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Natural Gas Technology Revolution in the Context of the Energy Revolution Research Review

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Abstract

The third energy revolution is in full swing, and China, as a large energy country, is continuously promoting the deepening of energy structure and energy transformation. The article analyses the characteristics of the natural gas technology revolupation from the traditional and emerging business of natural gas in China, and concludes that it is necessary to increase the development of natural gas exploration, further improve the system of natural gas production, supply, storage and marketing, accelerate the breakthroughs in green technology of natural gas so as to optimize the energy structure, and help China's natural gas develop in a healthy way.

Keywords

Energy Revolution; High-Quality Development; Natural Gas.

1. INTRODUCTION

In the Outline of the Thirteenth Five-Year Plan for China's Economic and Social Development, the Chinese Government established two strategic objectives, namely, to build a modern energy system and to accelerate the improvement of the ecological environment[1]. The concept of an energy revolution was initially proposed by Chinese President and is elaborated in depth in the Strategy for the Energy Production and Consumption Revolution (2016-2030), which signals the criticality and urgency of transforming China's energy development approach. The energy revolution is being promoted in five main areas: energy consumption, energy supply, energy technology, energy system construction and international cooperation on energy[2]. It is also the basis for sustainable economic development and energy security. According to the Outline of the Thirteenth Five-Year Plan for China's Economic and Social Development, building a modern energy system and accelerating the improvement of the ecological environment are two of the Chinese government's major goals. In terms of energy, the discourse of energy revolution was first proposed by Chinese President and then detailed in the document "Strategy for Energy Production and Consumption Revolution (2016-2030)", representing the importance and necessity of the transformation of China's energy development mode. There are five major directions for promoting the energy revolution, namely energy consumption, energy supply, energy technology, energy system and international cooperation on energy

In the course of the energy revolution, some scholars summarise the development trend of the energy revolution to get the type of energy from high-carbon to low-carbon development, the way of resource production from simple technology to technological productivity development, and the way of energy utilisation from direct primary conversion to multiple conversion development.[3] In the global energy consumption structure in 2020, natural gas consumption is 3.99×1012 m3 , accounting for 25.1%. In China, the proportion of natural gas in

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the primary energy consumption structure is only about 9%, the natural gas market is huge. As a clean energy source, natural gas produces far less polluting gases when burned than other fossil fuels, and can not only play a bridge role in this energy revolution. It is also the basic fuel for future development.[4] . Therefore, it is of great significance to study the natural gas technology revolution under the energy revolution and promote the high-quality development of the natural gas industry. The overall natural gas industry chain is relatively complete, and can be divided into traditional obligations represented by production, supply, storage and retrieval, and emerging business represented by integration with new energy sources. These two kinds of business are different subjects but closely linked to each other. Therefore, when studying the natural gas technology revolution under the energy revolution, we need to analyse the traditional business, emerging business and the coupling relationship between them.

2. COST REDUCTIONS AND EFFICIENCY GAINS IN TRADITIONAL OPERATIONS

The natural gas industry traditionally includes upstream exploration and development, midstream gas pipeline transportation, liquefaction and storage, and downstream gas distribution and marketing.[5] The three constitute the traditional business of natural gas. The three constitute the traditional business of natural gas, and the synergistic development of upstream, midstream and downstream together constitutes the synergistic driving force for the development of the traditional business of natural gas.

2.1. Continuous innovation and progress in exploration technology is the fundamental driving force of the gas technology revolution

The successful drilling of the Fredonia gas well in New York, USA in 1821 marked the beginning of natural gas exploration. Next, with the innovation of drilling technology and seismic exploration technology, natural gas geological theory and the continuous development of comprehensive exploration technology, it promotes the upstream natural gas industry production to rise continuously. From the 1870s, when the theory of marine oil production sprouted, to the 1920s, when the theory of onshore oil production was formed, to the 1940s, when the theory of coal gas formation was established, the two major theories of natural gas formation, namely, the theory of oil-type gas and the theory of coal gas formation, have contributed to the breakthroughs in the world's new field of natural gas exploration.[6] The two major theories of natural gas genesis, namely, oil-type gas and coal gas theory, have contributed to the breakthrough of natural gas exploration in the world. After entering the 21st century, the research scope of natural gas exploration has become wider, including plate tectonics and oil-containing basins, natural gas generation theory and gas source, modern stratigraphy and natural gas reservoirs and cover layers, natural gas transport theory, gas-bearing systems and natural gas distribution laws, etc. Meanwhile, the geological theory of coalbed methane (CBM) has been developed. Meanwhile, significant progress has been made in the application of the geological theory of coalbed methane and the study of deep basin gas.

The introduction of seismic survey technology provides a technical means for surveyors to better understand the underground structure and rock physical parameters. With the continuous innovation of technology, seismic survey technology has changed from simple one-dimensional, two-dimensional, to more complex and accurate three-dimensional data acquisition and processing.[7] . Seismic and two-dimensional exploration Three-dimensional seismic and two-dimensional exploration technology, compared with the spatial data can be obtained is more huge, exploration efficiency has been improved at the same time can also reduce costs. In addition, the progress of seismic imaging technology allows surveyors to better understand the nature of underground rocks and reservoir distribution. The development of geochemical analysis technology can be used to predict the location and properties of natural

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gas reservoirs by analysing rock and fluid samples.[8] The development of geochemical analyses.

Improved horizontal well drilling and completion and fracking modifications are effective technological tools to increase natural gas production and development efficiency.[6] The shale gas revolution, represented by fracking and horizontal wells, has enabled the United States to become energy independent. Prior to 2002, shale gas development in the U.S. was dominated by vertical wells, but in 2003, Davyin Energy applied its drilling and logging technology to the development of horizontal shale gas wells and achieved good results. It opened the prelude to horizontal well development. Afterwards, with the continuous development of repeat fracturing technology and multi-stage fracturing, as well as the third generation of fracturing technology mainly represented by long horizontal wells super fracturing, the length of shale gas horizontal wells in the United States has reached 3,000-5,000 metres, and the average fracture spacing has been reduced to 30 metres, which has lowered the production cost of equivalent barrels of oil to 30 U.S. dollars. By 2022, the US will produce 1.23×1012 m3 of natural gas, of which 8,068×108 m3[9] of shale gas will be produced, accounting for more than 65%. Through the continuous progress of exploration technology, the development of oil and gas geological theory is continuously promoted, thus making the.Expanding the exploration area from shallow to deep, further promoting the revolution of natural gas technology, and guaranteeing China's energy security.[10]

2.2. Natural gas transport and storage, and the continuous improvement of trading mechanisms are internal drivers of the natural gas technology revolution

Pipeline transport is the most economical way to deliver natural gas.In 1891, the first gas pipeline was laid between Canada and the United States, which opened the prelude of natural gas pipeline trading. Currently, the United States is the country with the longest natural gas pipeline in the world, with a natural gas pipeline length of 198.43×104 km[3] accounting for 69.3% of the world's total length; as of the end of 2022, the total mileage of natural gas pipelines in China is about 11.6×104 km (including the provincial pipeline network and local pipelines of 4.69×104 km.)[10] Meanwhile, China will accelerate the construction of its pipeline network in the coming period as the country's economy continues to develop and its demand for energy expands in the future. In this regard, Huang and[11] et al. analysed the role of natural gas pipeline network in the energy internet and concluded that with the expanding energy demand in the future, natural gas pipeline network will enter a new stage of development.

Zhou Shuhui[12] Zhou Shuhui and others argued that the construction of a natural gas market system should focus on strengthening the responsibility of gas storage, peak adjustment and supply protection, strengthening the supervision of intermediate links, and promoting the reform of local pipeline networks to integrate into the "one network".

Guo Haitao[13] Guo Haitao and others argued that the establishment of the National Pipeline Network Company (NPNC) has created favourable conditions for further natural gas market reform during the 14th Five-Year Plan period, and that it is necessary to focus on reforming the upstream market, advancing the market-based institutional reform of provincial pipeline networks, innovating the mechanism for allocating pipeline capacity, and increasing the public disclosure of information and supervision of pipeline and transmission costs.

Chen Rui[14] and others pointed out that after the establishment of the national pipeline network company, it should strengthen the supervision of natural gas production, transportation and marketing, especially the regional pipeline network; implement the dynamic adjustment mechanism of natural gas gate price to ease the price transmission; clarify the rules of multiple imports to reduce the impact on the international market while preventing importers from speculating; and encourage the signing of long-term purchase and sale agreements.

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LNG is a form of natural gas that has been compressed and cooled to below -161.5°C to convert it from a gaseous state to a liquid form. The volume of natural gas under this conversion is greatly reduced, only 1/625 of the volume of the same amount of gaseous state. it reduces the cost of storage and transportation of natural gas, and LNG trade is gradually becoming the mainstay of the natural gas trade. in 2021, the global annual trade volume of LNG was 5,162×108m3 (3.80×108 t) [14-16]. Among them, China's import volume is 984.2×108 m3 as the world's largest importer. Fu Zihang[15] et al. proposed the concept of interoperability by studying the interconnection of LNG receiving terminals and transmission pipeline networks, suggesting the unification of the measurement units of both and other eight key factors. Han Guangzhong[16] By studying the operational difficulties of newly built LNG receiving terminals in China, they propose to build an LNG futures trading centre to change the domestic pricing and other ways to solve the operational problems of LNG receiving terminals. Zhang Ming[17] et al. study the characteristics of LNG storage tank wind field under different wind speeds, which is an important guidance for the safe construction of LNG storage tanks.2023, the annual supply of natural gas is sufficient to meet the demand of the residents and industry, in which the gas storage plays an important role. Natural gas storage is an important infrastructure for guaranteeing the safe supply of natural gas and solving the problem of peak adjustment, and is one of the key links in the natural gas industry chain. By the end of 2023, the working gas capacity of China's underground gas storage was about 220×108 m3, accounting for about 5.7% of the apparent natural gas consumption in that year. It is far lower than the international level of 15%, and needs to vigorously develop the theoretical technology of gas storage reservoirs. Ding Guosheng[18] et al. concluded that domestic gas storage reservoirs have reached the international leading level in terms of gas reservoir siting, etc., and proposed that the next step is to research on the digital and intelligent platform of gas storage reservoirs and other technologies.

Natural gas prices have historically been the focus and hotspot of attention for all parties in the natural gas market. Since the publication of the Central Pricing Catalogue in 2020, the State has not reformed or adjusted the price of natural gas and its formation mechanism, and the market has traded and delivered natural gas in accordance with the established pricing mechanism. Despite buyers' views on the volume and price of gas in the liberalised part of the market, the market reflected a generally calm market

Li Ting dong[19] et al. show that China's natural gas pricing mechanism has the following problems: the permitted rate of return for natural gas pipelines is too high, there is still room for optimisation of the "benchmark price + floating range" price management method, and an influential benchmark price has not yet been formed.

Bai Jun[20] believes that China's natural gas market still suffers from overlapping policies, a competitive market that has yet to be formed, poor price transmission, and insufficient market regulation.

Fu Shu[21] 's study shows that gate prices impede price marketisation, but also points out that conditions do not yet exist in China's natural gas market to fully liberalise prices due to insufficient upstream competition, inadequate infrastructure, and the low influence of price trading centres.

Zeng Ming[22] et al. analysed the experience of constructing competitive natural gas markets in developed countries and concluded that the construction of competitive natural gas markets is the basis for price marketisation

2.3. The expanding field and scale of natural gas consumption is a central driver of the gas technology revolution

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With the continuous updating and advancement of technology, the type of natural gas consumption has gradually increased from the initial single combustion to natural gas chemical, city gas, natural gas power generation and other fields. Natural gas power generation, industrial fuels and city gas are the three main areas of global natural gas end-use consumption, accounting for 39.1 per cent, 32.3 per cent and 21.2 per cent of end-use consumption, respectively; in addition, natural gas chemical and transport account for 6.0 per cent and 1.5 per cent of end-use consumption.[23] In addition, the natural gas chemical and transport sectors accounted for 6.0% and 1.5% respectively. In China, natural gas consumption started late and the technology is relatively backward, so in the initial stage, the use of natural gas is mainly concentrated in chemical gas and industrial fuel. But with the country's vigorous development of technology continues to progress, China's natural gas consumption structure has also undergone significant changes. City gas, industrial fuel, both occupy about 70% of the country's natural gas consumption. And natural gas power generation accounted for 21.7% and the world's natural gas structure still has a large gap. 2022 China's per capita gas consumption is only 270m3 only one-tenth of the United States. Through the development of natural gas efficient use of technology, expanding the urban fuel gas market, expanding industrial fuel gas, the development of natural gas power generation projects and other measures, to increase the proportion of natural gas in primary energy consumption, and continue to optimise the structure of natural gas consumption, to achieve the maximum value of the use of natural gas resources.

Firstly, in the field of city gas, it is necessary to highlight the dominant position of natural gas. As the level of China's cities and towns continues to rise, city gas has a greater potential for the construction of new towns and cities. Secondly, we will continue to expand the field of industrial gas, and the continuous implementation of national environmental protection policies will be conducive to the continued expansion of natural gas as an industrial sector.

Natural gas power generation is one of the important areas of natural gas consumption in China, and with the continuous and orderly construction of natural gas distributed energy, natural gas peaking power stations and natural gas cogeneration projects in China, natural gas power generation projects are also expected to play a greater role in the context of the overall loose pattern of natural gas supply and demand.[24] The project is expected to play a greater role in the context of the overall easing of natural gas supply and demand.

3. EMERGING BUSINESSES IN FULL SWING

In 2021, the world's new energy consumption 25.18×108 t oil equivalent, primary energy accounted for 17.7%; China's new energy production 6.5×108 t oil equivalent, primary energy accounted for 21.2%, consumption accounted for only 17.3%. At present, the world is in a period of transition from oil and gas to new energy, the new energy development speed and scale of development is increasing year by year, the new energy consumption in 2050 is expected to reach 50%, the coordinated development of fossil and new energy, multi-energy complementary scenarios will be the main scenarios of the future energy system. Natural gas serves as a bridge in the process of energy transition, and promoting the integration of natural gas and new energy is an inevitable trend for future development.

3.1. Constructing a new type of power system

The key to overcoming the instability of renewable energy, especially photovoltaic power generation and wind power generation, lies in the allocation of sufficient and flexible peak storage capacity. Natural gas power generation has the characteristics of fast start/stop, flexible operation, clean and low-carbon, which makes it one of the best ways to solve the bottleneck of renewable energy power generation industry development. 2023 natural gas will only account for 9% of China's primary energy consumption, which is not only a big gap with developed

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countries, but also much lower than the global average level. Including Luo Zuoxian[26] et al.[27] et al, Jian Li[28] et al, Fan Kunle[29] et al.[30] Although they did not make predictive analyses and studies on the total installed power generation capacity, installed new energy generation capacity and installed natural gas power generation capacity in China, they all expressed their worries about the constraints on the flexibility of China's future power system caused by the insufficient scale of installed natural gas power generation capacity, and also expressed confidence in the future development prospects of the natural gas power generation industry under the new type of power system, and predicted that it could realise a certain degree of incremental development accompanied by the continuous maturity and development of the natural gas industry. With the maturity and development of the natural gas industry, and with reference to foreign development laws, it can be concluded that the utilisation of natural gas mainly relies on the promotion of power generation. Accordingly, the state has introduced a series of policies to promote the utilisation of natural gas.

At present, the research and implementation paths of natural gas participation in the construction of a new power system mainly focus on two directions, one is the development proposal and implementation path under the reform of China's power market and the requirements of the construction of a new power system; the other is the implementation path based on the combined development of natural gas and renewable energy. Chen Rui[31] Chen Rui et al. (2021) proposed to clarify the position of "active development" of natural gas, establish upstream and downstream cooperation mechanisms, and increase scientific and technological innovation to promote the sustainable development of China's gas and electricity industry. Zhou Shuhui et al. (2021) suggest that natural gas cogeneration and distributed energy should be carried out in key air pollution prevention and control zones, and that natural gas and wind resources should be bundled with renewable power in regions with abundant natural gas and wind resources. Huang Rang et al. (2021) suggest that the construction of peaking markets and facilities should be promoted, and that corresponding policies on the consumption of renewable energy should be introduced and special studies on integrated development should be carried out. Carry out special studies on integration and development.

Overall, natural gas-fired power generation, as a clean peaking energy source for the long term, will have a significant impact on the construction of a new power system. The domestic natural gas industry should be guided by the national power market reform and the construction of new power systems to effectively utilise the flexible and clean attributes of natural gas. The state should introduce appropriate policies to promote the participation of natural gas in the new power system.

3.2. Natural Gas + Hydrogen Convergence

Hydrogen energy, which is green, non-polluting and comes from a wide range of sources, is an important part of China's new energy system, and a key hub connecting renewable and traditional energy sources. (Zhang Chao 2022) According to the China Hydrogen Energy and Fuel Cell Industry Innovation Strategic Alliance, by 2030, hydrogen energy will account for 5% of China's end-use energy consumption system, with a consumption of 0.35×108 t. By 2050, hydrogen energy will account for 10% of China's end-use energy consumption, with a consumption of 0.60×108 t. Hydrogen energy will play an important role in the integration of the natural gas industry under the country's dual-carbon target.

Natural gas and hydrogen are both clean energy sources with similarities in transport, storage and use, and can even be transformed and supplemented in certain scenarios. The integration of the more mature natural gas industry and the promising hydrogen energy will explore a new energy model suitable for China's national conditions.

Duan Yanzhi[32] In the upstream segment of the natural gas industry, Duan Yanzhi[32]and others have proposed the use of natural gas as a feedstock for hydrogen production in order to

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promote cost-effective hydrogen production for field trials and industrial applications; in the midstream segment, pipeline "hydrogen doping" technology is seen as the key to realising large-scale and long-distance delivery of hydrogen; and in the downstream industry, the construction of hydrogen refuelling stations can be coordinated with new stations by optimising existing In the downstream sector, by optimising the existing network of gas stations and coordinating the retrofitting of existing stations with the construction of new hydrogen refuelling stations.He Runmin[33] (2023) Taking Sichuan and Chongqing as a representative region, we analyse the development path of the integration of natural gas and hydrogen industry. He concludes that Sichuan and Chongqing need to rely on rich natural gas resources, transform and upgrade to actively participate in the natural gas hydrogen business, and provide a model of Sichuan and Chongqing for the high-quality integrated development of China's natural gas industry. Qiu Yue et al. assessed the development potential of hydrogen energy in China from multiple perspectives, analysed the key technologies in the supply chain of hydrogen-blended natural gas, and constructed an integrated energy system for the penetration of hydrogen-blended natural gas by combining the results of the techno-economic analysis of HCNG.

4. CONCLUSION

In order to safeguard national energy security, achieve synergistic development of economy and environmental protection, and launch the natural gas technology revolution under the energy technology revolution, China's natural gas industry development is based on "integrated layout, scientific and technological innovation; multi-energy complementary, multi-dimensional integration; flexible, efficient, optimised and upgraded", and to further improve the natural gas production, supply, storage and marketing system. First, continue to strengthen natural gas exploration and development efforts, strategic layout to support the natural gas storage and production, focusing on the efficient development of natural gas and improve the recovery rate of key technologies, to release the potential production capacity of conventional low-grade gas reservoirs and unconventional gas, focusing on overcoming the "neck" problem, to change the key core technologies dependent on the mouth, the plight of the constraints of others. Secondly, we will accelerate the green transformation and development of natural gas, breakthroughs in new natural gas technologies, new areas of natural gas succession, and the integration of natural gas and new energy sources, so as to promote China's "natural gas revolution", and build a new energy system that is "clean, safe, highly efficient and sustainable" in China, and to build a "strong natural gas country". To build a new energy system in China that is "clean, safe, efficient and sustainable", and to build a "strong natural gas country". Thirdly, we will build a safe and reliable natural gas industry chain and market system, and optimise the market supply and demand structure. On the supply side, we will promote the construction of pipeline gas, increase the layout and allocation of LNG, and increase the scale of gas storage, so as to form an overall pattern of diversified supply, orderly use and flexible deployment; on the consumption side, we will increase the proportion of natural gas in primary energy consumption, optimise the structure of energy consumption, and realise the development of low-carbon and cleaner energy use.

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