Forecast of Future Natural Gas Market Demand in China and Analysis of the Situation of Gas Storage Capacity Construction

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Abstract. In the context of dual carbon, with the adjustment of global energy structure and the development of clean energy, natural gas will become a substitute for traditional energy and an important component of sustainable energy. In the future, the proportion of natural gas in the energy structure will increase year by year. At present, China's natural gas industry is developing rapidly, with the promotion of new energy and clean energy policies, as well as the continuous acceleration of coal to gas and coal to electricity. The demand for natural gas in China has been increasing year by year, with natural gas consumption reaching 366.3 bcm in 2022, expected to reach 538 bcm in 2030, and 594.2 bcm in 2035. The safe supply of natural gas also faces new challenges. As an important component of the construction of the natural gas production, supply, storage, and sales system, the construction of underground gas storage depots is of great significance for improving China's natural gas industry, ensuring the national economy and people's livelihood, and maintaining national energy security. This article comprehensively considers the four major industries such as chemical and residential gas consumption, as well as the conversion of coal to gas and coal to electricity in the northern region. It predicts the future demand for natural gas in China and the demand for gas storage capacity construction in this context. From 2025 to 2035, a peak shaving market area in the western region, a peak shaving hub

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area in the central region, and a consumption market area in the eastern region will be formed, and efforts will be made to build UGS warehouses with a WGV accounting for 10% or more of natural gas consumption, With the promotion of new energy policies such as natural gas power generation, efforts will be made to build UGS facilities with a WGV accounting for 16% or more of natural gas consumption after 2035, forming a peak shaving and strategic reserve pattern for UGS facilities in the western and northeastern import corridor areas, achieving a peak shaving and strategic reserve of 79.3–83.6 bcm.

Keywords: Natural gas market demand · Peak shaving demand · Gas storage and peak shaving capacity · Strategic reserve

1 Prediction of Natural Gas Market Demand

1.1 Development Status

Natural gas is a high-quality, efficient, green, and clean low-carbon energy source that can form a positive complementarity with renewable energy. It is the only fossil energy that maintains growth under the "dual carbon" goal. Against the backdrop of countries around the world committed to net zero emissions, global natural gas demand continues to increase.

In the context of low-carbon energy transformation, the clean nature of natural gas has driven its application and demand in the field of electricity. According to data from the International Gas Union (IGU), for every 1 terawatt hour of power generation, coal emits approximately 76 tons of CO and 0.67 tons of nitrogen oxides, accompanied by the production of particulate matter such as sulfides and dust. However, natural gas only emits 37 tons of CO and 0.14 tons of nitrogen oxides, with no emissions of sulfides and particulate matter.

With the vigorous implementation of clean heating and coal to gas projects in northern China, the consumption of natural gas has rapidly increased. In 2022, the national natural gas consumption reached 366.3 bcm, mainly distributed in the four major industries of urban gas, industrial fuel, power generation, and chemical industry.

1.2 Demand Forecast

Based on the current development status of the natural gas market, combined with external environmental factors, the consumption coefficient method and extended prediction method are used to predict the demand of China's natural gas market.

1.2.1 Prediction Method

The prediction of natural gas market demand in provinces is based on the unit of prefecture and city, and the demand of each city is summarized to obtain the natural gas market demand in the province.

The demand forecast for natural gas market in prefecture and city will also be divided into 7 industries for utilization. The natural gas market is divided into urban gas, industrial fuel, natural gas power generation, and natural gas chemical industry. Urban gas is divided into residents, public services, heating, and transportation (vehicles and ships).

The natural gas market demand prediction adopts the consumption coefficient method, extended prediction method, and a combination of two methods. The terminal utilization is divided into seven gas consuming industries, among which the consumption coefficient method is used in industries such as industrial fuel and heating, the extended prediction method is used in residents, public services, and transportation, and the project analysis method in the consumption coefficient method is mainly used in power generation and chemical industry.

1.2.2 Prediction Results

It is expected that during the 14th Five Year Plan period, various regions will strengthen the implementation of the "dual control" policy to reduce coal consumption. At the same time, the reform of the oil and gas system will be deeply implemented, various links of natural gas will be streamlined, and the natural gas market will show a rapid growth trend. It is expected that the demand for natural gas market will reach 442 bcm in 2025, accounting for 11% of the total energy consumption. During the 14th Five Year Plan period, the average annual increase will be 27 bcm; It is expected that the demand will reach 538 bcm by 2030, with energy accounting for over 13% (see Fig. 1).

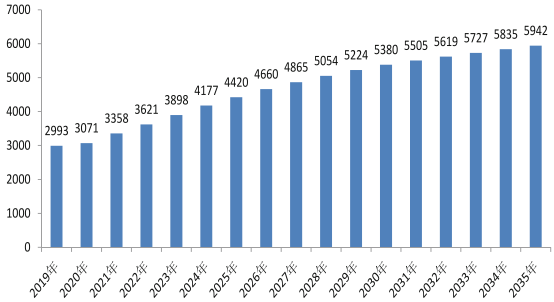

Fig. 1. Forecast of Natural Gas Market Demand in China (100 million cubic meters)

In the future, the Bohai Rim and Yangtze River Delta regions will still have the largest demand in China, with an estimated demand of 225.1 bcm by 2030, accounting for 41.8% of the national total. Affected by factors such as industrial transfer and clean development of the Yangtze River Economic Belt, the proportion of demand in the central and southern regions will gradually increase, from 10.4% in 2019 to 14.9% in 2030, with an increase of 45.1 bcm in demand [1, 2].

2 Analysis of the Situation and Scale Prediction of Gas Storage Capacity Construction

2.1 Current Situation of Gas Storage Capacity Construction

2.1.1 Underground Gas Storage

UGS storage has two main functions: firstly, to regulate the imbalance of gas consumption, to cut peak and fill valley. When the natural gas market gas consumption in summer is lower than the pipeline gas transmission capacity, the surplus gas is injected into the storage. In winter, when the market gas consumption exceeds the pipeline gas transmission capacity, natural gas is extracted from the storage to supply users; Secondly, as an emergency reserve and strategic reserve, when the gas source or upstream gas transmission system malfunctions, undergoes maintenance, or is interrupted due to political, economic, diplomatic, military, and other factors, the UGS can ensure continuous gas supply and ensure the normal operation of the gas transmission system.

China's gas storage has been going through 20 years. As of the end of 2022, China has built 24 UGS depots (clusters) (including 13 for PetroChina, 3 for the national pipeline network, 7 for Sinopec, and 1 for Ganghua), with 60.3 bcm total designed storage capacity and 27.4 bcm WGV(working gas volume), a total daily gas injection capacity of 170 million cubic meters per day, and a total gas production capacity of 280 mcm per day (Table 1). It is expected to generate a WGV of 19.2 bcm by 2022, accounting for approximately 5.2% of the annual natural gas consumption, There is a significant gap with the world average of 12% -15% [3].

2.1.2 LNG Receiving Station

At present, China has established four major natural gas import channels, among which the offshore channels are mainly imported LNG. Compared to UGS, LNG receiving stations have limited space, but they have a short utilization period. The disadvantage is that they are limited by LNG supply sources and are only distributed in coastal areas. The peak shaving method of LNG receiving stations mainly involves daily and hourly peak shaving, as a supplementary method for peak shaving in UGS depots. At the end of 2022, China has built 24 LNG receiving stations, which have 109.57 million tons/year receiving capacity, forming an annual UGS capacity of approximately 6 bcm (Table 2).

Table 1. List of in-service gas storage facilities

Serial number	Affiliated enterprise	UGS	seat	Storage capacity (100 million cubic meters)	WGV (100 million cubic meters)	Gas injection capacity (10000 m^3 / day)	Gas production capacity (10000 m^3 / day)	Production time (year)
1	PetroChina	Suqiao	5	70.5	23.3	1300	2100	2013
2		Bannan	3	10.7	5.6	240	400	2014
3		Shan224	1	8.6	3.3	220	420	2014
4		Lvjuhe	1	5.7	3	200	400	2022
5		Sudong	1	22.3	10.8	600	1256	2022
6		Shuangtuozi	1	10.7	5.3	294	467	2022
7		Sizhan	2	5.2	3.1	280	330	2022
8	Joint venture between PetroChina and national pipeline network	Hutubi	1	107	45.1	1550	2800	2013
9		Xaingguosi	1	42.6	23	1400	2850	2013
10		Shaugn6	1	57.5	32.2	1200	1500	2014
11		Lei61	1	5.3	3.4	200	360	2021
12	National pipe network	Banqiao	6	70	30	1755	3400	2000
13		Jing58	3	17.4	7.8	400	600	2010
14		Jintan	1	26.4	17.1	900	1500	2005
15		Liuzhuang	1	3.9	1.8	150	200	2011
16	Joint venture between national pipe network and Sinopec	Wen23	1	84.3	32.7	1800	3000	2017
17	Sinopec	Wen96	1	5.9	2	180	245	2012
18		Jintan	1	11.8	7.2	450	1500	2018
19		Qingxi	1	4.3	1.9	93	150	2022
20		Bai 9	1	3.6	1.5	74	128	2022
21		Dalaoba	1	7.2	2.0	62	100	2022
22		Gujiazi	1	2.0	1.4	50	50	2022
23		Wei11	1	10.1	5.1	450	500	2022
24	TOWNGAS	Jintan	1	10	6	270	600	2018
total			38	603	274.6	17318	28756	

Table 2. Design Parameters of Existing LNG Receiving Stations in China

LNG Project Name	Affiliated Enterprise	Design capacity (10000 tons/year)	Production time
Shanghai Wuhaogou	Shenergy Group Co., Ltd	150	2000
Guangdong Dapeng	CNOOC	680	2006
Fujian Putian	CNOOC	630	2008
Liaoning Dalian	National Pipeline Network	600	2009
Shanghai Yangshan	Shenergy Group Co., Ltd./CNOOC	600	2009
Jiangsu Rudong	PetroChina	1000	2011
Zhejiang Ningbo	CNOOC	700	2012
Jiufeng	Jiufeng Energy	150	2012
Caofeidian	PetroChina	650	2013
Zhuhai Jinwan	CNOOC	350	2013
Tianjin	National Pipeline Network	600	2014
Hainan Yangpu	National Pipeline Network	300	2014
PetroChina Shennan	PetroChina	27	2014
Shandong Qingdao	Sinopec	700	2014
Guangxi Beihai	National Pipeline Network	600	2016
Guangdong Huilai	National Pipeline Network	200	2017
Shenzhen Diefu	National Pipeline Network	400	2018
Sinopec Tianjin	Sinopec	1080	2018
Xinao Zhoushan	Xinao Co., Ltd	500	2018
Guanghui Qidong	Guanghui Energy	500	2018
Guangxi Fangchenggang	National Pipeline Network	60	2019
Shenzhen Hua'an	Shenzhen Gas	80	2019
Yancheng Lvneng Port	CNOOC	300	2022
Hangzhou Jiaxin	Jiaxing Gas/Hangzhou Gas	100	2022

2.2 Prediction of Gas Storage Capacity Scale

(1) The country has put forward clear requirements for gas supply enterprises, and the task of building UGS capacity is arduous.

Since 2014, with the continuous growth of natural gas demand in China, the issue of natural gas supply security has become prominent. National ministries and commissions have successively issued multiple documents requiring gas supply enterprises to accelerate the construction of production, supply, storage and sales systems, and accelerate the construction of gas storage facilities. In April 2018, the National Energy Administration issued the "Opinions on Accelerating the Construction of Gas Storage Facilities and Improving the Market Mechanism for Gas Storage Peak shaving Auxiliary Services" (NDRC Energy Regulations [2018] No. 637), which clearly stated that gas supply enterprises should have a gas storage capacity of no less than 10% of their annual contract sales volume by 2020, 5% of urban gas, and 3 days (1%) for local governments at or above the county level. If calculated based on 16% of the consumption in 2035, the country needs to build a gas storage capacity of 95 billion cubic meters, The construction of gas storage capacity faces severe challenges [4–6].

(2) The geological conditions for building a reservoir are complex, and the cost of building a reservoir is high.

In China, most of the existing UGS reservoirs are in terrestrial sedimentary environments with fragmented geological structures. The main reservoir types are medium to low permeability gas reservoirs, which have low permeability, poor storage conditions, and high pressures. Due to water flooding in the gas reservoir at the end of production, the storage capacity of the gas reservoir is small.Some gas reservoirs are buried at a depth of up to 4500 m, while 95% of the gas storage in the world are buried below 2500 m. The construction of salt caverns is mainly based on the sedimentary salt layer of continental salt lakes, with multiple interlayers and low grade. The scale of the caverns is small, with some buried depths approaching 2000 m. However, 95% of salt cavern underground gas storage reservoirs in the world are buried below 1500 m, making the construction conditions very complex. These unfavorable factors have brought significant difficulties to the construction of UGS facilities. Drilling and completion under deep and low-pressure conditions, reservoir protection, operation and maintenance of high-pressure gas injection and production systems, the capacity and production of UGS facilities all require a considerable amount of time and cost [7, 8].

(3) The increasingly complex goals of database construction pose new challenges to database construction technology.

Since the UGS establishment, China has achieved four key technological breakthroughs in UGS: firstly, it has created a dynamic sealing theory for complex geological bodies; The second is to create a theory and optimization design for the utilization of complex UGS capacity; Thirdly, key technologies for the construction of complex UGS engineering have been innovated; Fourthly, we have innovated risk warning and control technologies for the long-term operation of complex UGS facilities, and the technology for UGS facilities is becoming increasingly mature[9].

However, the current key consumer market area in China is the eastern coastal region, with fragmented geological structures and a lack of gas reservoir targets. The goal of reservoir construction is gradually shifting towards various types such as low-permeability gas reservoirs, oil reservoirs, and complex salt layers, posing new challenges to reservoir construction technology. For example, the integrated

construction technology of natural gas top gravity drive oil and gas storage has been preliminarily formed, and has been successfully applied to oil and gas storage reservoirs such as Tarim and Liaohe [10, 11].

(4) Long construction cycle restricts the rapid formation of UGS capacity.

Project approval, preliminary evaluation, scheme design, engineering construction, production operation, and reaching capacity and production capacity are indispensable stages of gas storage construction. It takes approximately 3–5 years from project approval to scheme design; The larger the scale, the longer the production cycle. The construction period of depleted gas reservoirs is generally more than 5 years, salt cavern gas storage tanks are generally around 8–10 years, and the construction and capacity reaching period of aquifer and water flooded gas storage tanks can be as long as ten or even several decades. The geological conditions for the construction of salt cavern gas storage in China are complex, and the brine digestion capacity of local salinization enterprises restricts the construction progress, resulting in slow cavity building speed and long construction period. For example, the construction of Jintan Salt Cave Gas Storage has been in progress for over 10 years [12].

2.3 Layout Thinking

By 2025, the infrastructure of six major gas storage centers will be basically formed in the country, namely the western peak shaving market area, the central peak shaving hub area, and the eastern consumer market area. After 2035, efforts will be made to form a seasonal peak shaving and strategic reserve pattern in the western and northeastern import channel areas. The site selection type will shift from salt caverns and depleted gas reservoirs to the collaborative construction of aquifers and gas drive oil recovery, as well as the collaborative transformation of atmospheric fields and gas storage reservoirs.

According to the "non-uniform coefficient method" to calculate the seasonal peak demand for natural gas (only considering UGS and LNG), China's UGS capacity needs to reach 40–44.2 bcm, 55–59.2 bcm, and 65–71.3 bcm in 2025, 2030, and 2035.

After 2035, on the basis of meeting seasonal peak shaving, some strategic reserves will be constructed. Considering various scenarios such as the interruption of the China Russia East Line, the interruption of Central Asian gas, and the interruption of offshore LNG, and referring to the reserve experience of 3–6 months of natural gas consumption in foreign countries, combined with China's gas storage capacity, China's natural gas reserve capacity will consider a 3-month natural gas consumption, with a demand for 9.3 billion cubic meters of Russian gas reserves, 12.3 billion cubic meters of Central Asian gas, and 8 billion cubic meters of offshore LNG, Considering only one of the air intake interruptions, it is predicted that by 2035, the demand for seasonal peak shaving and strategic reserve construction in China's gas storage facilities will reach approximately 79.3–83.6 billion cubic meters, gradually realizing that the working gas volume of gas storage facilities will account for 16% or more of natural gas consumption.

3 Conclusion

1) This article predicts China's natural gas demand using the consumption coefficient method and extended prediction method. It is expected to reach 538 billion cubic meters by 2030 and 594.2 billion cubic meters by 2035.
2) According to the "non-uniform coefficient method" for seasonal peak shaving, China's gas storage capacity needs to reach 40–44.2 billion cubic meters, 55–59.2 billion cubic meters, and 65–71.3 billion cubic meters in 2025, 2030, and 2035. After 2035, on the basis of meeting seasonal peak shaving, some strategic reserves will be constructed. In multiple scenarios, the intake will be interrupted and a 3-month natural gas reserve will be constructed. It is expected that by 2035, China's demand for seasonal peak shaving and strategic reserve construction will reach approximately 79.3–83.6 billion cubic meters.

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