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Research Paper

Natural gas utilization in China: Development trends and prospects

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ABSTRACT

It has been an important objective in China's energy development strategy to accelerate the promotion of natural gas utilization, cultivate main sources of natural gas, and increase the proportion of natural gas consumption. Based on the analysis of the development of natural gas utilization in China over the past 3 decades by means of classified and comparative research, this paper reveals the shift in the development pattern of China's natural gas utilization structure from the domination of industrial gas and chemical gas to a relative balance among industrial fuel, urban gas, and power generation gas. Sustained and steadily growing natural gas is an important basis for the rapid growth of natural gas utilization. Maintaining moderate growth in the natural gas transmission and distribution network is an important guarantee for the rapid growth of natural gas utilization. The slowdown in the world's economic growth has not caused any significant adverse impact on the rapid growth in China's electricity generation gas. The natural gas utilization policy has no effect on the adjustment of industrial fuel gas any longer. Industrial fuels and chemical gas are greatly subject to natural gas prices. Based on China's energy consumption targets for 2020 and 2030, this paper estimates the gas consumption of major gas areas and their development position, namely, more development space for industrial fuels, still rapid growth in urban gas but hardly major breakthroughs in gas proportion, rapid growth in power generation gas and a more prominent role in peak shaving, sustained high growth in transportation gas and challenges from new energy and low oil prices, and a significant decline but still a large scale in chemical gas.

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0. Introduction

History is an indication of the future. In order to effectively control air pollution and actively address climate change, China has accelerated the promotion of natural gas utilization, cultivated main sources of natural gas, and further increased the proportion of natural gas consumption. This has been an important objective in China's energy development strategy. China has ushered in a new era in the use of natural gas. Based on an analysis of the current situation of natural gas utilization in China and a clear understanding of the trends and laws of development of natural gas utilization, making targeted efforts in promoting natural gas utilization is, therefore, of great practical significance to the achievement of the strategic goals of energy development.

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1. Current situation of natural gas utilization in China

Impacted by natural gas resources, natural gas pipelines, natural gas markets and other factors, the China's natural gas consumption is mainly based on local and nearby resources before 1996 (Yongwu, 2004). With the completion of the third Shaanxi-Beijing Gas Pipeline in 1997 and the operation of West-East Gas Pipeline I in 2004, natural gas has been gradually transported for a long distance from the resource area to the central market, ushering in a new era of natural gas utilization. Depending on gas utilization characteristics of different users, natural gas users are mainly from the following six areas: urban gas (such as resident cooking, domestic gas and centralized heating), industrial fuels (industrial projects fueled by natural gas), gas for power generation (such as distributed gas energy, natural gas peaking power stations or cogeneration), chemical gas (such as hydrogen production from natural gas), gas for transportation (such as public transport, freight logistics and ship transportation fueled by natural gas), and gas for other purposes (National Development and Reform Commission, 2012).

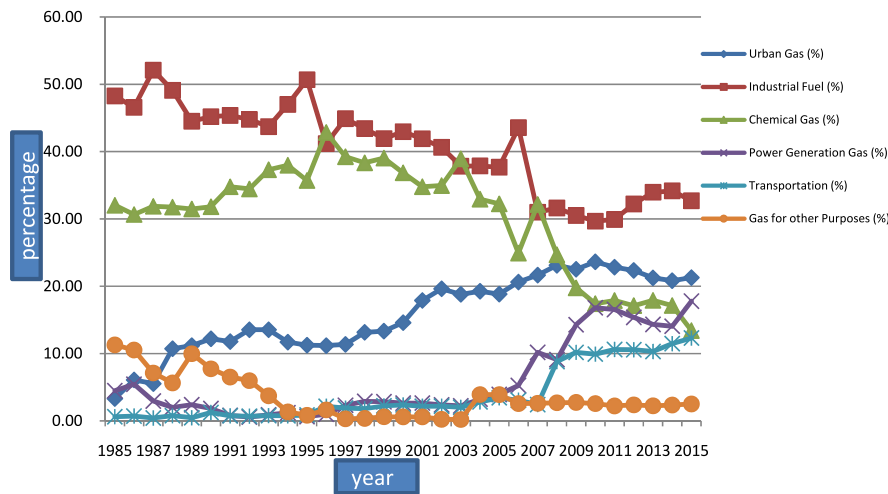


Fig. 1. Structural distribution of natural gas utilization in 1985–2015 (National Bureau of Statistics of the People's Republic of China, 1997–2017).

Since the beginning of the 21st century, impacted by coal, fuel oil, electricity and other alternative energy sources, especially soaring natural gas prices, the share of industrial fuel gas in China's natural gas utilization mix has declined, but still at 30%, making industrial fuel gas the largest gas use area. Urban gas consumption has maintained rapid growth, with domestic gas consumption increasing 83 times between 1985 and 2015. Since 2016, urban gas has made up more than 20% of China's natural gas utilization mix, but still with a big gap with the largest gas use area. Power generation gas experienced robust growth after 2007, making it the third largest gas use area in China. Gas for transportation has grown slowly since 2008. Chemical gas has been on the decline. In the 30 years from 1985 to 2015, a new pattern for natural gas utilization in China was formed, which featured a shift from the domination of industrial gas and chemical gas to a relative balance among industrial fuel, urban gas, and power generation gas. (See Fig. 1)

2. Main influencing factors and development trends of natural gas utilization in China

Globally, natural gas is mainly used as urban gas, industrial fuels and fuels for power generation. Natural gas utilization is impacted by a great number of factors, including resource availability, natural gas infrastructure (Jun et al., 2011a), economic situation, development policies, and the price level (Guohua, 2011).

2.1. Natural gas supply

The downstream natural gas consumption market is fundamental to the development of the natural gas industry (Mingqing et al., 2001). An overview of changes in natural gas utilization in China over the past 3 decades until the operation of the third Shaanxi-Beijing gas pipeline and West-East Gas Pipeline reveals amazing discoveries. From 1985 to 2015, China's natural gas production increased by 8.12% on an average annual basis, while natural gas utilization increased by 9.43% on an average annual basis. Since China started natural gas import in 2006, breakthroughs in the increase in natural gas imports have been made, with China's external dependence of natural gas up from 1.03% to 31.63% (as shown in Fig. 2). Imported natural gas has played an increasingly important role in meeting growing demand for natural gas in China.

Before the first Shaanxi-Beijing Gas Pipeline was put into operation (1985–1996), the average annual growth rates of natural

gas utilization and natural gas production in China were low, but basically balanced, as shown in Fig. 3. After the first Shaanxi-Beijing Gas Pipeline was put into operation (1997–2003), without the support of imported natural gas, the average annual growth rate of natural gas utilization in China was 2 percentage points higher than that of natural gas production. Especially after West-East Gas Pipeline was put into production (2004–2015), in response to rapid growth in both natural gas consumption and natural gas production in China and in order to bridge the widening gap between natural gas production and natural gas demand, it was necessary to keep increasing natural gas imports, for natural gas production cannot meet growing need for natural gas any longer (as shown in Fig. 3). Maintaining a certain amount of natural gas production can help maintain and foster the natural gas market, while expanding natural gas utilization can in turn enhance natural gas production and lead to the continuous expansion of natural gas supply to meet rapidly growing demand for natural gas. The sustained and steady increase of natural gas resources is an important basis for the rapid development of natural gas utilization.

2.2. Natural gas transmission and distribution pipe network

Natural gas is a special commodity. The construction of its transmission and distribution pipe network is essential to its delivery and utilization by end users. Natural gas pipelines grew at an average annual rate of 7.16% in China from 1985 to 1996 (as shown in Fig. 4), while the figure was 10.51% from 1985 to 1996, both higher than the average annual growth rate of natural gas utilization of the same period. This shows that natural gas pipeline construction played a leading role in promoting the growth of natural gas consumption and pipeline construction has promoted growth in natural gas consumption. Since West-East Gas Pipeline I was put into operation (2004–2015), natural gas pipelines grew at an average annual rate of 12.47% in China, but still lower than that of natural gas utilization of the same period. This shows that the rapid growth of natural gas utilization depends to a certain extent on the construction of pipelines, but the rapid growth of natural gas utilization in turn demanded growth in natural gas pipelines. Maintaining moderate growth in natural gas transmission and distribution networks is an important guarantee for the rapid growth of natural gas utilization.

2.3. World economic situation

During the Asian financial crisis (1997–1999), except for gas for power generation, urban gas, industrial fuels, chemical gas and

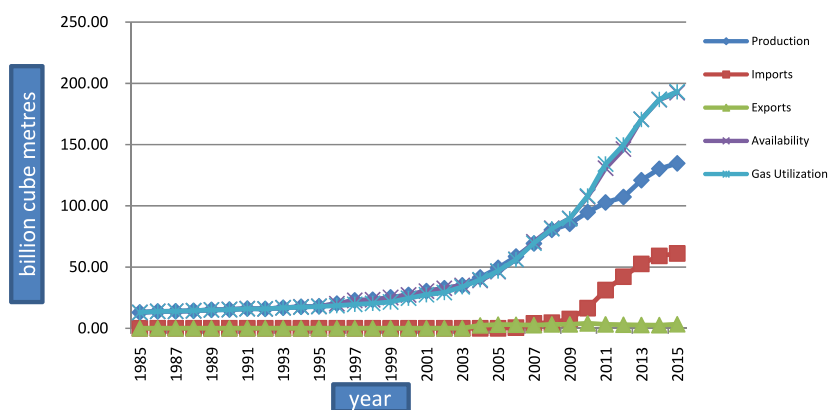


Fig. 2. Production and demand of natural gas in China in 1985–2015 (National Bureau of Statistics of the People's Republic of China, 1997–2017).

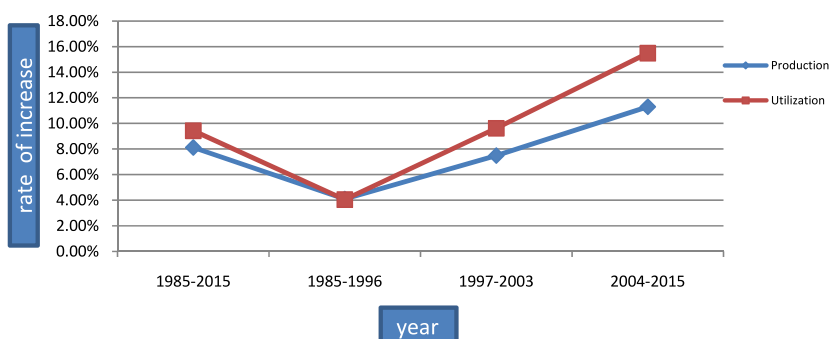


Fig. 3. Changes in average annual growth rate of natural gas production and utilization in 1985–2015 (National Bureau of Statistics of the People's Republic of China, 1997–2017).

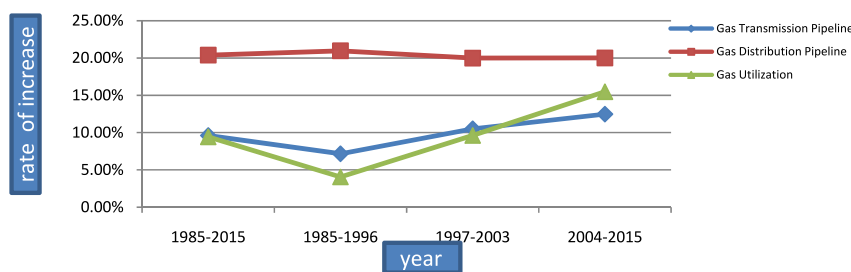


Fig. 4. Average annual growth rate of natural gas transmission pipelines and distribution pipelines in 1985–2015 (National Bureau of Statistics of the People's Republic of China, 1997–2017).

Table 1

Average annual growth rate of gas utilization in main gas areas in 1985–2015 (National Bureau of Statistics of the People's Republic of China, 1997–2017).

Period	Urban gas (%)	Industrial fuels (%)	Chemical gas (%)	Gas for power generation (%)	Transportation (%)	Gas for other purposes (%)	Total gas utilization (%)
1985–1996	15.34	1.82	6.08	−9.91	15.78	−13.35	3.3
1997–1999	13.6	1.37	4.6	16.36	13.9	47.76	4.87
2000–2008	23.04	11.8	10.49	35.67	36.87	40.3	16.17
2009–2015	12.6	14.99	6.59	17.91	17.33	11.99	13.68

transportation gas grew at a slower average annual rate in China (as shown in Table 2). After the Asian financial crisis, gas consumption grew rapidly in all main areas in China. After the outbreak of the global financial crisis of 2008, the world economy was hit hard, resulting in a slowdown in the world's natural gas consumption growth (Guosong and Huan, 2010). Nevertheless, in spite of this global recession, China maintained an average annual growth rate of 13.68% in natural gas utilization. Except for chemical gas, all the gas areas witnessed an average annual growth rate of more than 12%. (Also see Table 1.)

In recent years, plagued by overcapacity, weak demand and falling oil prices in the international market, the world economy has shown a trend of slow growth (The Research Team of Foreign Economic Research Institute of the National Development and Reform Commission, 2015). In 2015, China's gross domestic product (GDP) increased by 6.9% (National Bureau of Statistics of the People's Republic of China, 2017a), down 0.5 percentage points from 2014. In 2016, China experienced a further economic slowdown and increased its GDP by 6.7% (National Bureau of Statistics of the People's Republic of China, 2017b), facing mounting downward

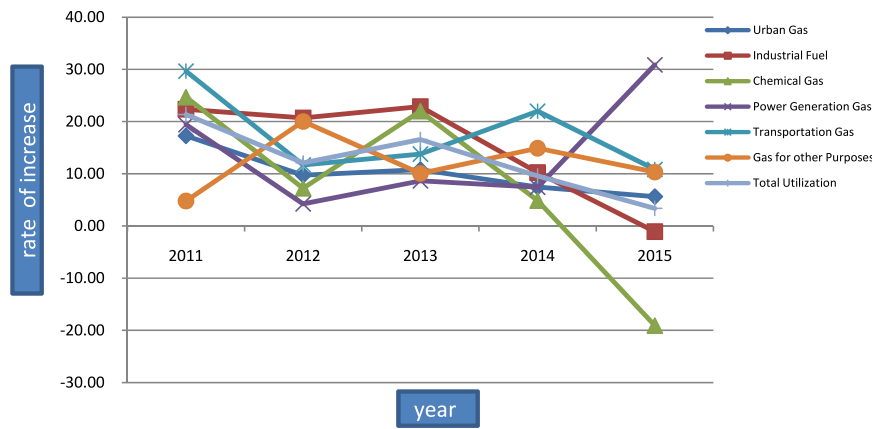


Fig. 5. Average annual growth rate of natural gas in main gas areas in 2011–2015 (National Bureau of Statistics of the People's Republic of China, 1997–2017).

Table 2

Annual growth rate of natural gas utilization in main gas areas in 1985–2015 (National Bureau of Statistics of the People's Republic of China, 1997–2017).

Period	Urban gas (%)	Industrial fuels (%)	Chemical gas (%)	Gas for power generation (%)	Transportation (%)
1985–2002	16.45	3.85	5.45	1.05	12.98
2003–2007	23.96	13.84	14.06	74.98	25.45
2008–2012	14.86	16.37	5.69	32.01	21.22
2013–2015	6.53	4.43	−7.88	18.56	16.27

economic pressure. In spite of a high increase rate of natural gas utilization from 2011 to 2013, as shown in Fig. 5, the growth rate has been on the decline since 2014, only at 3.36% in 2015. All the main areas, except for gas for power generation, suffered a decline in annual growth rate. It shows that the prolonged slowdown in world economic growth has not caused any significant adverse impact on the rapid growth of China's electricity generation.

2.4. Natural gas utilization policies

Before 2002, urban gas consumption experienced the fastest average annual growth, at 16.45%, followed by gas for transportation, at 12.98%, while chemical gas, industrial fuels and gas for power generation grew at a slower rate (as shown in Table 2). Thanks to the Chinese market-oriented reform of utilities, which began at the end of 2002, state-owned, private and foreign-funded enterprises entered the gas market. While the reform promoted rapid growth, it also resulted in subsequent imbalanced supply and demand. In response to the ensuing "gas shortages", the National Development and Reform Commission promulgated the *Policies on the Utilization of Natural Gas* in October 2007, in an attempt to curb the excessive growth in natural gas demand by prioritizing natural gas utilization (Yijun, 2012). Since then, demand for gas in all the main gas areas was on the decline, except for consumption of industrial fuels. Nevertheless, no obvious effect was achieved in the efforts to give top priority to securing the supply of urban gas. As natural gas supply and demand situation was improved, the Chinese government promulgated the new *Policies on the Utilization of Natural Gas* in 2012, clearly setting the goal of increasing the proportion of natural gas in the primary energy consumption structure in natural gas utilization. The document also made positive adjustments to consumption of industrial fuels and gas for power generation. Given adjustments of city-gate prices, the growth of industrial fuels dropped significantly, as shown in Fig. 5. Overall, the *Policies on the Utilization of Natural Gas* has not produced the desired effect.

2.5. Natural gas prices

Prices are the key to natural gas utilization. According to scholars' research on China's natural gas price reform (Baiqiang, 2009;

Lianzeng, 2011; Yijun, 2015), natural gas prices in China can be divided into four stages from 1985 to 2015: double-track system (of the state fixed price and the market price) of natural gas prices in 1985–1992, the structural prices of natural gas in 1993–2005, government guidance prices in 2006–2013, and city-gate gas prices in 2014–2015. Overall, the prices were on the increase.

In the first three stages, with the exception of urban gas, all the main gas areas showed an upward trend in average annual growth rate (as shown in Fig. 6). Consumption of gas for power generation and transportation enjoyed the fastest growth, while industrial fuels and chemical gas grew slowly. In the fourth stage, gas for power generation slowed down, gas for transportation and chemical gas had the most significant decline, and growth in urban gas and industrial fuels was on the decline. In 1985–2015, the price of gas for power generation was most robust, followed by the price of transportation gas, the price of industrial fuels, and the price of chemical gas. Natural gas prices had a great impact on the growth of industrial fuels and chemical gas.

3. Prospects for natural gas utilization in China

Natural gas accounted for 6.3% of China's primary energy consumption in 2016. Accelerating the promotion of natural gas utilization is the fundamental way to achieve the goal: natural gas accounts for 10% of China's primary energy consumption by 2020 and about 15% by 2030 (National Development and Reform Commission of the Peoples Republic of China, 2017a). Based on this goal, by 2020, total consumption of primary energy should be kept at about 4.8 billion ton of standard coal equivalent (SCE) (General Office of the State Council of the People's Republic of China, 2017), while natural gas utilization should reach about 390 billion cubic squares. By 2030, total consumption of primary energy should be kept at about 6 billion ton of standard coal equivalent (SCE) (National Development and Reform Commission of the Peoples Republic of China, 2017b), while natural gas utilization should reach about 740 billion cubic squares.

If G_B represents the natural gas utilization in the future year, G_A represents the natural gas utilization in the initial year, R represents the average annual growth rate, B represents the future year, and A represents the initial year (Wang et al., 2014), the estimated

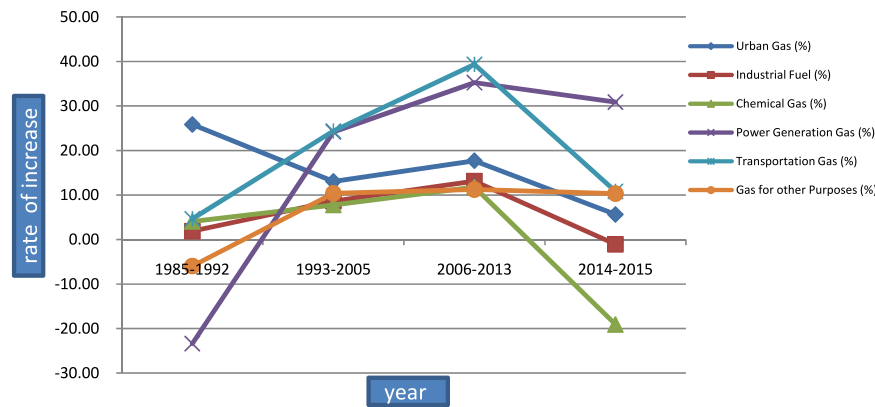


Fig. 6. Impact of natural gas price on main gas areas.

natural gas utilization can be calculated using the following formula:

$$G_B = G_A \times (1 + R)^{(B-A)}$$

In the next 10–15 years, China will still enjoy a quite broad space for natural gas utilization and development, and main gas areas will have their unique characteristics, as shown in Table 3.

3.1. Industrial fuels: a large space for growth, but susceptible to prices

As an efficient, high-quality, and clean energy source, natural gas has been greatly promoted by the central and local governments in China as an effective solution to the coal-to-gas boiler conversion and energy conservation and emissions reduction. With a huge space for development, it will remain the largest energy source consumed in the foreseeable future. However, natural gas as an industrial fuel is susceptible to the prices of coal, fuel oil, electricity and other alternative energy, and is not affordable. In the long run, China's natural gas prices will keep rising, eventually at the same level of international prices, which will have a certain negative impact on the use of natural gas as an industrial fuel to some extent. Therefore, if its average annual growth rate is 15% in 2015–2020 and 6% in 2020–2030, the consumption of natural gas as an industrial fuel will reach about 127 billion cubic meters and 225 billion cubic meters in 2020 and 2030, still accounting for about 32% and 30% of total natural gas consumption in China, respectively.

3.2. Urban gas: rapid growth, hardly major breakthrough in gas proportion

As an important part of natural utilization, urban gas accounted for one-fifth of total natural consumption after 2006, a proportion still slightly low compared with that in the EU, the United States and Russia (Guosong et al., 2010). With the accelerated process of urbanization, if the consumption of urban gas will continue to increase rapidly at an average annual rate of around 13% by 2020. After 2020, it will enter a plateau period and then gradually slow down to about 7%. It is expected that the consumption of urban gas will reach about 76 billion cubic meters and 150 billion cubic meters in 2020 and 2030, still accounting for about 20% of China's total natural gas consumption.

3.3. Gas for power generation: fast growth, a more prominent role in peak shaving

Natural gas power generation can help increase the transmission capacity of gas pipelines during the initial production and

shorten the payback period. It is also conducive to the seasonal peak shaving and gas supply security of the natural gas pipe network (Jun et al., 2011b). With increases in the amount of utilization of natural gas and the widening peak/valley gap, natural gas power generation will play a more prominent role in peak shaving. Thus, in the process of natural gas utilization and development, it is a strategic choice for China to build an appropriate amount of natural gas peak-shaving stations in a timely manner. The robust development of distributed energy and the operation of cogeneration gas power plants in key areas for air pollution control will greatly promote the growth of gas for power generation. If the consumption of gas for power generation will continue to increase at an average annual rate of 17% by 2020 and 10% in 2020–2030. It is expected that the consumption of gas for power generation will reach about 75 billion cubic meters and 195 billion cubic meters in 2020 and 2030, accounting for about 20% and 26% of total natural gas consumption, respectively.

3.4. Transportation gas: continued high-speed growth, but facing challenges from new energy and low oil prices

In the new century, especially since 2007, the consumption of gas for transportation has shown a trend of high-speed growth, with a rising proportion in China's natural gas utilization structure. Impacted by low oil prices and new energy vehicles, the annual growth rate has declined in the past two years. As more and more natural gas will be used for public transport, freight and logistics and shipping, the proportion of gas for transportation in China's natural gas utilization structure will rise to some extent. If the consumption of gas for transportation will increase rapidly at an average annual rate of 16% in 2010–2015 (as shown in Table 2) and 8% in 2020–2030, the consumption of gas for transportation will reach about 50 billion cubic meters and 110 billion cubic meters in 2020 and 2030, accounting for about 13% and 15% of total natural gas consumption, respectively.

3.5. Chemical gas: a significant decline but still on a certain scale

Since this century, with the constant development of some natural gas to methanol projects, projects producing methanol using natural gas instead of coal, and natural gas-fueled nitrogen fertilizer projects, the utilization of chemical gas has grown significantly faster than the previous century. Even though, the trend of a dwindling proportion of chemical gas in China's natural gas utilization structure cannot be reversed. Especially after the promulgation of the Policies on the Utilization of Natural Gas 2012 prohibiting natural gas to methanol projects, chemical gas experienced a tough period in advance. Nevertheless, as a large agricultural country and a

Table 3
Estimate of gas consumption in main gas areas in 2020 and 2030.

	2020			2030		
	Growth rate (%)	Gas consumption (100 million m ³)	Share (%)	Growth rate (%)	Gas consumption (100 million m ³)	Share (%)
Industrial fuel	15%	1270	32%	6%	2250	30%
Urban gas	13%	760	20%	7%	1500	20%
Power generation gas	17%	750	20%	10%	1950	26%
Transportation	16%	500	13%	8%	1100	15%
Chemical gas	0%	300	7.50%	0%	300	4%

country with a large population, China must maintain a certain capacity of nitrogen fertilizer production to meet the needs of agricultural production. It is expected that the consumption of gas for transportation will maintain at 30 billion cubic meters in 2020 and 2030, accounting for about 7.5% and 4% of China's total natural gas consumption, respectively.

4. Conclusion

The increase of natural gas supply and transmission and distribution pipe network accelerates the fast growth of natural gas utilization, meanwhile the situation of world economy is slowly affecting the natural gas utilization of China. The national policy shows less affection, and natural gas prices have various influence on the main gas utilization areas. Before 2030, natural gas will remain in the stage of fast development. Despite the declining tendency of chemical gas utilization will not change, urban gas, industrial fuels, gas for power generation, and gas for transportation will keep increasing rapidly. The prospect of natural gas utilization in China is fairly promising.

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