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The Functional Orientation and Transformation Rationale of Natural Gas Within China's Novel Energy System Amidst the Dual Carbon Target

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Abstract: Under the dual constraints of carbon neutrality goals and energy security, the strategic positioning of natural gas in China 's new energy system is undergoing a profound reshaping. Among the three major fossil fuels, only natural gas has not been set as the upper limit of consumption peak. This policy signal highlights the special strategic value of natural gas. This paper systematically analyzes the historical evolution of natural gas function orientation from the theoretical level, and demonstrates the triple functions of natural gas under the goal of carbon peak carbon neutralization, that is, the ballast function of energy security dimension, the regulator function of power system dimension and the key link function of multi-energy coordination dimension, and reveals the transition logic of natural gas from supplementary energy to basic pillar energy and its driving mechanism and constraints. It is believed that natural gas is not a simple transitional energy, but a strategic energy with both support and flexibility in the evolution of energy system, and its functional transformation has inherent logical necessity.

Keywords: New Energy System; Natural Gas; Functional Positioning; Energy Transition.

1. Introduction

The " 15th Five-Year Plan for the Construction of New Energy System " jointly issued by the National Development and Reform Commission and the National Energy Administration requires the initial construction of a clean, low-carbon, safe and efficient new energy system by 2030. The ' 15th Five-Year Plan for Oil and Gas Development ' anchors the two major tasks of ensuring energy security and green low-carbon development, and proposes to build a modern oil and gas industry system by 2030. In the context of intensive policy introduction, a core question needs to be answered. Under the rigid constraint of carbon neutrality target, what role should natural gas play in China 's new energy system What kind of evolution process has its functional orientation experienced What is the internal logic of transformation. The answers to these questions are not only related to the direction and pace of investment in the natural gas industry, but also to the feasibility and economy of China 's energy transformation path.

The proportion of natural gas in China 's primary energy consumption is relatively low, far below the global average. However, it is this relatively low proportion, coupled with its characteristics as a recognized clean energy in fossil energy, that gives natural gas a huge space for growth in the future energy system. The proposal of the Central Committee of the Communist Party of China on formulating the fifteenth five-year plan for national economic and social development clearly requires to promote the peak consumption of coal and oil, but does not set the peak consumption target for natural gas. This policy signal clearly shows that natural gas will gain a greater development stage during the " 15th Five-Year Plan " period, and its strategic position is moving from the edge to the center. This paper uses literature research and policy analysis to systematically sort out the theoretical evolution of natural gas function positioning, construct an analytical framework of historical evolution, function positioning and transformation logic, and explore the inevitability, boundary conditions and strategic value of natural gas role transformation from the theoretical perspective of energy system evolution.

2. Historical Evolution of Natural Gas Functional Positioning

(1) Before the 14th Five-Year Plan: The Supporting Role of a Supplementary Energy

Before the 14 th Five-Year Plan, China 's natural gas industry was at the edge of the energy structure for a long time. Subject to relatively poor resource endowments, natural gas accounts for a relatively low proportion of primary energy consumption, which has long hovered between 5 % and 8 %. The focus of industrial development is mainly on urban gas and a few industrial fields, and the positioning in the energy strategy is vague and the function is single. At the time, natural gas was seen more as a icing on the cake clean fuel to replace some of the bulk coal and liquefied petroleum gas than as a key support in the energy system. From the perspective of industrial policy, the development and utilization of natural gas is mainly subject to urban environmental governance and chemical raw material demand, and lacks systematic strategic positioning and long-term planning.

(2) The 14th Five-Year Plan Period: The First Transition to a Bridge Fuel

During the ' 14th Five-Year Plan ' period, under the multiple impacts of intensified global geopolitical conflicts and market fluctuations, the natural gas industry has achieved a systematic reshaping of the development paradigm, and its strategic positioning has undergone the first qualitative transition [1].

From the supply side, the status of domestic pneumatic ballast is unprecedentedly consolidated. The national natural

gas production has continuously increased by more than 10 billion cubic meters. Breakthrough progress has been made in unconventional natural gas, and the total proportion of shale gas, coalbed methane and coal-to-gas production has increased significantly, becoming an important force for increasing reserves and production. At the import end, a multi-supply pattern of equal emphasis on pipeline gas and liquefied natural gas has been formed. The China-Russia Eastern Gas Pipeline has achieved full-load gas transmission, further optimizing the import source structure. From the perspective of infrastructure, the national oil and gas network is accelerating. During the ' 14th Five-Year Plan ' period, the establishment and operation of the national pipeline network group were completed, and the level of fair opening and interconnection of the pipeline network was significantly improved. From the demand side, the consumption structure continues to optimize, and the consumption structure of urban gas, industrial fuel, power generation gas and chemical gas tends to be more balanced. Among them, the proportion of power generation gas has steadily increased, becoming the most growth potential consumption field.

It is the goal of carbon peak carbon neutrality that has injected a new strategic connotation into natural gas. Natural gas, as the fossil energy with the lowest carbon emission intensity, its carbon emission per unit calorific value is only about 60 % of that of coal, and plays an important transitional role in reducing coal and replacing coal [2]. The positioning of bridge energy is thus established, and natural gas is regarded as a transitional choice to connect high-carbon coal and zero-carbon renewable energy.

(3) Intrinsic Driving Forces of the Positioning Evolution

The evolution of natural gas positioning from supplementary energy to bridge energy is driven by dual driving forces [3].

The first driving force is the emission reduction constraint of carbon peak carbon neutralization target. China is committed to striving to achieve carbon peak by 2030 and carbon neutrality by 2060, which is a tight time and heavy task. In the industrial, construction, transportation and other fields, the replacement of coal by natural gas can achieve significant emission reduction effect without changing the basic structure of terminal energy-using equipment.

The second driving force is the guarantee pressure of energy security strategy. The global energy pattern is accelerating adjustment, geopolitical uncertainty is rising, China 's oil dependence on foreign countries is high, and the energy security situation is grim. Natural gas has irreplaceable value in ensuring energy security by virtue of its advantages such as large potential of domestic resources, relatively diversified sources of imports and continuous enhancement of reserve capacity.

3. The Triple Functional Positioning of Natural Gas under the Carbon Peaking and Carbon Neutrality Goals

In the ' 15th Five-Year Plan ' period, under the dual constraints of carbon neutrality goals and energy security, the functional orientation of natural gas has evolved from a single bridge energy to a composite triple role [4].

(1) The Ballast Stone Function of Energy Security Dimension

Natural gas resources are widely distributed, the supply mode is flexible, and the storage technology is mature. Under the background of the increasingly prominent volatility of renewable energy, natural gas is an indispensable force to ensure the stable operation of energy systems [3].

Domestic gas production has great potential. The proven rate of natural gas resources in China is far lower than the world average. Deep, ultra-deep, deep-water and unconventional resources have become important replacement areas for increasing reserves and production. During the ' 15th Five-Year Plan ' period, domestic natural gas production is expected to continue to maintain rapid growth. Import sources tend to be diversified. China has formed three onshore import channels of Central Asian pipeline gas, China-Myanmar pipeline gas and China-Russia pipeline gas. Coupled with coastal LNG receiving stations, import sources cover multiple regions. The peak shaving capacity of the reserve has been continuously enhanced. The ' Oil and Gas Development ' 15th Five-Year Plan ' has clearly set new targets for the construction of long-distance oil and gas pipelines. The increase in the working gas volume of the gas storage has significantly enhanced the seasonal peak shaving and emergency supply capacity.

The core essence of energy power is summarized as three overall plans, namely, coordinating clean and low-carbon transformation and energy security, coordinating traditional energy upgrading and new energy cultivation, and coordinating domestic supply and international cooperation. Natural gas is precisely the key energy species at the intersection of these three co-ordinations.

(2) Regulator Function in the Power System Dimension

The core challenge of the new power system is the volatility and intermittency caused by the high proportion of renewable energy access. Natural gas power generation has become a key technical option to make up for this shortcoming because of its rapid start and stop, strong adjustment ability and far lower carbon emission intensity than coal.

From the perspective of technical characteristics, the variable load rate of large-capacity gas turbines is much better than that of coal-fired units. It takes only tens of minutes from cold start to full load operation. This flexibility makes gas power an ideal choice to cope with intra-day load fluctuations. During the 14 th Five-Year Plan period, the installed capacity of natural gas power generation in China increased significantly, but the proportion of gas power installed capacity was still low compared with developed countries. In the area where the proportion of new energy installed capacity is rapidly increasing, the construction of flexible start-stop gas peaking units has become a realistic choice to ensure the real-time balance of power system. The functional orientation of the gas and electricity is accelerating from the traditional base load power supply to the role of peak regulation and frequency modulation, and emergency supply. The annual utilization hours of gas and electricity may show a downward trend, but its system value per unit hour will increase significantly.

The bundled delivery mode of natural gas power generation and renewable energy is emerging. In the northwest region, the wind-solar-gas-storage integrated base uses natural gas power generation to provide peak-shaving support for large-scale wind-solar bases, effectively improving the utilization rate of transmission channels and power supply reliability.

(3) Key Nexus Function in the Multi-Energy Synergy Dimension

The most unique value of natural gas in the new energy system is that it serves as a key link between high-carbon fossil energy and zero-carbon renewable energy.

The complementary synergy between natural gas and renewable energy is becoming the mainstream application mode. The ' 15th Five-Year Plan for Oil and Gas Development ' clearly requires accelerating green transformation and cultivation of new productivity, and promoting the integration of oil and gas and multi-energy development. In the application scenarios such as industrial parks and large public buildings, the natural gas CCHP system operates in coordination with distributed photovoltaic and energy storage facilities to achieve a significant improvement in energy efficiency.

The industrial integration of natural gas and hydrogen demonstrates broad prospects [4]. Existing natural gas pipelines are regarded as potential infrastructure for large-scale hydrogen transmission in the future, with retrofitting costs far lower than building new pure-hydrogen pipelines [5]. Hydrogen blending in natural gas pipelines has progressed from laboratory validation to large-scale demonstration. The first large-scale demonstration project for green hydrogen-natural gas blending in China was officially launched, and a comprehensive urban gas hydrogen-blending technology experimental platform has systematically conducted research on the effects of blending ratios on pipe materials, burners, safety protection, and other key aspects. The infrastructure advantage of the national oil and gas “one-network” system provides unique institutional and technical conditions for the integrated development of natural gas and the hydrogen industry[6].

The deep coupling of natural gas with carbon capture technology is also noteworthy [7]. The 15th Five-Year Plan for Oil and Natural Gas Development incorporates, for the first time, targets for CO_2 capture, utilisation, and storage (CCUS) injection. The deep coupling of the natural gas industry chain with CCUS technology is expected to achieve low-carbon or even zero-carbon energy supply in the medium term, offering a feasible deep-decarbonisation pathway for industrial sectors that are difficult to electrify.

The triple functions of natural gas in the new energy system are mutually supportive and organically unified. The ballast stone provides the basic guarantee for the regulator and the key link. The regulator creates conditions for the large-scale access of renewable energy, and the key link opens up new space for the long-term value of natural gas.

4. Logical Analysis of Natural Gas Functional Transition

(1) Logical Transition from Transitional Energy to Foundational Pillar Energy

The role of natural gas in the ' 14th Five-Year Plan ' period is bridge energy, a transitional role connecting high carbon and zero carbon. Entering the ' 15th Five-Year ' period, this role is undergoing a qualitative leap. Natural gas will go beyond a single fuel attribute to ensure energy security ballast, support the new power system regulator, and help the triple role of the key link of low-carbon transformation, and move towards a new stage of systematic leap in both scale and quality.

The logical basis of this transition is that the new energy system is not built overnight. Under the condition that new energy has not yet fully possessed the conditions of scale and economic substitution, natural gas has become a key medium to bridge the gap between coal and new energy subjects by virtue of its comprehensive advantages of cleanliness, flexibility and accessibility. The unique value of natural gas is not the cleanest, nor the most sufficient, but the most balanced. It is the best balanced fossil energy among energy availability, economic affordability and environmental sustainability.

(2) Driving Mechanisms of the Transition

The functional transition of natural gas is driven by multiple forces.

Policy-driven is the primary driving force. The proposal of the Central Committee of the Communist Party of China on formulating the fifteenth five-year plan for national economic and social development clearly proposes to promote the safe, reliable and orderly replacement of fossil energy, which not only clarifies the long-term direction that fossil energy will eventually be replaced, but also emphasizes the safe, reliable and orderly gradual rhythm. Various provinces, autonomous regions and cities have successively issued the ' 15th Five-Year Plan ', all of which have placed the construction of new energy systems in an important position, and natural gas has been highlighted in many plans. The ' Energy Law ' provides a fundamental guarantee for the legal status of natural gas in the new energy system. The implementation of the one-area and one-price mechanism of inter-provincial natural gas pipeline transportation has effectively reduced the cost of terminal gas consumption and created price conditions for the expansion of natural gas utilization.

Technology-driven provides the feasibility of transformation. The complementary technology of natural gas and wind-solar power generation is becoming more and more mature, and the technology of hydrogen blending in pipelines is from demonstration to promotion. Deep, ultra-deep, deep water and unconventional resources have become important replacement areas for increasing reserves and production, and significant progress has been made in the localization of heavy-duty gas turbines. Technological progress has expanded the scope of resource exploitation on the supply side, expanded the application scenarios on the demand side, and improved system efficiency on the transmission side.

The market drive has formed the endogenous power of transformation. Power generation gas has become an important growth pole of natural gas consumption. The expansion of the national carbon market has partially compensated the low-carbon premium of natural gas. The improvement of the upstream and downstream price linkage mechanism of natural gas will help to rationalize the cost transmission mechanism and provide sustainable economic support for downstream applications such as gas and electricity.

(3) Constraints on the Transition

Supply security constraints are the most prominent. China 's external dependence on natural gas has been at a high level for a long time, and the volatility of the international natural gas market has increased. How to reduce the risk of external dependence while expanding the use of natural gas is a difficult problem that must be solved.

Economic constraints cannot be ignored. The cost of gas-electric fuel is high and lacks competitiveness in the electricity spot market. The linkage mechanism between gas price and electricity price is not perfect, and the dilemma of mismatching between peak shaving responsibility and market-oriented transaction income restricts the large-scale

development of gas and electricity. The economy of natural gas replacing coal depends on the relative change of carbon price level and gas price trend.

The substitutable constraint still exists. With the continuous decline in the cost of wind power and photovoltaic power generation and the breakthrough of energy storage technology, the substitution process of renewable energy for natural gas may be faster than expected. Natural gas is facing downward pressure on total demand in the medium and long term. This is the dialectical proposition that the basic pillar energy positioning must face, not only to sustain the present, but also to retreat into the future.

5. Conclusion and Implications

The analysis of this paper shows that the positioning of natural gas in the new energy system has experienced the evolution path from supplementary energy to bridge energy to basic pillar energy. The function of natural gas under the target of carbon neutralization is the unity of the three roles of ballast, regulator and key link. This transformation is not only a passive choice under the pressure of emission reduction, but also an active demand for the internal evolution of the energy system, which is logically inevitable. The core value of natural gas lies in its unique position as a balanced energy source, maintaining a balance between cleanliness, stability and economy that other energy sources cannot match.

Based on the above analysis, the following policy implications are proposed. First, clarify the strategic positioning of the basic pillar energy of natural gas, clarify the positioning connotation and time boundary of natural gas in the ' 15th Five-Year Plan ' and subsequent policies, and form a road map for dynamic adjustment. Second, improve the gas and electricity price compensation mechanism and auxiliary service market, and establish a multi-dimensional price system of electricity price, capacity price and auxiliary service compensation, so that the system value of gas and electricity can be reasonably reflected. Thirdly, accelerate the institutional supply of the integrated development of natural gas and hydrogen energy, and introduce the safety standards, quality standards and operation specifications of hydrogen blending in natural gas pipelines as soon as possible, so as to clear the institutional obstacles for industrial integration.

The realization of the carbon neutrality goal of carbon peak is a gradual process, and the role of natural gas in it will also be dynamically adjusted. The construction of China 's new energy system is divided into three stages : foundation period, construction acceleration period and comprehensive completion period. The functional focus and exit rhythm of natural gas should be different. How to grasp the strategic positioning of natural gas in a dynamic manner is not only a frontier topic of academic research, but also a realistic challenge for policy formulation.

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