This article summarizes the development of supply chain management, the composition of the natural gas supply chain, and analyzes the current situation of China's natural gas supply chain based on the complexity of the natural gas production, supply, storage, and marketing supply chain system. It summarizes the research on natural gas supply chain management, analyzes the challenges faced by China's natural gas supply chain management at this stage, and proposes countermeasures and suggestions for natural gas supply chain management, with a view to providing a reference basis for the development of the natural gas industry.

KEYWORDS

Natural gas; Supply chain management; Challenges; Countermeasures and suggestions

1. INTRODUCTION

At the current stage, the development of China’s natural gas industry has entered a new era. The growth in demand for ecological civilization construction, a relaxed global supply environment, the “Belt and Road” initiative, the prospects of domestic resources, technological progress, and marketization that reduce costs will all promote a new round of construction of the natural gas industry chain [1-8]. The concept of a community with a shared future for mankind has influenced the world and resonated with people. The green transformation of energy and low-carbon development have become a common consensus and concerted action among countries worldwide. China’s low-carbon transformation of energy has become an important shift, and it is imperative to accelerate the construction of a clean, low-carbon, safe, and efficient energy system. Green development has become the general trend [9]. In this context, clean, high-quality, and efficient natural gas energy is increasingly valued. Accelerating the utilization of natural gas is the only way to build a clean, low-carbon, safe, and efficient modern energy system [10]. The diversification of resources, the balance of market supply and demand, the complexity of storage and transportation facilities, as well as the impact of risks such as systemic and non-systemic risks of the natural gas supply chain, and the transmission of technology and information resources, pose new challenges for building a high-quality development of China’s natural gas production, supply, storage, and sales supply chain system. This paper, based on the complexity of the natural gas production, supply, storage, and sales supply chain system, provides a review of research on natural gas supply chain management in China, analyzes the challenges currently faced by natural gas supply chain

management, and proposes strategies based on China's specific national conditions and the current state of the natural gas industry development.

2. SUPPLY CHAIN MANAGEMENT AND THE COMPOSITION OF THE NATURAL GAS SUPPLY CHAIN

2.1. Supply Chain Management

The concept of the supply chain originated from Peter Drucker's "economic chain," which was developed into the "value chain" by Michael Porter in 1980, and later extended to the "supply chain." The concept of supply chain management is related to the value chain. Research on supply chain management first appeared in the 1990s. John [11] studied warehouse management based on American warehousing trends and proposed that supply chain management be seen as a major trend in promoting management success, which helps companies achieve successful warehousing operation goals. He also suggested that supply chain management should facilitate a partnership between suppliers and distributors, becoming a common interest body, to create the greatest customer satisfaction at the minimum cost. In 1996, Tong Wenhua [12] considered the integrated development needs of Chinese enterprises in production, supply, and sales, and believed that supply chain management is about integrating production, supply, storage, and sales into one chain, managing and optimizing all links to ensure the fastest possible movement of production materials through production and distribution channels, and selling finished products to consumers as quickly as possible, while also reducing inventory and achieving systematic automation in procurement, production, inventory, finance, and equipment. In 1997, Feng Guo'an [13] believed that under the background of globalization and diversification, procurement management should shift towards supply chain management, which could greatly promote the process of value creation in enterprises.

Currently, the academic definition of the supply chain mostly refers to the network of all individuals, organizations, resources, activities, and technologies involved in the production and sales process of a product [14]. The supply chain can be divided into multiple stages, from the procurement of raw materials to the design and manufacturing of products, then to supply and transportation, and finally the delivery of finished products to consumers. Supply chain management starts from the aspects of production, storage, supply (logistics), and sales in the supply chain links. By integrating and optimizing the allocation of resources, it avoids supply chain risks. At the same time, it enables cooperation among enterprises in the supply chain and aims to reduce costs and energy consumption, maximize profits, and optimize all aspects of the supply chain. This ensures the effective utilization of resources in the supply chain network and promotes the overall efficiency of the supply chain to be optimal.

2.2. Composition of the Natural Gas Supply Chain

The natural gas supply chain refers to the collection of upstream, midstream, and downstream enterprises that are interconnected through the production, transportation, or consumption of natural gas. The exploration and development of natural gas are known as the upstream of the supply chain, the storage and transportation of natural gas are called the midstream, and the consumption of natural gas is referred to as the downstream [15]. The relationships between the various segments of the natural gas supply chain are intricate, and a large number of industries are associated with it.

1) Upstream Segment

The upstream of the natural gas supply chain includes the production and supply of natural gas. The production and supply resources in the upstream mainly consist of domestic production resources and imported resources. Domestic production resources can be divided into domestic oil and gas fields, coalbed methane fields, and coal-to-gas plants, with the main source of output being oil and gas fields.

Domestic gas sources mainly include conventional natural gas, shale gas, coalbed methane, and coal-to-gas; imported resources mainly include imported pipeline gas and LNG (Liquefied Natural Gas).

2) Midstream Segment

The midstream of the natural gas supply chain includes the transportation and storage of natural gas. The midstream segment mainly consists of natural gas pipelines, underground gas storage facilities, LNG receiving stations, liquefaction plants, LNG transport vehicles, LNG transport ships, and CNG (Compressed Natural Gas) transport vehicles. By 2022, the national natural gas pipeline network had reached a scale of 1.18x10^5 km, with 38 storage facilities built, totaling 19.1 billion cubic meters of working gas capacity. There are 24 LNG receiving stations built, with an annual unloading capacity of 100 million tons [16]. By the end of 2023, China Petroleum had initiated 24 projects for expanding capacity, building new storage facilities, and evaluating storage facilities, with four new storage facilities—Wenxiyi, Nanpu 1, Huabei Wen 23, and Kekeya—put into operation before the heating season, increasing the peak-shaving capacity by 3.7 billion cubic meters year-on-year.

3) Downstream Segment

The downstream of the natural gas supply chain includes the sales and utilization of natural gas. The distribution of natural gas in the downstream segment mainly has two directions: one is direct sales to end-users; the other is sales to various natural gas distributors. Natural gas distributors sell natural gas to users through pipelines, transport vehicles, and canned methods.

According to the characteristics of the natural gas supply chain, it can be divided into four parts: production, supply, storage, and sales. China is committed to building a high-quality natural gas production, supply, storage, and sales system, strengthening the management of the natural gas supply chain, and improving the stability and systematicness of the natural gas production, supply, storage, and sales system. This necessitates cooperation between natural gas producers, pipeline operators, storage operators, peak-shaving operators, and marketing businesses to achieve a better balance in the supply chain and create greater overall benefits.

3. OVERVIEW OF THE DEVELOPMENT STATUS AND SUPPLY CHAIN MANAGEMENT RESEARCH OF CHINA'S NATURAL GAS SUPPLY CHAIN

3.1. Current Status of China's Natural Gas Supply Chain

Since the Reform and Opening-up policy, China's natural gas industry has achieved leapfrog development. For example, from the "Baisha" pipeline project initiated in the 1970s to the construction of major projects like the West-to-East Gas Pipeline and the Central Asian Natural Gas Pipeline, the scale and technical level of China's natural gas pipeline network have been significantly improved. Additionally, China has vigorously developed the LNG industry, including the construction of LNG receiving stations and transport ships, and the development of underground gas storage facilities, all of which signify the modernization and internationalization of China's natural gas industry. The development of China's natural gas industry has undergone a transformation from initial exploration to rapid growth, and then to technological innovation and market internationalization. The development of China's natural gas industry can be divided into several important stages:

(1) The initial stage from 1949 to 1975. During this period, China's natural gas production increased from 10 million cubic meters to 10 billion cubic meters, with small gas fields in the Sichuan Basin being the main source of production. The development of the natural gas industry at this stage was characterized by a small overall scale and a predominant consumption pattern of consuming near the source area.

(2) The period of slow growth from 1976 to 2000. During this time, China's natural gas production increased from 10 billion cubic meters to 30 billion cubic meters. National natural gas industry development plans began to be implemented gradually, cross-regional pipelines were constructed, and the consumption area expanded. The development of the natural gas industry at this stage was still based on domestic resources, with production determining consumption quantity.

(3) The period of rapid growth since 2001. China's natural gas production has grown rapidly, increasing from 30 billion cubic meters to over 1300 billion cubic meters. However, due to the relatively late development of China's natural gas industry and its relatively weak infrastructure, there is still a significant gap from mature international markets in terms of stable supply, developed pipeline networks, and interconnection. The future development potential is immense [17].

In today's world, the impact of the COVID-19 pandemic is widespread and profound, the "Russia-Ukraine conflict" has erupted, global energy prices have soared, and the European energy crisis has intensified. The world is experiencing a century-old great change that is accelerating, and the global energy supply and demand situation is continuously fluctuating. China's energy security and stability also face new challenges. The natural gas industry in China presents the following characteristics:

(1) Rapid growth in natural gas supply

In 2023, China's natural gas production reached 232.43 billion cubic meters, an increase of 5.6% year-on-year. By the end of 2023, the Southwest region had built an annual production capacity of 40 billion cubic meters of natural gas. China's natural gas industry is expanding production domestically, enhancing its self-reliance, and experiencing rapid growth in production.

(2) Accelerated increase in natural gas demand, with the gap between production and sales widening year by year

In 2023, China imported 119.97 million tons of natural gas (equivalent to 165.2 billion cubic meters), an increase of 9.9% year-on-year. In 2023, the total natural gas consumption in China was about 394.53 billion cubic meters, an increase of 7.6% year-on-year. While consumption continues to grow, the gap between natural gas production and sales in China is also expanding year by year, and the self-sufficiency rate is declining. In 2023, the self-sufficiency rate of natural gas was only 58.88% [18].

(3) The initial formation of the natural gas production, supply, storage, and sales system.

As China's natural gas industry enters a stage of low-carbon, sustainable, and coordinated development, with the "national integrated network" of natural gas storage and transportation systems beginning to take shape, China is enhancing its natural gas supply capacity, further optimizing the natural gas production, supply, storage, and sales system, and seeking to maximize the overall benefits of the natural gas supply chain. This is the trend in future natural gas supply chain management research.

3.2. Overview of Research on Natural Gas Supply Chain Management in China

Currently, research on natural gas supply chain management in China mainly focuses on the following five aspects:

(1) Pipeline Network Optimization

Given the increasing natural gas consumption in China, it is becoming increasingly challenging to meet the growing demand. Ensuring a balance between supply and demand, promoting a balance between production and sales, and alleviating the contradiction between supply and demand is particularly important. Gong Weilong et al. [19] have categorized the functions of interconnected pipeline projects into three types: gas supply, gas transfer, and security. Based on economic evaluation methods, underground gas storage peak-shifting gas economic benefit evaluation methods,

and security economic benefit quantification evaluation methods, they have established economic evaluation models for each function. Taking the Min-Yue branch trunk line interconnection project as an example, they have conducted economic benefit index calculations. Tian Lei [20] has analyzed the development status of technical equipment in the natural gas transportation field, combined with the direction of energy transformation, identified the orientation of innovation, and proposed key research and development directions for the natural gas industry. This has significant implications for promoting independent innovation in energy technology and equipment and supporting the construction of a new energy system.

Some scholars have also conducted pipeline network optimization research based on the objectives of minimizing costs, energy consumption, and maximizing benefits. Liu Enbin et al. [21] have analyzed the reasons for high energy consumption in long-distance natural gas pipelines and established an optimization model for pipeline operation based on dynamic programming. This model aims to minimize the total energy consumption of large natural gas pipeline compressor stations. Liu Dingzhi et al. [22] have aimed to minimize the total cost of the natural gas supply link and established a mathematical model for pipeline transmission planning optimization. Using Gurobi software for calculation, they have analyzed the timing of pipeline construction through quantitative analysis of resources and pipeline transmission. Zhao Yanfang et al. [23] have taken a holistic approach to the natural gas industry chain, aiming to maximize the overall benefits of the industry chain, and established a mathematical model of the production, transportation, and sales system. Using CPLEX software as a calculation tool, they have solved the model.

Some scholars have focused on technological advancements. As the core of industry development, China's natural gas transportation technology and equipment have continuously achieved innovation breakthroughs, establishing an independent transportation technology system, and significantly increasing the domestic production of natural gas transportation equipment. Tian Lei [20] has analyzed the current status of technical equipment in the transportation field and proposed key research and development directions for the natural gas industry in line with China's energy transformation needs. Li Chunqi et al. [24] have compared three natural gas simulation methods (Central Finite Difference Method, Implicit Cell Centered Method, and Implicit Cell Centered Linearization) and found that all three methods are compatible. The Central Finite Difference Method has poor computational stability and slow calculation speed, while the Implicit Cell Centered Method and Implicit Cell Centered Linearization Method yield consistent results but with slower calculation speed. The Implicit Cell Centered Linearization Method is the fastest with high accuracy and stability.

(2) LNG Optimization

The cost of LNG (Liquefied Natural Gas) mainly includes investment costs, sales costs, transportation fees, loss costs, external fuel and power costs. Overall, the cost of LNG is relatively fixed; to some extent, the cost of LNG does not increase with the rise of international market offshore prices. Utilizing the cold energy of LNG can help reduce costs at various downstream stages.

Zou Cai'nan et al. [25] have analyzed the current status of energy development at home and abroad and believe that LNG and stored gas will play an extremely important role in China's entire natural gas industry chain under the condition that the peak of domestic gas and pipeline gas is basically determined. Hua Ben [26] has summarized the pricing strategies for downstream LNG users and analyzed the following results: LNG combined cycle power plant users have a lower price tolerance and should enjoy the lowest possible price; urban residential (commercial) gas users should have a higher gas price but consider the affordability of low-income populations; for scaled cities and industrial park distributed energy system users, a "low profit, high sales" strategy should be implemented; refining and petrochemical enterprises should be offered lower prices to encourage extensive use of LNG; although vehicle fuel users have a strong price tolerance, it is necessary to leave reasonable profits for other links in the industry chain, and prices should not be raised arbitrarily; for tanker transport companies, the LNG selling price should fully consider the factors for expanding

the satellite station user market, and appropriate profits should be given to downstream companies to achieve a win-win situation.

(3) Storage Facility Optimization Research

The objective of constructing storage facilities is to ensure supply while also considering economic benefits. Under the guidance of overall benefits, the integration of storage facility site selection, evaluation, design, construction, operation, and management processes becomes particularly important, which raises higher requirements for the digital, informational, and intelligent management and research of storage facilities.

Su Zhan [27] summarized the types of underground gas storage facilities and analyzed the development and trends of global underground gas storage facilities. Based on the construction experience of foreign gas storage facilities, he put forward several suggestions for the construction of China's natural gas reserve peak-shifting system, providing a reference for the construction of gas storage facilities in China. Wang Zhen et al. [28] believed that under the background of "carbon neutrality," the strategic position of LNG and gas storage facilities should be continuously enhanced, and the related infrastructure of LNG and gas storage facilities should be built in an orderly manner to ensure the balance of natural gas supply and demand. Yang Mengxin [29] comprehensively and systematically reviewed the literature on economic benefit evaluation, natural gas industry chain, and economic benefit evaluation of gas storage facilities at home and abroad. Based on the summary of existing economic evaluation methods, starting from the current situation of economic benefit evaluation of gas storage facilities in China, he summarized the characteristics of economic benefit evaluation of gas storage facilities in China, and constructed a discounted cash flow model based on Monte Carlo simulation. Through the analysis of economic benefit evaluation of specific cases, the results show that the improved net present value model can not only consider multiple uncertainties but also directly quantify the size of risks.

(4) Research on Natural Gas Market and Pricing Optimization

With the continuous improvement of economic and scientific levels, the demand for energy in modern society has further increased, which has also promoted the maturation of the natural gas market environment in China. While the natural gas market is facing development opportunities, it is also facing new challenges. Xie Ruijun [30] expounded on the deficiencies in the development of the natural gas market and proposed that natural gas enterprises should effectively develop and cultivate the market based on the actual situation of real life to achieve the perfection of the natural gas market. Gao Zhenyu et al. [31] based on the consumption data of natural gas in "China Energy Statistics Yearbook," analyzed the consumption structure, important influencing factors, and development trends of the natural gas market in China, and believed that accelerating the price reform of various links in the natural gas industry chain could further promote the prosperity of the natural gas market. Zhang Hongliang et al. [32] based on the supply and demand situation of the natural gas market in China in 2021, analyzed the influencing factors of the natural gas supply and demand in China in 2022, and accordingly predicted the demand for the natural gas market in China in 2022. It is suggested that on the basis of strengthening the capacity construction of gas storage facilities, the implementation of gas storage peak-shifting gas volume should be done well, the construction of the "last mile" pipeline should be strengthened, and the innovation of natural gas purchase and sale handover mode should be carried out to ensure the safe supply of natural gas market demand in China.

4. CHALLENGES IN NATURAL GAS SUPPLY CHAIN MANAGEMENT IN CHINA

China's natural gas industry has withstood the test of the pandemic and achieved rapid development, ensuring the national demand for natural gas through increased production and storage. However, in recent years, the natural gas industry has also faced some difficulties, especially in terms of

exploration and development technology, market mechanisms, and the construction of storage and transportation facilities [33]:

1) Exploration and Development Technology Needs Improvement

Natural gas is an organic compound buried in sedimentary rocks that forms through complex organic chemical reactions over long periods of geological time. It is a high-quality combustible gas stored in the strata. Its main component is methane, along with nitrogen, carbon dioxide, hydrogen sulfide, and trace amounts of inert gases [34]. It is a clean, low-carbon, and efficient fossil energy source. According to the data from the Ministry of Natural Resources, in 2023, the newly discovered geological reserves of natural gas increased by 981.2 billion cubic meters, with 415.5 billion cubic meters of new technically recoverable reserves. By the end of 2023, the remaining technically recoverable reserves of natural gas in China were 6,683.47 billion cubic meters, up 1.7% year-on-year. Exploration and development technology is the key to the rapid development of the natural gas industry. Therefore, the current geological theory of natural gas resources and exploration technology need breakthroughs. Key technologies for the efficient exploration and development of deep, tight, and volcanic rock gas reservoirs need to be advanced. Technologies such as fine seismic identification and prediction of shale gas reservoirs, horizontal well geosteering, large-scale fracturing, and effect monitoring and evaluation, as well as intensive "factory" production models, still need to be improved. Moreover, core technologies and equipment for the development of natural gas hydrates and shallow gas hydrates in deep waters need further research [35].

2) Natural Gas Supply and Demand Mismatch, High Degree of Dependence on Imports

In 2023, China imported 119.97 million tons of natural gas (equivalent to 165.2 billion cubic meters), an increase of 9.9% year-on-year. The gap between production and sales of natural gas in China has been widening, and the self-sufficiency rate has been declining year after year. In 2023, the self-sufficiency rate was only 58.88%.

3) Low Efficiency of Natural Gas Pipeline Network and Storage Infrastructure

In 2018, the Central Economic Work Conference in Beijing redefined infrastructure construction, including 5G, artificial intelligence, industrial internet, and the internet of things as "new infrastructure." In 2019, "strengthening the construction of new-generation information infrastructure" was included in the government work report. During the Two Sessions in 2020, "new infrastructure" became a hot topic for many representatives and committee members. Due to the characteristics of long construction cycles and large investment scales in natural gas infrastructure, although China has made good progress in infrastructure construction in recent years, there is still a significant gap with developed countries. In 2023, the total mileage of natural gas pipelines in China reached 118,000 kilometers, with significant differences between provinces in terms of long-distance pipeline coverage.

4) Higher Requirements for Natural Gas Transportation

At this stage, China's national natural gas transportation system has been initially formed, with diverse pipeline flows and a vast geographical area. This makes the planning and operation of natural gas storage and transportation facilities more complex.

5) New Challenges in Balancing Natural Gas Supply and Demand

With economic development, the demand for natural gas as a clean energy source continues to grow, and the sales volume of natural gas is also increasing year by year. The contradiction between peak shaving demand and supply capacity remains prominent.

5. POLICY RECOMMENDATIONS

In the context of the new era, the development of the natural gas industry faces new opportunities. The continuous growth in demand for natural gas and the expanding market present significant opportunities for the development of the natural gas industry; the state's emphasis on clean energy and the goal of achieving carbon peak by 2030 and carbon neutrality by 2060 create new opportunities for the natural gas industry; and a favorable international trade environment also provides important opportunities for the development of the natural gas industry. To seize these opportunities and better develop the natural gas supply chain, this article proposes the following policy recommendations based on the current situation of natural gas supply chain management in China:

(1) Increase investment in the research and development of natural gas exploration technology to accelerate the formation of a market mechanism with orderly entry and full competition in exploration and development, promoting steady and rapid growth in natural gas production.

(2) Promptly advance the diversification of natural gas imports to form a diversified supply mechanism with domestic and international complementarity and stable supply, while also accelerating the improvement of fiscal, tax, and other industry support policies, establishing a comprehensive emergency system for natural gas supply assurance, and improving the natural gas supply and demand forecasting and early warning mechanism.

(3) Establish a mechanism to enhance natural gas reserves and production levels, establish and improve natural gas peak shaving and emergency response mechanisms, and establish a sound natural gas demand side management and peak shaving mechanism. Introduce a natural gas pipeline system reform plan and actively promote its implementation.

(4) Actively and prudently advance the alignment of natural gas prices, improve the dynamic management capabilities of the industrial chain, and further open the natural gas market.

REFERENCES

[1] Jiang Zi'ang, Wang Fuping, Duan Yanzhi, et al. Development Trend and Countermeasures of China's Natural Gas Market Under the New Situation - Taking the Chuan-Yu Gas Region as an Example [J]. Natural Gas Industry, 2016, 36(4): 1–7.

[2] Pan Jiping, Yang Lili, Wang Luxin, et al. Thoughts on the Development Strategy of China's Natural Gas Resources Under the New Situation [J]. International Petroleum Economics, 2017, 25(6): 12–18.

[3] Zou C, Zhao Q, Chen J, et al. Natural Gas in China: Development Trend and Strategic Forecast [J]. Natural Gas Industry B, 2018, 5(4): 380–390.

[4] Liu Yijun, Ma Li. Impact of Low Oil Prices on the Natural Gas Industry Chain [J]. Natural Gas Industry, 2016, 36(6): 98–109.

[5] Xue Jieqiong. Oil Economy News [J]. International Petroleum Economics, 2017, 25(5): 107–109.

[6] Yang Shenghong. Development Strategy of Zhongneng Natural Gas Company [D]. Inner Mongolia University, 2020.

[7] Zhang Fudong, Zhang Jinhua, Zheng Dewen, et al. Integration and Development of Hydrogen, Natural Gas Industry Chain and Value Chain [A]. Proceedings of the 31st National Natural Gas Academic Conference (2019) [C]. China Petroleum Society Natural Gas Committee, 2019: 5.

[8] Zou C, Zhao Q, Chen J, et al. Development Trend and Strategic Forecast of China's Natural Gas Industry [J]. Natural Gas Industry, 2018, 38(4): 1–11.

[9] Jin Guanghui, Peng Xiang. Analysis of the Optimization of the Natural Gas Production, Supply, Storage and Sales System in Southern China - Based on the Current Situation of China Petroleum Group's Southern Natural Gas Production, Supply, Storage and Sales [J]. International Petroleum Economics, 2022, 30(2): 70–75.

[10] Ren Zhijun, Jiang Jianwen, Zhang Yingjun, et al. Perfection Strategy of the Natural Gas Production, Supply, Storage and Sales System in Sichuan Province [J]. Journal of Southwest Petroleum University (Social Sciences Edition), 2019, 21(6): 1–7.

[11] John C. Spain. Warehousing Trends in the United States [J]. Information and Computer, 1996(8): 28–30.

[12] Tong Wenhua. Integration of Production, Supply and Marketing: A New Era of Circulation [J]. Information and Computer, 1996(10): 33–35.

[13] Feng Guo'an. The Impact of Procurement Management's Development to Supply Chain Management on Research, Education and Professional Practice [J]. China Materials Flow, 1997(6): 27.

[14] Li Bo, Lin Sen, Zheng Wei. Basic Theory and Practice of Supply Chain Management in the Information Age [J]. Supply Chain Management, 2022, 3(7): 5–14.

[15] Zhang Wei. Coordinated Development and Upgrading of the Natural Gas Industry Chain [D]. China University of Geosciences (Beijing), 2013.

[16] Liu Dingzhi, Zhang Yuantao, LiANG Yan. Optimization Technology and Prospect of Natural Gas Industry Chain System [J]. Chemical Automation and Instrumentation, 2023, 50(5): 632-643+659.

[17] Li Jian, She Yuanqi, Gao Yang, et al. Development Situation and Prospect of China's Natural Gas Industry [J]. Natural Gas Industry, 2020, 40(4): 133–142.

[18] Zhou You, Zhang Jiajia, Zhang Liangkai, et al. Analysis and Trend Prediction of the International Natural Gas Market in 2024 [J]. Journal of Beijing Institute of Technology (Social Sciences Edition), 2024, 26(2): 76–83.

[19] Gong Weilong, Zhang Jiahong, Yan Ruiguang, et al. Economic Benefit Evaluation of the Natural Gas Interconnection Pipeline Project [J]. Natural Gas Industry, 2019, 39(11): 132–138.

[20] Tian Lei. Innovation Trend of China's Natural Gas Transportation Technology and Equipment Under the New Situation [J]. China Energy, 2022, 44(12): 16–22.

[21] Liu Enbin, Kuang Jianchao, Lü Liumin, et al. Stable Operation Optimization of Large Natural Gas Pipelines [J]. Journal of Southwest Petroleum University (Natural Science Edition), 2019, 41(5): 150–160.

[22] Liu Dingzhi, Zhang Yuantao, Liang Yan, et al. Construction and Application of Natural Gas Pipeline Optimization Model Based on the "National Integrated Network" [J]. Oil, Gas and New Energy, 2021, 33(5): 64–70.

[23] Zhao Yanfang, Liu Dingzhi, Zhao Jun. Design and Practice of Natural Gas Production, Transportation and Sales Optimization Model [J]. Oil and Gas Storage and Transportation, 2016, 35(12): 1319–1324.

[24] Chunqi L, Xianzhong Y, Jun L, et al. Comparison of Three Implicit Difference Methods for Dynamic Simulation of Natural Gas Pipeline Network [J].

[25] Zou C, Zhao Q, Chen J, et al. Natural Gas in China: Development Trend and Strategic Forecast [J]. Natural Gas Industry B, 2018, 5(4): 380–390.

[26] Hua Ben. Cost Analysis and Pricing Strategy of the LNG Industry Chain [J]. International Petroleum Economics, 2007(3): 30–33.

[27] Su Zhan. Research on the Development Trend of Global Underground Gas Storage and Its Implications for China's Gas Storage Peak Shifting System [J]. Quality and Market, 2021(7): 143–145.

[28] Wang Z, Kong Y, Li W. Review on the Development of China’s Natural Gas Industry in the Context of “Carbon Neutrality" [J]. Natural Gas Industry B, 2022, 9(2): 132–140.

[29] Yang Mengxin. Economic Benefit Evaluation of Gas Storage in the Natural Gas Industry Chain [D]. Yangtze University, 2023.

[30] Xie Ruijun. On the Development and Cultivation of the Natural Gas Market [J]. Petrochemical Technology, 2017, 24(8): 191.

[31] Gao Zhenyu, Bai Hua, Wang Yingguo, et al. Research on China's Natural Gas Market Based on Terminal Consumption Structure [J]. Chinese and Foreign Energy, 2021, 26(4): 1–8.

[32] Zhang Hongliang, Fang Botao, Li Xuefei, et al. Prediction of China's Natural Gas Market Supply and Demand in 2022 [J]. International Petroleum Economics, 2021, 29(12): 44–52.

[33] Shen Xilin, Wu Junxian, Fu Hongming, et al. Operation Status of China's Natural Gas Industry in 2020 [J]. Journal of Southwest Petroleum University (Social Sciences Edition), 2021, 23(4): 1–8.

[34] Zhang Wenming, TuO Yunfu. Have You Paid Attention to Safety When Using Gas? [J]. Safety, 2006(2): 54–58.

[35] Jiang Changliang. Management and Technological Innovation of the China-Russia Eastern Gas Pipeline Project [J]. Oil and Gas Storage and Transportation, 2020, 39(2): 121–129.