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Research Article

Gas production peaks in China: Research and strategic proposals☆,☆☆

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Abstract

The peaks of natural gas production are of great significance to the planning of national energy strategy, the coordinated development of natural gas industry chain and the investment decision-making for oil and gas companies. Therefore, based on natural gas geological and development characteristics, the production peaks of conventional gas (including tight gas), CBM and shale gas in China have been systematically analyzed and forecasted using multiple methods. The following conclusions are drawn: first, the cumulative gas production in China will reach 280−330 bcm by 2035 and 330−410 bcm by 2050; second, the conventional gas production peaks will be easily predicable during the forecast period, while the peaks of CBM and shale gas production need to be further forecasted and tracked continuously; third, with the possible breakthrough of gas hydrate exploration and development being considered, gas production in China has a great potential and bright future. In order to achieve a strategic goal of energy transformation and conservation and to guarantee a safe and stable gas supply, a timely profound analysis and study will be necessary on the international political, economic and energy development situation for a global gas strategic layout. In view of this, based on the analysis of domestic natural gas supply and demand situation, the following proposals are put forward: to speed up the domestic tapping and commercial production of those deep-strata, deep-water and unconventional gas resources to consolidate the dominant position of domestic natural gas supply; to attach great importance to a strategic layout of overseas gas resources utilization and to adopt various ways to ensure the security of domestic gas market; to accelerate the evaluation of gas hydrate development in order to enlarge and consolidate the gas resource basis; and to strengthen a dynamic forecast on the peaks of gas production in order to continuously enhance the soft power in international competition.

Keywords: China; Natural gas; Conventional gas (including tight gas); Shale gas; CBM; Peak production; Forecasting model; Suggestions; Strategic planning

Over a decade of rapid development, China has ranked among the world's leading producers and consumers of natural gas. At present, the pressure of climate change and the development of new technologies in the energy sector drive the global energy revolution. “More clean energy and less carbon dioxide” has become the main theme of energy revolution. Increasing the proportion of natural gas consumption represents China's best realistic choice for controlling air pollution and smog. Therefore, there is great potential for the development of China's natural gas market in the future. Scientific research and judgment on gas production peaks are of great significance to the formulation of national energy strategies, the overall arrangement of domestic gas and imported gas resources, and the rational planning of natural gas business development. The study on production peak is a complex and systematic task involving many factors such as resource base, economic level, geopolitics, technological progress, and environmental protection, and involves great difficulties in accurate evaluation; thus, comprehensive multi-disciplinary research is required. In this paper, based on the knowledge and experience of natural gas strategic research of

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many years, the authors assessed gas production peak in China by resource types with a variety of methods and multiple scenarios, in order to provide a basis for the deployment of national energy strategy and the development planning of natural gas industry.

1. Knowledge of gas production peak

1.1. Basic concept

The rise and evolution of the study on "Peak Oil" originated from the "Bell Curve" law of mineral resources discovered by Hubbert (a famous American petroleum geologist) in 1949 [1]. He believed that the production of oil, as a non-renewable resource, in any region, will reach a peak and then inevitably begin to decline [1]. In 1956, Hubbert boldly predicted, in spite of the continuous growth of oil production in the United States, that oil production in the country would decline after reaching a peak in 1967−1971. Truly, the US oil production reached its peak in 1970. This "precise" prediction made Hubbert's Peak Oil Theory cause a sensation, which pushed the peak oil research to a climax.

With the deepening of research, the concept of "peak oil" has been supplemented and improved. Campbell, an Irish geologist, defined the peak oil as the peak value and its arrival period for oil and gas production in an oil region or country [2]. Skrebowski, the former U.S. energy consultant, defined the peak oil as a point after which oil production will no longer increase; however, this point does not mean that oil is depleted, but that oil production will not increase [3].

The first medium-/long-term forecasting model for oil and gas reserves and production in China was proposed by Academician Weng Wenbo, a famous geophysicist. He pointed out in his book *Theory of Forecasting* [4]published in 1984 that any finite body experiences a natural process of rising−growing−flourishing−declining, so does oil and gas exploitation. On this basis, the Weng's Model for oil/gas reserves and production forecasting was established. Later, Chen Yuanqian and other scholars also made a lot of analysis and research on oil and gas production forecasting [5,6].

Natural gas was initially developed and utilized later than oil and it had always been taken as a product associated to oil. The production peak of gas is far less concerned than oil, and no report has been found on the systematic study of global gas production peak. The authors believe that the gas production peak should be studied with a full consideration to the upstream, midstream and downstream integration of the natural gas industrial chain, and both the consumer market and transmission & distribution network construction require a long stable period of gas supply. Therefore, the gas production peak is defined as the production at the time when the gas production in a country or basin reaches the maximum (with the fluctuation not more than 5%) and keeps continuous and stable for not less than 20 years. In other words, the arrival of gas production peak does not mean that natural gas production is about to be depleted, but it will experience a longer plateau period.

1.2. Significance

The study on gas production peak is of urgent and realistic significance to energy transformation and CO_2 emission reduction, promoting sustainable socio-economic development, and raising people's awareness of scientific utilization of natural gas resources. In terms of a nation, a reasonable assessment of gas production peak is conducive to its formulation of energy security strategy, proactive planning for the utilization of overseas gas resources, and scientific deployment of national gas development. In terms of an oil company, understanding gas production peak is beneficial for a company to scientifically prepare its development strategy, make oil/gas field development planning, and rationally allocate its assets, in order to maximize its economic returns and ensure its sustainable development. In terms of the gas industry chain, the production peak is the key to the coordinated development of the industry chain, and also the foundation for the construction of the transmission & distribution networks in the midstream and the market development in the downstream.

1.3. Uncertainties

As mentioned above, the study on production peak is a complex and systematic task that involves many factors. Research institutes and scholars often have their respective conditions for determining the production peak. Once the conditions change, the peak will change. Even the same institute or scholar may have its/his recognition on the peak changing with the conditions. Therefore, there are uncertainties in the determination on the production peak. The oil peak has been argued for years in the industry, mainly because people paid too much attention only to the outcome of the peak, but ignored the conditions for it.

It is certain that oil and gas, which are limited in quantities, are subject to a peak objectively. The focus of research should be on the size of the peak and arrival of the peak. As oil and gas resources expand from onshore conventional and unconventional resources, to offshore, and to polar, the scale of resources is increasing continuously. Meanwhile, the factors such as technological breakthroughs, incentive policies, and energy structure adjustment, are changing. All these drive us to consistently investigate and correct the recognition on peak.

2. Gas production peak in China

2.1. Gas production forecasting method

At present, gas production forecasting methods mainly include analogy method (e.g. gas recovery rate method), life model method (e.g. Hubbert model and Weng's model), combination model method (e.g. gray-Hubbert method), reserve/production ratio controlling method, production composition method, reservoir engineering method, and supply-demand integration forecast method (Table 1). Each method corresponds to specific characteristics and application conditions. In the early stage of basin exploration and

Table 1
Gas production forecasting methods.

No.	Forecasting method	Data needed	Features
1	Life model: Hubbert model, Weng's model, HCZ model	Ultimate cumulative resources produced, production history	Prediction of future production trends depends on the history of natural gas development
2	Combination model: gray–Hubbert, Neural network–Hubbert	Cumulative production, production history, weight of influencing factors (e.g. geology, technology, market, policies, etc.)	With the advantages of good fitting effect by gray theory and neural network, further optimize the life cycle model and get better global prediction results
3	Reserve/production ratio controlling method	Remaining recoverable reserves, yearly incremental recoverable reserves, reserves/production ratio	Depends on the incremental reserves size and the balance between reserves and production
4	Production composition method	Reserve index, development index, development speed	High reliability, but involves more parameters
5	Analogy method (e.g. gas recovery rate)	Basin/gas field resources/reserves, gas production rate	The main method at early development stage, with large uncertainty
6	Reservoir engineering	Production history of gas field, geological model	Forecast the production of a single gas reservoir or gas field
7	Supply–demand integration	Supply, demand, supporting facilities, policies, etc.	Integration of upstream, midstream and downstream, involving multiple parameters

development, the analogy method is generally adopted; in the middle and later stages, the life model and combination model methods are used. At gas field level, the reservoir engineering methods are generally used; at the basin and country level, the life model method, production composition method, combination model method, and supply-demand integration method are more popular. For the short-term forecasts, the production composition method and combination model method are more accurate; for the medium and long-term forecasts, the life model and reserve/production ratio controlling methods can be more useful for grasping the macro trend. The supply-demand integration method focuses on the market demand and forecasts the production based on the requirements of the integrated development of natural gas business.

Over years of efforts, the authors proposed a Natural Gas Production Forecasting System (NGPF system) after developing a series of new methods like the gray-Hubbert, neural network-Hubbert and production composition (uncertainty model) [7,8] on the basis of original gas production forecasting methods (Fig. 1). The NGPF system can reflect the macro development trend and also improve the prediction accuracy, making the scientific prediction of the development

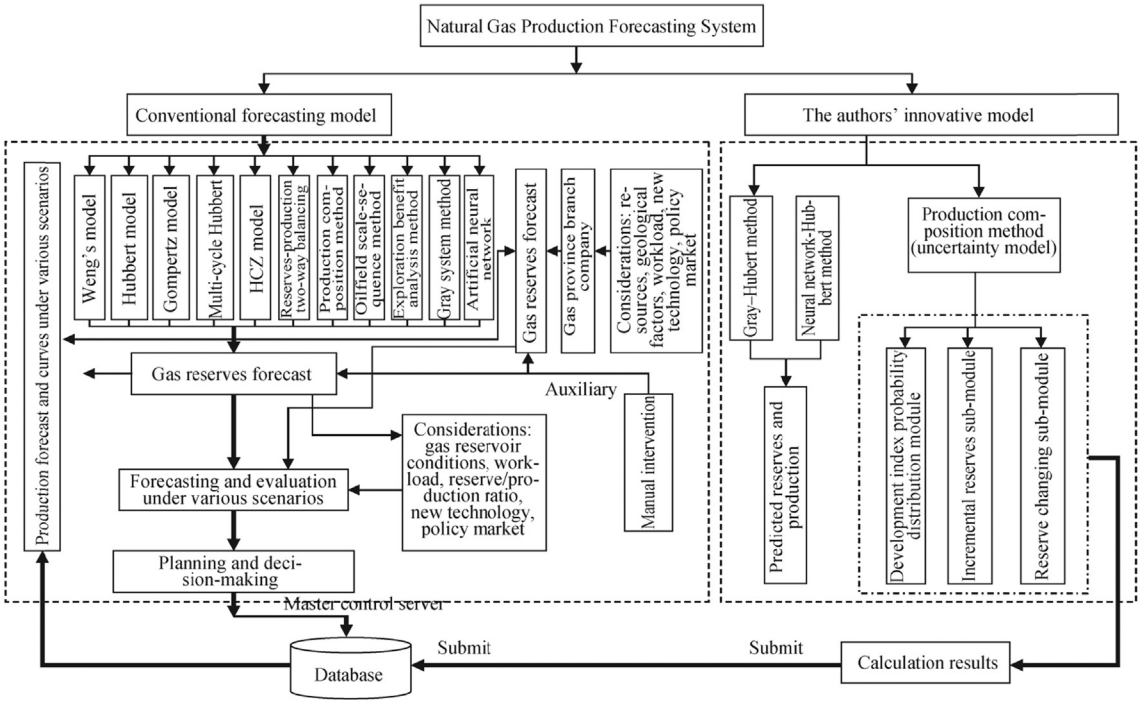

Fig. 1. Schematic diagram of NGPF system.

trend of natural gas production easy and quick. Based on this system, together with different resource characteristics, this paper forecasts the domestic production of conventional gas (including tight gas, the same below), coalbed methane (CBM) and shale gas, and integrates them in chronological order to obtain the development trend of China's natural gas production.

2.2. Conventional gas

2.2.1. Resource base

Quantity of gas resources is the basis for production forecasting. According to the dynamic evaluation results of national oil and gas resources in 2015, the recoverable gas resources in China are 50.1 × 10^{12} m^3 [9]. As of the end of 2016, China's proved recoverable gas reservoir gas reserves were 6.64 × 10^{12} m^3, and the percentage of proved gas reserves was 13.3%. Overseas exploration and development practices show that the percentage of proved gas reserves in mature basins ranges between 30% and 60% [10]. Depending on the domestic natural gas geological conditions, the ultimate percentage of proved gas reserves in China is set at 40% and 50%, corresponding to the cumulative proved recoverable gas reserves ranging from 20 × 10^{12} to 25 × 10^{12} m^3.

Since 2000, as the increasing energy demand and prominent environmental issues along with the rapid economic development, natural gas has received unprecedented attention as a relatively clean and efficient energy resource. Oil companies continue to increase their investment in natural gas business. China's gas reserves achieve a peak growth, with average annual incremental proved recoverable reserves more than 3000 × 10^8 m^3 (Fig. 2). From the perspective of the development strategies of the country and oil companies, natural gas is still the focus of strategic development in the medium and long term. Based on natural gas resources and recent exploration results, the authors reckon that China's natural gas reserves can continue to grow at peak rate till 2030, and predict the potential for incremental recoverable reserves after 2030 by fitting with the life model (Table 2). According to this trend, the percentage of proved gas reserves in China is expected to reach 23% and 33%, respectively, in 2030 and 2050, which are in a reasonable range.

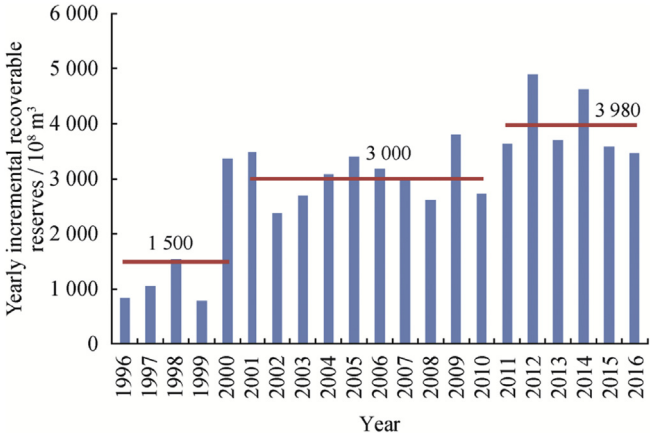

Fig. 2. Statistical results of conventional gas incremental recoverable reserves in China from 1996 to 2016.

2.2.2. Research results

Based on the results of resource potential analysis above, China's conventional gas production before 2050 was predicted with multiple methods.

2.2.2.1. Life model and combination model methods. Production changes like a life cycle, that is, production often experiences a rapid rise in adolescence, a relative stability in the prime of life, a sharp decline in old age, and a slow decline in the low production period. This is the theoretical basis for the Weng's model, Hu-Chen-Zhang's model, Hubbert model, and gray-Hubbert model. Based on the analysis results using these methods, it is believed that China's conventional gas production peak will arrive around 2026, with the quantity ranging from 2400 × 10^8 to 2600 × 10^8 m^3 (Fig. 3).

2.2.2.2. Production composition method. The production composition method is to estimate the potential of gas production in each basic unit (i.e. gas field, project or block) according to the development index, and then multiply the potentials of all units to obtain the total production target. This method can provide a relatively reliable prediction result, but more parameters are needed. Considering the uncertainties of development index, the distribution rules of development index in more than 100 large and medium-sized gas fields around the world were based to determine the probability distribution of the development index. Random probability was used to measure the results, and 200 times of probability distribution of production was simulated and calculated. The predicted gas production peak for P95 and P5 in China ranges between 1800 × 10^8 and 2500 × 10^8 m^3, and the predicted gas production peak for P50 is about 2100 × 10^8 m^3 (Fig. 4 and Table 3).

2.2.2.3. Reserve/production ratio controlling method. With the reserve/production ratio as a controlling condition, the production is predicted. By reasonably controlling the matching relationship between production and reserves,

Table 2
Forecasting results of conventional gas recoverable reserves growth potential in China.

Forecasting results	2017–2020	2021–2025	2026–2030	2031–2040	2041–2050
Cumulative proved recoverable reserves in the period/10^{12} m^3	1.40	1.75	1.60	2.80	2.20
Average annual proved recoverable reserves/10^8 m^3	3500	3500	3200	2800	2200
Cumulative proved recoverable reserves at the end of the period/10^{12} m^3	8.04	9.79	11.39	14.19	16.39

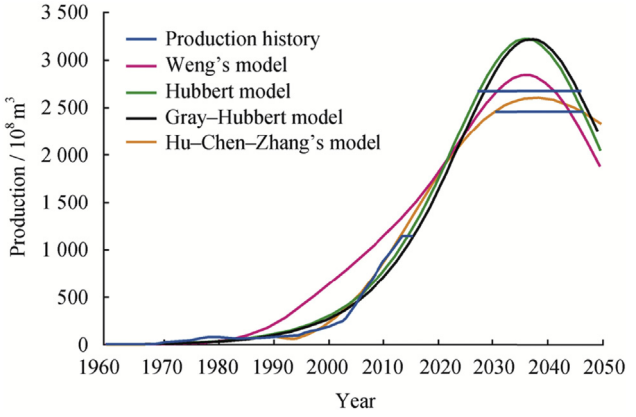

Fig. 3. Forecasting results of China's conventional gas production using the life model and combination model methods.

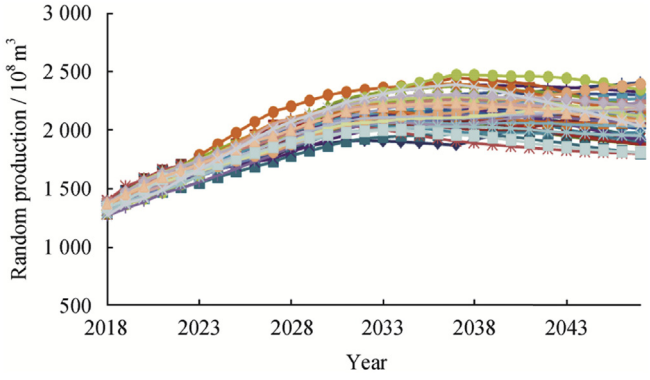

Fig. 4. Forecasting results of China's conventional gas production using the production composition method.

production is maintained stable for a longer period, and thus sustainable development of natural gas business is achieved. Its core is the reasonable value of reserve/production ratio. According to the changes of reserve/production ratio at different stages in many countries, and the gas resource features in China, an evaluation was made with two scenarios of reserve/production ratio (20 and 25) in the stable production period [11]. The evaluation results show that China's conventional gas production peak ranges between 2100×10^8 and 2300×10^8 m^3, and the peak arrival time will be 2028 and 2030, respectively.

2.2.2.4. Comprehensive analysis. The life model method and the combination model method are based on the evaluation results of natural gas resources, so the prediction results are higher. The production composition method is based on the superposition of gas field production, with the consideration of the uncertainty in the production of each gas field. The reserve/production ratio controlling method is based on the matching relationship between reserves and production and the constraints for the stable production period, so its prediction result is reliable. Through comprehensive analysis, it is recommended that China's conventional gas production peak ranges between 2000×10^8 and 2200×10^8 m^3 (Table 4).

2.3. CBM

According to the dynamic evaluation of national oil and gas resources released by the Ministry of Land and Resources in 2015, the geological resources of CBM in shallow coal beds with the depth smaller than 2000 m in China are 30×10^{12} m^3, and the recoverable resources are 12.5×10^{12} m^3. The recoverable resources in favorable zones with development economics are 4×10^{12} m^3, and they are mainly distributed in the southern Qinshui Basin, the eastern edge of the Ordos Basin, the northern part of eastern Yunnan-western Guizhou Basin, and the southern Junggar Basin. From the exploration and development practices, it is known that China's coalbed methane is dominantly of high-rank, different from low-rank in other countries. CBM exploration and development technologies in China are still weak in the aspects of deep medium- and high-rank coals and low-rank coals. By the end of 2016, the cumulative proved CBM reserves in China had been 6928×10^8 m^3, and the recoverable reserves had been 3485×10^8 m^3. After more than 20 years of efforts, industrial CBM production has been achieved, and two major surface production bases have been built in the Qinshui Basin and the eastern edge of the Ordos Basin. In 2016, the coalbed methane production in China was 45×10^8 m^3.

The National Energy Administration proposed that, during the period of the Thirteenth Five-Year Plan, the incremental proved CBM reserves will be 4200×10^8 m^3, and by 2020 the quantity of CBM extracted will be 240×10^8 m^3 [12]. Depending on gas price, number of wells, single well daily production, and other parameters, Liu Qi and Zhang Yingbin [13] predicated that China's CBM production will range from 100×10^8 to 250×10^8 m^3 in 2020 and from 300×10^8 to 500×10^8 m^3 in 2030. According to the research results of the Ministry of Land and Resources [9], the proved CBM reserves in China will maintain a steady growth by 2030; the cumulative CBM reserves will exceed 3500×10^8 m^3 during 2016–2020, with an annual average of 700×10^8 m^3, and over 9400×10^8 m^3 during 2021–2030, with an annual average of 946×10^8 m^3; CBM production will be 251×10^8 m^3 in 2020, and 370×10^8 m^3 in 2030.

Table 3
Forecasting results of China's conventional gas production peaks for different probabilities.

Probability	Peak arrival year	Peak start year to end year	Peak production interval/10^8 m^3	Peak production average/10^8 m^3
P95	2029	2029–2048	1787–2186	1892
P50	2030	2030–2049	2056–2186	2132
P5	2031	2031–2050	2312–2501	2430

Table 4
Forecasting results of China's conventional gas production peak by different methods.

Method	Peak production/ 10^8 m^3	Peak arrival time
Life model, combination model	2400–2600	2028–2030
Production composition	1800–2500	2029–2031
Reserves/production ratio controlling method	2100–2300	2028–2030
Comprehensive analysis results (the authors' recommendation)	2000–2200	2028–2030

The authors set the resource recovery scenarios based on the analysis of the future resource potential in key basins, and with reference to the experiences of developed blocks in China and abroad. The target will be shallow CBM resources with the depth smaller than 1000 m in the Qinshui Basin and the eastern margin of the Ordos Basin in the near term, other shallow coalbeds with the depth smaller than 1000 m in the medium term, and the resources with the depth of 1000–1500 m in the long term. The authors made a prediction referring to the experience of CBM development in China and abroad based on the following controlling conditions: for the resources in shallow areas with a depth smaller than 1000 m, the percentage of proved reserves, recovery factor, and recovery efficiency at the end of stable production period will take a median value – 40%; for resources in the depth of 1000–1500 m, the percentage of proved reserves and recovery factor will take 30%, and the recovery efficiency at the end of the stable production period will take 40%. Moreover, the development index refers to the development performance of the blocks like Fanzhuang, Qinshui and Baode; the recovery rate of recoverable reserves is 3%, and the productivity construction period (including drainage) is 3 years. It is predicted that China's CBM production will be between 200 × 10^8 and 300 × 10^8 m^3 by 2035. If the mining rights are obtained successfully and breakthroughs are made in the development technologies of deep coals with medium–high rank and coals with low-rank, together with the continuous financial subsidies, China's CBM production is expected to be 500 × 10^8 m^3 in 2050.

2.4. Shale gas

According to the dynamic evaluation of national oil and gas resources, the geological resources of shallow shale gas with the depth less than 4500 m are 122 × 10^{12} m^3, and the recoverable resources are 22 × 10^{12} m^3. The recoverable resources in favorable areas with development economics are 5.5 × 10^{12} m^3, and they are mainly distributed in the Sichuan Basin and its periphery. By the end of 2016, the cumulative proved shale gas reserves in China had been 5441 × 10^8 m^3, and the recoverable reserves 1360 × 10^8 m^3. In 2016, the national shale gas production was 78.8 × 10^8 m^3.

Since the US shale gas revolution got success and triggered the significant increase in natural gas production, some Chinese organizations have evaluated and analyzed the prospects of shale gas development in the country. The results show that the forecasts of shale gas production in China in 2020 are basically the same, ranging from 100 × 10^8 to 200 × 10^8 m^3; however, there is a large difference in the predicted shale gas production in China in 2030, ranging from 200 × 10^8 to 1500 × 10^8 m^3 [14–19].

The recoverable resources of shale gas in the United States are 18.8 × 10^{12} m^3; the output in 2015 was 4300 × 10^8 m^3 [20], and the gas recovery rate of recoverable reserves in the major shale gas producing areas [21] in the stable production period is 2.3%–3.0% (Table 5). Based on the resources reported, the authors made a comparison of the shale gas resources in the United States and the development rules of major producing areas. It is found that 5.5 × 10^{12} m^3 shale gas resources in the Sichuan Basin and its periphery can guarantee a production scale of 1200 × 10^8 m^3. If there is a breakthrough in the marine-continental and continental shale gas in the medium and long term, China's annual shale gas production can exceed 1500 × 10^8 m^3.

2.5. Comprehensive evaluation of gas production peaks in China

Based on the forecast results of conventional gas, CBM, and shale gas production, considering the time effect of resource replacement, the authors forecasted that China's gas production would be between 1750 × 10^8 and 1850 × 10^8 m^3 in 2020, between 2800 × 10^8 and 3300 × 10^8 m^3 in 2035, and between 3300 × 10^8 and 4100 × 10^8 m^3 in 2050 (Table 6).

In terms of the gas production composition, conventional gas corresponds to a long exploration and development time, and mature development rules and technologies. Its future development trend is clear. The conventional gas production peak range is basically determined, and the predicted production scale is with high credibility.

Table 5
Comparison of relevant parameters in major shale gas production areas in the U.S.

Relevant parameter	Antrim	Barnett	Fayetteville	Haynesville	Eagle Ford
Development phase	Decline	Decline	Decline	Stable production/Decline	Decline
Recoverable reserves/10^{12} m^3	0.198	1.25	0.9051	2.11	1.92
Cumulative production by 2017/10^8 m^3	982	5032	2213	4071	2480
Recovery efficiency by 2017	50.0%	40.0%	24.4%	19.3%	13.0%
Production in 2017/10^8 m^3	22	293	175	405	408
Annual peak production/10^8 m^3	55	516	287	704	493
Stable production/10^8 m^3	51.6	470	275	482	444
Recoverable gas recovery rate	2.60%	3.76%	3.04%	2.28%	2.31%

Data Source: Production data from the US Energy Information Administration (EIA); Reserves data from Ref. [21].

Table 6
Forecasting results of gas production in China.

Type	10^8 m^3				
	2020	2025	2030	2035	2050
Conventional gas	1500–1550	1800–1900	2000–2200	2000–2200	2000–2100
CBM	60–80	100–150	150–200	200–300	300–500
Shale gas	190–220	200–400	400–600	600–800	1000–1500
Total	1750–1850	2100–2450	2550–3000	2800–3300	3300–4100

CBM and shale gas are still in the initial stages of scale development. The scale of resources is to be identified and the quality of resources is low. Influenced by factors such as development technologies, gas prices, and policies, the forecasting results are in great uncertainty, and the production peaks and arrival time still remain to be tracked continuously.

Moreover, there is a great uncertainty in China's natural gas supply, which is natural gas hydrate. On May 10, 2017, the gas hydrate test production project in the South China Sea was first tested and the pilot production lasted for 60 days. The cumulative gas production exceeded 30×10^4 m^3. This sets a new world record for gas production time and total output, and represents a key step in the exploration and development of natural gas hydrates [22]. Some economic and technical bottlenecks still remain, but they are believed to be solved probably. Once a dramatic breakthrough is made, the potential of natural gas hydrate will be enormous and it may become an important impetus for China's natural gas production to rise to a new level.

3. Conclusions and suggestions

In conclusion, the authors reckon that the conventional gas production peaks in China will be predicable during the forecast period, while the peaks of shale gas and CBM production need to be further forecasted and tracked continuously. With a possible breakthrough in natural gas hydrate exploration and development, China's gas production growth will be of great potential.

In terms of the energy consumption revolution in China and the requirements for beautiful China construction, it is expected that domestic natural gas demand will reach 5500×10^8 m^3 and 8000×10^8 m^3 in 2035 and 2050, respectively; domestic gas production will not meet the demand. In order to increase the gas supply scale, achieve the strategic goals of energy transformation, energy conservation and emission reduction, and ensure the safe and stable gas supply, the following recommendations are made.

3.1. To speed up the domestic tapping and commercial production of those deep-strata, deep-water unconventional natural gas resources to consolidate the dominant position of domestic natural gas supply

The conventional gas resources are abundant in deep strata and deep waters, and they are less explored and developed. So, they are of great potential for increasing reserves and production. Gas accumulation mechanisms in deep strata, seismic prediction, and wellbore technology are theoretical and technical challenges that restrict the exploration and development of gas in deep strata. It is recommended to strengthen the study on the integration of seismic data collection, processing, and interpretation in deep strata, make more efforts in developing the technologies for safe and rapid drilling, reservoir identification, reservoir protection, and reservoir reformation, and promote continuous breakthroughs in oil and gas exploration and development in deep strata, so as to lay a solid foundation for resource development. In terms of offshore resource development, there are bottleneck problems such as disputes over sovereignty and immature development technologies. It is proposed to fully use China's diplomatic and military forces to initiate substantive exploration and development of offshore oil and gas, to strengthen research and development of marine geophysical exploration technology and marine drilling engineering and equipment, and to enhance team building. At the same time, it is recommended to strengthen cooperation with overseas companies with strong offshore exploration and development technologies, learn from their experiences and technologies. With these efforts, we will try to promote the rapid growth of offshore oil and gas reserves and production.

Shale gas and CBM are in the early stage of exploration and development. As of the end of 2016, the proved recoverable resource rates were 0.6% and 2.8%, respectively, while scale development is facing challenges in engineering technology, economic benefits, and safety and environmental protection. It is recommended to strengthen overall planning and the efforts of implementation, further demonstrate the resource scale and development conditions (including technology, economy, policies, and environmental protection), do a good job in transforming production and operation modes, strengthen external technical exchanges and cooperations. Through technical cooperation, technology introduction, and independent R&D and other means, a set of energy-saving, clean unconventional natural gas development technologies suitable for China's geological characteristics will be developed, thereby promoting the development of unconventional natural gas with scale economy.

The domestic exploration and development of natural gas will be strengthened to improve the self-supply capacity. The proportion of domestic gas and imported gas will be controlled reasonably. It is proposed that the dependence on imported gas be controlled within 50% to ensure the dominant position of domestic gas supply and the energy supply.

3.2. To attach a great importance to the strategic layout of overseas gas resources utilization and to adopt various ways to ensure the security of domestic gas markets

The potential of natural gas resources is huge globally, providing a solid foundation for China to make a full use of foreign natural gas resources. Particularly, the current sluggish global economic recovery and low oil prices have a great impact on the energy strategy and foreign cooperation policies of major resource countries and oil and gas consuming countries, and the interested parties in the energy sector have entered the period of policy adjustment. Russia, Venezuela, Ecuador, Kazakhstan, Algeria, and other countries are forced to take measures to adjust their foreign cooperation strategies, lower the threshold for foreign cooperation and open more channels to attract international funds. On the basis of consolidating and strengthening the existing overseas gas resources, new foreign gas sources will be sought, and more information on policies, energy production and consumption will be collected from gas resource countries. Foreign cooperation will be enhanced by means of joint ventures, reciprocal holding shares, and joint venture cross management, buying reserves, buying gas fields and so on. The independent development and investment of overseas natural gas will be promoted in an all-round manner. The independent development rate of overseas natural gas will be increased, and overseas natural gas supply bases will be established, in order to ensure stable domestic natural gas supply and stable economic development. In particular, it is necessary to seize the opportunity of US natural gas conversion from import to export, and international LNG supply is sufficient before 2020 or even later, to encourage oil companies, local enterprises, and private companies to participate in joint imports, and pay more attention to gas price situation and the comparison and optimization of multiple gas sources, sign some long-term, low-cost contracts, and enlarge diversified natural gas import channels.

3.3. To accelerate gas hydrate evaluation and development in order to expand and consolidate gas resource basis

Gas hydrates are abundant in nature, and they are mainly distributed in deep water areas in the continental permafrost zone and at the bottom of the ocean. Preliminary exploration results show that natural gas hydrate resources in China seas are approximately 80×10^{12} m^3 [22]. Though there was a breakthrough in natural gas hydrate exploration and development in 2017, exploration and development is a complex and systematic project. There are no mature recovery technologies in the world and there is still a long way to go for commercial development. It is recommended that the government set up a major scientific and technological project for gas hydrates, invest more in human, physical, and financial resources, and systematically carry out evaluations of gas hydrate development. If there is a breakthrough in the development technologies, there is still much room for improvement in gas production peak in China. Therefore, we must be full of confidence in China's gas production peak and persist expanding gas utilization and optimizing energy consumption structures.

3.4. To strengthen a dynamic study on the peaks of gas production in order to continuously enhance the soft power in international competition

Under the background of globalization and informatization, changes in every factor such as resources, markets, macroeconomy, and geopolitics will trigger huge fluctuations in the energy market. Therefore, it is necessary to make continuous dynamic analysis on gas production peak, so that effective measures can be taken in time to respond to the changing global gas market. It is recommended that the government set up a dedicated project and rely on relevant domestic research institutions to conduct continuous evaluations on natural gas macroeconomic policies, supply and demand scale analysis models, key index values, and the potential of supply and demand. Furthermore, exchanging visiting scholars and joint research projects should be carried out with the famous research institutions such as EIA, to learn from their advanced systems and methods, understand the most advanced academic ideas in the world, and cultivate a group of experts with global perspective, global thinking, and long-term vision strategy. These experts can and will closely track the political, economic, and energy situations around world, dynamically evaluate the industry situations and issue the global gas industry development reports. In this way, China's influence on the international stage is expected to improve.

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