

Research article

China's natural gas exploration and development strategies under the new normal

Lu Jialiang, Zhao Suping*

Langfang Branch, PetroChina Research Institute of Petroleum Exploration & Development, Langfang, Hebei 065007, China

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Abstract

China's natural gas industry has experienced a great leap-forward development in the past decade. Since the second half of 2014, however, international oil price has dropped sharply and global oil and gas markets have been sluggish. In China, economy growth rate slows down and resource environments tend to be more restricted. And energy production and consumption revolution speed up, and the development of natural gas industry experience profound changes internally and externally. Through review on the achievements in recent high-speed development and analysis on the future development of China's natural gas industry, it is believed that the growth rates of China's natural gas output and consumption will slow down and the supply and demand fundamentals present loose states. Low-permeability tight, deep—extra deep and unconventional reservoirs will be the principal targets of natural gas exploration and development and the tendency of resource deterioration is inevitable. The pressure to the decrease of gas price rises due to the sustained recession of oil price and the sharp decrease of alternative energy price. The normal means to increase benefits is to control investment strictly and reduce cost greatly. As for the new normal, five suggestions are proposed for natural gas exploration and development in China. Firstly, reinforce exploration continuously by guaranteeing work load and investment at the required level, and tamp the development basis. Secondly, pay much attention to early development evaluation, give prominence to plan implementation design and control productivity construction rhythm. Thirdly, pay attention to the top-level design of mature gas field development and adjustment, with fine description and management as the priority, and improve overall development level. Fourthly, strengthen the researches on exploration and development technologies, with the simplification and practicability of technologies as the focus, and reduce the cost effectively. And fifthly, summarize high-speed development experience of natural gas industry, pay attention to the demonstration and design of key indicators, and strengthen the study on progressive planning.

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At the end of 2004, the West-to-East Gas Pipeline Project was completed and officially put into operation, marking the fast development period of China's natural gas industry. In the past decade (2004–2014, the same hereinafter), China's natural gas industry has experienced a great leap-forward development and has obtained a series of achievements in the fields of exploration and development, pipeline transportation

support, and consumption and utilization. A relatively complete industrial framework is basically established. China's natural gas industry contributes greatly to the energy structure optimization and energy conservation and emission reduction in China. After ten years' fast development, China is now one of the major natural gas producers and consumers in the world, and the effect of China's natural gas markets on global natural gas market and their integration degree increase remarkably. Since the second half of 2014, however, global oil market has experienced profound change. International oil price has dropped sharply and now still stays at the low level, and global

* Corresponding author.

E-mail address: zhaosp69@petrochina.com.cn (Zhao SP).

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oil and gas markets have been sluggish. In China, economy growth rate slows down and resource environments tend to be more restricted. With the speeding up of energy production and consumption revolution, natural gas industry is experiencing profound changes internally and externally. Both challenges and opportunities exist. In this paper, the future development situations of natural gas industry is analyzed and studied after the experience concluded through ten years' fast development of China's natural gas industry is reviewed and summarized. Then, natural gas exploration and development strategies are proposed so as to grasp the opportunities under the new normal, adjust development concepts in time and ensure fast and healthy development of natural gas industry in China in the long term.

1. Review on the fast development of natural gas industry in China

1.1. Continuous exploration breakthrough and reserves increasing at peak rate

Since 2004, great breakthrough of natural gas exploration has been realized in the areas of Kuche and Tazhong, the Tarim Basin, in tight sandstone gas reservoirs in the Ordos Basin, in the Upper Triassic Xujiahe Formation gas reservoirs, Puguang Gas Field, Yuanba Gas Field and Longwangmiao Formation gas reservoirs in central Sichuan Basin, and in Dongfang 13-2 in the Yinggehai Basin. Natural gas reserves have been increasing continuously, with yearly average proved gas in place over $6000 \times 10^8 \text{ m}^3$, including recoverable reserves of $3600 \times 10^8 \text{ m}^3$. The cumulative proved gas in place in the past decade is $6.34 \times 10^{12} \text{ m}^3$, more than the sum of national cumulative proved reserves before. At the end of 2014, the national cumulative proved gas in place was $10.45 \times 10^{12} \text{ m}^3$, including recoverable reserves $6.2 \times 10^{12} \text{ m}^3$. With further exploration of coalbed methane (CBM), the accumulative proved CBM in place was $6266 \times 10^8 \text{ m}^3$. As for shale gas exploration, great discovery has been obtained in the field of marine shale in the Sichuan Basin [1]. In 2014, the proved geologic reserves initially submitted by the Fuling Shale Gas Field was $1067 \times 10^8 \text{ m}^3$. Based on the latest data, the total shale gas reserve in this basin by 15th October 2015 was $5400 \times 10^8 \text{ m}^3$, including $3800 \times 10^8 \text{ m}^3$ from Sinopec and $1600 \times 10^8 \text{ m}^3$ from PetroChina. Ten years' reserves increasing at peak rate provides the firm basis for the fast increasing of natural gas output.

1.2. Moving into the queue of major gas producers based on the fast increasing of gas production

With the successive commissioning of long-distance natural gas pipelines (e.g. West-to-East Pipelines, Shaanxi–Beijing) Gas Pipelines and Eastward Pipelines of Sichuan Gas), the bridges between the resources and the markets have been set up continuously. A number of large gas fields over $50 \times 10^8 \text{ m}^3$ were developed and put into production successively, including Kela 2, Dina, Sulige, Yulin and Puguang gas fields, so

natural gas production rose fast to $1296 \times 10^8 \text{ m}^3$ in 2014 from $410 \times 10^8 \text{ m}^3$ in 2004. Within ten years, the natural gas production was more than doubled, with yearly average rising rate of 12.2% and yearly production incremental of $88.6 \times 10^8 \text{ m}^3$. Compared with other countries at fast development stage, China's production rising rate and incremental both ranked in top three (Table 1). The rank of China's natural gas production in the world jumped to the 6th in 2014 from the 17th in 2004.

1.3. Continuous technical innovation and integration impelling scale beneficial development of complex gas reservoirs

In order to solve the bottleneck issues that restricted the development of complex gas reservoirs, major scientific research projects have been set up, basic researches and on-site pilots have been carried out vigorously, and innovative and integrated technologies have been developed continuously in recent ten years. A lot of progress has been achieved in terms of fine description of heterogeneous reservoirs, staged fracturing stimulation of horizontal wells, fast drilling, safety development technologies of high-acidity gas reservoirs, and standardized design, digitalized construction and factory-like operation modes, based on which, complex gas reservoirs are developed efficiently in large scales, typically including Sulige low-permeability tight gas reservoirs, Kuche extra deep gas reservoirs, Tazhong fracture-pore carbonate gas reservoirs, Puguang high-sulfur gas reservoirs and Xushen volcanic gas reservoirs. With the continuous innovation and integration, the reserves of complex gas reservoirs, which account for 70% of total proved reserves, are developed and utilized effectively, and support strongly the fast ascending of natural gas production in China.

1.4. The basic completion of national main pipeline networks with the speeding up of transportation and distribution system construction

After the West-to-East Pipeline I was put into production at the end of 2004, the construction of China's long-distance

Table 1

Natural gas production rising rate and incremental of different countries at the fast development stage.

Country	Fast development stage	Yearly average production incremental/ 10^8 m^3	Yearly average production rising rate
U.S.A	1931–1967	123.00	6.1%
Canada	1987–2002	86.06	6.7%
Algeria	1994–1999	38.93	9.0%
Indonesia	1983–1996	34.57	9.1%
U.K.	1992–2000	71.13	9.8%
Malaysia	1984–2004	25.57	10.4%
Australia	1988–1994	21.17	10.6%
India	1985–2003	14.11	11.1%
Norway	1995–2004	69.70	12.2%
Egypt	1998–2004	24.33	14.0%
China	2004–2014	88.60	12.2%

Note: The basic data is derived from BP energy statistics (2015).

gas pipelines is speeding up, and the West-to-East Pipelines II, III and IV the Shaanjing Gas Pipelines II and III, and the Eastward Pipeline of Sichuan Gas were put into production successively. At the end of 2014, the natural gas main pipelines that had been put into operation in China was 8.5×10^4 km long, and the pipelines in the principal gas zones were interconnected. Therefore, a framework of natural gas pipe networks running from the east to the west and from the south to the north, covering the whole country and connecting with overseas was basically set up. Over 20 underground gas storages (UGS) were built up, with gas peak shaving capacity 43×10^8 m³. UGSs are rebuilt in salt caverns and various gas reservoirs besides depleted condensate reservoirs. Therefore, the conflict between gas consumption and gas peak shaving capacity in winters are relieved effectively and the elasticity of natural gas supplying chains is increased [2].

By the end of 2014, over 70 LNG plants had been built up in China, with total productivity of about 2700×10^4 m³/d [3]. In 2006, the first LNG receiving terminal in China was put into production (Shenzhen Dapeng). By the end of 2014, 11 LNG receiving stations had been put into production in China, with total receiving capacity of 4080×10^4 t/a. Another 2000×10^4 t/a LNG productivity is in construction [4]. LNG has been one important way in China for strategic reserves, peak shaving and access to foreign natural gas resources.

1.5. The basic establishment of multi-element gas supplying framework with the fast promotion of natural gas importing

In 2006, LNG was firstly imported abroad. In 2010, central Asia pipeline gas was initially imported. In recent years, great progress has been realized in utilizing foreign natural gas resources. In order to ensure the safety of energy supply, the imported gas sources keep increasing in quantity and range. In 2014, the imported natural gas by China was totally 584×10^8 m³, including 271×10^8 m³ imported LNG and 313×10^8 m³ pipeline gas (Fig. 1). The gas is imported from 22 countries, and the ratio of imported gas dependency is

31.5%, so a multi-element gas supplying framework composed of multiple gas importing sources is formed with the domestic gas as the basis [5].

1.6. Fast increasing of natural gas consumption and its ratio to energy consumption rising significantly

In the past decade, natural gas consumption markets have been enlarging fast and natural gas consumption has been increasing quickly. By the year of 2014, natural gas markets had spread to 30 provinces/municipalities with consumption over 1800×10^8 m³. Within ten years, natural gas consumption rose by 3.5 times, with yearly average increasing rate of 16.3%, much higher than that of other energy consumption and GDP in the same period. China is now the third natural gas consumer in the world, with the ratio of China's natural gas consumption to global natural gas consumption rising to 5.5% in 2014 from 1.5% in 2004. Now, China becomes more influential on global natural gas markets.

With the fast increasing of natural gas consumption, natural gas consumption patterns have been optimized, with the percentage of city gas and power generation gas rising continuously and the percentage of chemical gas dropping greatly (Fig. 2).

The ratio of natural gas to primary energy consumption in China rose remarkably from 2.5% in 2004 to 6% in 2014, even over 10% in some areas, and 25% (the highest) in Beijing, which is higher than worldwide average value (Fig. 3). Natural gas is one of the important contributors to the “APEC blue” and “parade blue” in the area of Beijing.

2. Basic characteristics of China's natural gas industry under the new normal

When Chairman Xi Jinping did the survey in Henan Province on 10th May 2014, he said, “China's development is still at the important strategic opportunity stage, so we must strengthen our confidence to adapt to the new normal with the interim characteristics of China's current economic development as the beginning point, and keep normal attitude strategically.” At the end of 2014, Chairman Xi Jinping provided

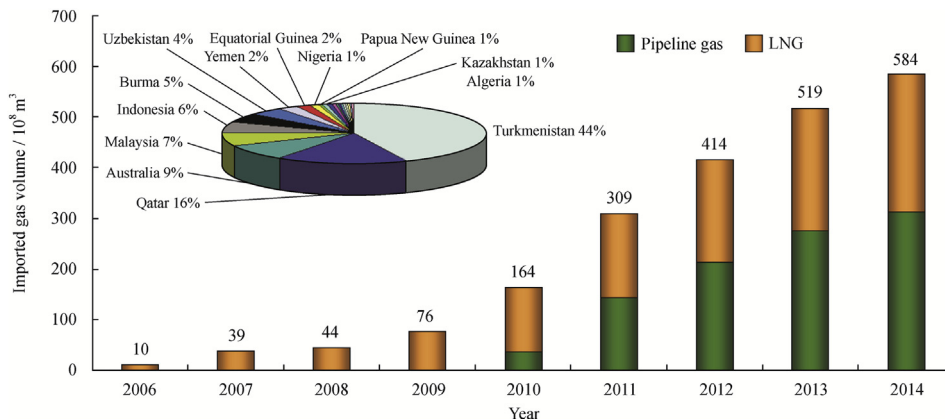


Fig. 1. China's natural gas importing quantity during 2006–2014.

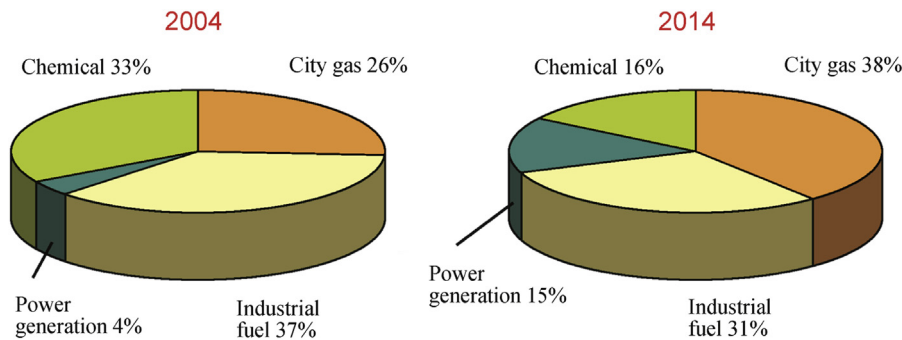


Fig. 2. Comparison of China's natural gas consumption mix in 2004 and 2014.

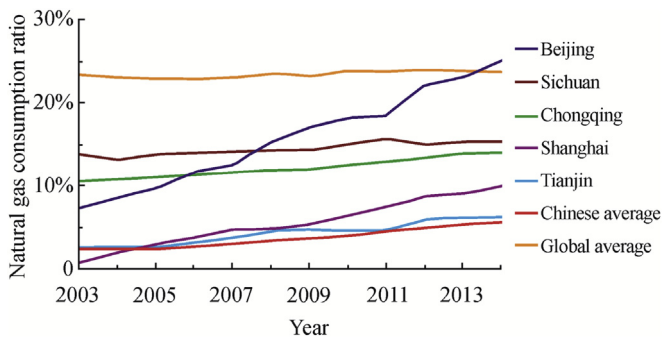


Fig. 3. The ratios of China's different areas and global natural gas consumption to primary energy consumption.

detailed analysis on the change trend of China's new economy normal in the Central Economic Work Conference. He emphasized, “Our economic growth has moved into the new normal, which is the inevitable reflection of interim characteristics of our economic development and is independent of man's will. Therefore, it is the major logic of our economic development at present and in the future to know, adapt and usher the new normal.” Based on this important judgment, the new normal is promoted to the national strategic level. China's economy is now under the new normal when economic growth converts from high rate to middle–high rate, economic patterns optimize continuously, and motivating force of economic growth converts to innovation from key elements and investment [6]. The intension of new normal has substantial effects on energy production and consumption, and even on the natural gas industry specifically. The basic characteristics are mainly as follows.

2.1. The increasing rates of natural gas production and consumption both tends to slow down, and its supply is sufficient to meet the demand

Based on the data issued by the Economic Operation Regulation Bureau of the National Development and Reform Commission (“NDRC”), national natural gas production in the first half of 2015 was $656 \times 10^8 \text{ m}^3$ with year-on-year increasing rate of 3.8%, and national natural gas consumption was $906 \times 10^8 \text{ m}^3$ with year-on-year increasing rate of

2.1% [7]. The increasing rates of production and consumption are obviously lower than the average increasing rate of the past decade and this trend will be lasting for several years.

Based on the analysis, the reasons for the slowdown of China's natural gas production are as follows. First, the major gas fields that were put into production before 2010 begin to decline successively. Second, the production of low-permeability – tight gas reservoirs declines fast, so it is necessary to discover new reserves of the same scale so as to guarantee the stable production of the gas fields. Thirdly, with the increasing of the cardinal number of natural gas production, the increasing rate will still drop even though the yearly incremental is the same. And from the view point of resource reserve, China's natural gas industry itself is now lack of strength after nearly ten years' fast development. And furthermore, the increasing rate of natural gas production is also restricted by the market slump.

The slowdown of increasing rate of natural gas consumption is mainly caused by the following two items. On one hand, macroeconomy trend is one influential factor. In the past decade, national economy grew fast, clean energy was popularized vigorously, and the increasing rate of natural gas consumption was always higher than that of national GDP (Fig. 4). With the slowdown of economic increasing rate in 2014, however, natural gas demand of traditional energy consuming industries dropped significantly. Therefore, the production capacity of the downstream factories is decreasing. In this way, chemical fuels and chemical gas consumption decrease, and the quantity of city gas and power generation gas rises but at a low rate. On the other hand, the price of product oil, fuel oil and liquefied petroleum oil and coal has dropped significantly due to the effect of continuous decreasing of crude oil price since the second half of 2014, so the price difference between natural gas and the alternative resources has narrowed (Fig. 5). Therefore, the economic predominance of natural gas is weakened significantly, and even the “reverse replacement” of gas to coal and oil occurs in some areas [8].

While the increasing rates of China's natural gas production and consumption are both slowing down, the following several years will be the window period of concentrated delivery of the long term take-or-pay contracts signed at the earlier stage. Therefore, the natural gas supply is quite sufficient in the short term [9].

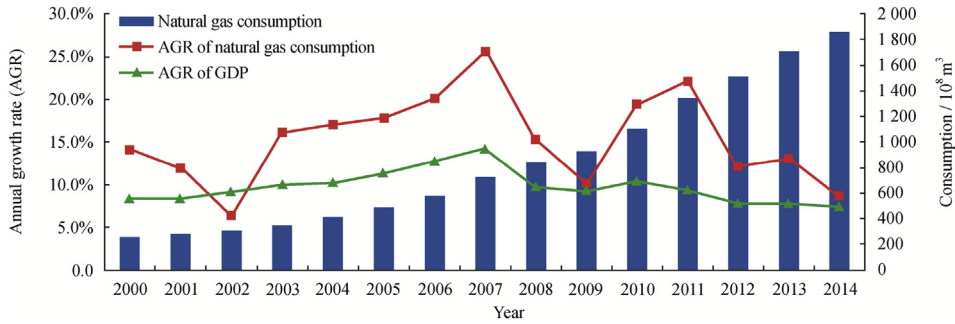


Fig. 4. Natural gas consumption and its increasing rate and GDP increasing rate in China.

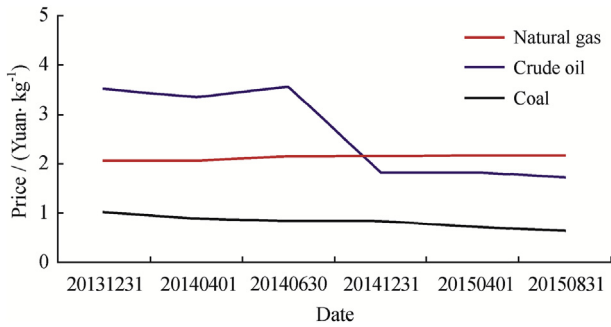


Fig. 5. Prices of natural gas, crude oil and coal in China from early in 2014 to the third quarter of 2015.

Note: 1. The prices of coal and natural gas are the actual prices in Guangzhou and the prices of crude oil is the Brent price. 2. China typically converts all its energy statistics into “metric tons of standard coal equivalent” (tce), a unit that bears little relation to the heating value of coals actually in use in China. One tce equal 29.31 GJ (low heat) equivalent to 31.52 GJ/tce (high heat).

2.2. It is difficult to change the tendency of resource deterioration, with the low-permeability tight, deep–extra deep and unconventional reservoirs as the major targets of exploration and development

In China, natural gas resource is abundant, and leap-forward development has been realized in the past decade. However, oil and gas bearing basins are complex in structures and geological conditions, and the newly discovered reserves get worse and worse in quality with the progress of exploration and development [10]. In recent years, the ratio of low-permeability tight sandstones, volcanic and low-permeability

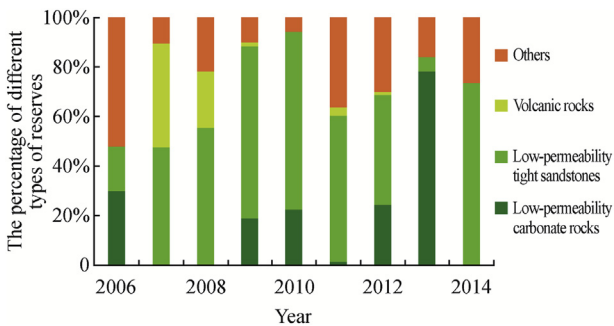


Fig. 6. The makeup of national proved natural gas reserves incremental during 2006–2014.

strong-heterogeneity carbonate gas reservoirs to newly discovered reserves in China is over three quarters (Fig. 6). In the future, exploration targets still focus on Ordos, Sichuan, Tarim and offshore basins and unconventional resources. It is possible to discover good-quality natural gas reservoirs that are similar to those of the Lower Cambrian Longwangmiao Formation, in the Sichuan Basin. Based on the whole distribution situations of remaining natural gas resources, however, the ratio of low-permeability, deep–extra deep and complex reservoirs is over 80%, so it is difficult to change the tendency of resource deterioration.

2.3. The decline of oil prices and the dropping of alternative energy price increase the pressure on gas price falling

After years' reform and adjustment of natural gas pricing mechanisms in China, the price of natural gas is currently pegged with that of imported fuel oil and LPG, so natural gas pricing is not completely dependent on government's policies, but related with supply-demand situations of energies. Based on the “Notice on Rationalizing the Price of Nonresident Domestic Natural Gas” which was issued by NDRC in February 2015, the maximum gas price at the city gate of gas incremental drops by 440 yuan/10³ m³ and that of gas inventory rises by 40 yuan/10³ m³. On April 1st, 2015, the price of gas inventory and gas incremental began to be unified. After the unification, the highest gas price at the city gate (2880 yuan/10³ m³) is in Shanghai and Guangdong, and the lowest (1850 yuan/10³ m³) is in Xinjiang. This price adjustment is based on the oil price of US\$90/bbl, but the oil price has been fluctuating at the low level, about US\$50/bbl since its significant drop in the second half of 2014. Based on the prediction of the global famous oil companies, such as Shell and BP, the trend of oil price in the future will not be optimistic. Due to the effect of low oil price, the price of alternative fuels drops continuously, and the pressure on the falling of natural gas price is immense in China.

It is definitely regulated in the “Energy Development Strategy and Agenda (2014–2020)” issued by General Office of the State Council in June 2014 that the competitive price shall be opened orderly and the wellhead and sale prices of natural gas shall be controlled by the markets. According to the “China's

Plan to Deal with Climate Change (2014–2020)” issued by NDRC in November 2014, natural gas consumption will be $3600 \times 10^8 \text{ m}^3$, with its ratio to primary energy consumption over 10% in 2020. The natural gas consumption markets are currently sluggish, so it is quite difficult to complete above mentioned targets. In order to stimulate the demand, therefore, it is imperative to accelerate the reform of natural gas price mechanism and decrease the price of natural gas.

2.4. Strict investment control and significant cost reduction are the normal measures to increase the benefits

In the past decade, the benefit of natural gas business chain has increased simultaneously with the continuous increasing of production scale and gas prices. In the future, the increasing rate of production will slow down and gas price is likely to drop, so the two major driving forces for the benefits of natural gas will be no more existed. With the increasing of resource deterioration trend, development cost will objectively higher and higher. And together with the continuous increasing of land acquisition cost, labor expense and HSE expense, the production and operation cost will increase rigidly. Therefore, investment control and cost reduction are two important measures to increase the benefits and they are generally used in oil companies. Since 2014, BP and Chevron have announced successively that they will cut down the capital outlay by 13% in 2015 so as to cope with the challenges of oil price dropping. It was reported by the related media that all major oil companies had already cut down their capital outlay by US\$180 billion to deal with the recent difficulties in oil industry [11]. In America, the number of the wells drilled in 2015 dropped to the same level of early 1990s. In the sluggish background of global oil industry, China's three major state-owned oil companies are also involved. The profit in the first half of 2015 decreased significantly, and the net profit of PetroChina, Sinopec and CNOOC experienced year-on-year decrease by 62.7%, 22.0% and 56.1% respectively. In the interim performance reports of the “Three Major Oil Companies”, the terms of “cost reduction and efficiency increase” and “Tapping new resources and reducing expenses” are frequently used [12]. And they are the main measures for increasing business levels of the companies for a certain period in the future.

3. China's natural gas exploration and development strategies under the new normal

The major revolution of global energy is jointly driven by the pressure of climate change and the development of new technologies in the field of energies, so main melody of energy revolution is “more clean energies and less carbon dioxide”. There is sufficient natural gas resource on the earth. As the cleanest fossil energy, natural gas is the most practical resource for improving environment and impelling economically sustainable development in the world. In order to deal with air pollution and smog in China, the optimal choice is to increase natural gas consumption ratio. In China, the rate of natural gas development and utilization slows down now under

the effect of multiple factors, but it is only the adjustment period after ten years' high-speed development. It is indicated from the current requirements of energy structure optimization, energy conservation and emission reduction, air pollution treatment and beautiful China construction that the fundamentals of natural gas great development in China are still remained the same. The strategy of “One Belt and One Road” provides broad space and opportunities for the development of natural gas industry. And it is predicted that another round of faster development will occur after 2020 [13–21]. At present, the key point is to be confident, behave actively and keep the concept of “lay the foundation, contribute to the future and attribute the success to the collectives” in mind, so as to do preparation for the new round of faster development of China's natural gas industry. Some suggestions are proposed for China's natural gas exploration and development strategies under the new normal.

3.1. Strengthen exploration, ensure working load and investment in position and tamp development basis continuously

Reserve is the essential basis for the existence and development of natural gas industry. In China, natural gas resource is sufficient in quantity, but its exploration degree is lower with the ratio of proved conventional natural gas resource less than 20% and the ratio of proved coalbed methane resource 1.7%. Besides, shale gas resource evaluation is still at the beginning stage. Therefore, there is great increasing space of natural gas reserves in China. It is shown from the statistics of the worldwide basins with higher exploration degree that the oil and gas resources all have the potential of fast reserves increasing before their proved ratio reaches 60%. In recent years, some major gas fields have been discovered and proved successively in Sichuan Basin after nearly 70 years' exploration, which demonstrates this rule. The increase of reserves is positively correlated with the input of working load and capital [22], so the only way to guarantee continuous increase of proved natural gas reserves is to increase exploration working load and capital input. Therefore, the state shall pay much attention to natural gas exploration input. Especially in the period with low oil price and deficient enterprise fund, the state shall provide financial and political supports and advocate scientifically exploration adventures by setting up national natural gas risk exploration funds, so as to develop new areas and fields and search for strategic replacement areas. The enterprises shall strengthen geologic research and guarantee effective input, so as to increase exploration success ratio, search for good-quality scale reserves, reduce oil and gas discovery cost and realize good-quality beneficial development. Based on the joint emphasis of the state and the enterprises, exploration working load and investment will be guaranteed, the proved reserves will be increased continuously and domestic natural gas production will rise fast, so that the basis for natural gas supply in China will be tamped and natural gas industry will be developed sustainably.

3.2. Pay much attention to pre-development evaluation and emphasize program arrangement and design and control productivity construction rhythm

Earlier evaluation is very important for the implementation of productivity construction, scientific development of gas fields and reduction of risks. In its Changbei cooperative project in the Ordos Basin, Shell spent two years completing one appraisal well with much time on reservoir, development technologies and economy evaluation, and realized good achievements. In recent ten years, domestic natural gas markets have been encountering the pressure of demand exceeding supply and peak shaving, so in some gas fields, the evaluation periods are short, and even productivity construction is performed while evaluation is conducted. In this way, the cognitions on gas reservoirs are limited, so the design capacity is higher than real, and the surface construction does not match the gas field capacity. And finally, the development effects of gas fields are influenced and the investment is wasted. In the new situations, it is necessary to grasp the favorable opportunities of economy slowdown, imported gas increase and market demand pressure alleviation to strengthen earlier evaluation on gas fields, deepen geologic and development performance cognitions on gas reservoirs, ascertain producible reserves, confirm major development technologies, demonstrate single-well allocation, development scale and arrangement, reinforce economic evaluation and work out development plan scientifically, so as to provide the firm basis for high-efficiency development of gas fields. In the meantime, it is necessary to control productivity construction rhythm with market demand as the fundamental basis, so as not only to guarantee market supply, but also to avoid idle productivity. Based on project optimization, oil companies can realize optimal capital allocation and maximum benefits under the conditions with low oil prices.

3.3. Pay attention to the top design for the development and adjustment of developed gas fields, emphasize fine description and management, and improve overall development level

Old gas fields contribute great to short–middle term natural gas production, so their development effects have direct effect on the realization of production targets. During the fast development in recent ten years, the production in some gas fields was once influenced by the requirements of peak shaving. The cognitions on geologic conditions which were obtained during the program design are not the same as the actual situations, so the program design is inconsistent with the actual flow rate section and it can hardly be used to instruct the later production arrangement. The top design for development and adjustment of old gas fields shall planned as a whole. Firstly, strengthen dynamic tracing and analysis and carry out production scientifically. Complete the monitoring system of gas field development behaviors, analyze

production performance characteristics of gas reservoirs periodically, understand development rules of gas fields, predict development tendency of gas fields, verify gas well deliverability and conduct production allocation rationally, so as to restrain the composite decline. Secondly, carry out fine gas reservoir description on old gas fields and analyze their development potentials. Based on fine description of structures and reservoirs, study interwell, interlayer and interblock communication relationship and reserve producing degree, rebuild geologic models, reestablish underground cognitions, understand distribution characteristics of remaining reserves in the gas reservoirs, perform productivity analysis and propose adjustment and potential tapping measures. Thirdly, deepen geologic cognitions in the periphery of gas reservoirs and carry out rolling and expanding exploitation and supplement productivity feasibility study and measure tests. And fourthly, prepare development adjustment program, optimize adjustment development arrangement and alleviate composite production decline as much as possible so as to improve the overall development level of gas fields.

3.4. Strengthen exploration and development technologies research, emphasize technical simplification and practicability and reduce the cost effectively

Science and technology constitute a primary productive force. When the tendency of resource deterioration is hard to be changed essentially, technical innovation is the only way to reduce cost and develop and utilize the resources effectively in large scales. Therefore, technical innovation shall be continued, and even be strengthened with technical simplification and practicability as the core, and the following key technologies shall be developed successively. First, reservoir fine description, 3D geologic modeling, optimization design of horizontal-well development, reservoir stimulation, low-cost drilling technologies, and ground process simplification and optimization technologies for poor quality complex gas reservoirs. Second, quantitative reservoir characterization technologies of fractured gas reservoirs, multi-phase seepage theories of complex gas reservoir and gas reservoir engineering methods of structurally complex wells. Third, fast well drilling and completion technologies for deep–extra deep and deep water, and single-well stimulation technologies (i.e. horizontal-well staged fracturing and large-scale acid fracturing). And fourth, producible resource evaluation technologies, key engineering technologies and equipment localization of unconventional natural gas. Finally, a series of low-cost development technologies are developed after technologies and process are optimized and the adverse factors (e.g. construction problems, long period, high cost, etc.) are removed. And moreover, much attention shall be paid to energy storage technologies and information oriented technologies with energy internet as the representative and their effects on natural gas industry shall be studies in advance.

3.5. Summarize experience and lessons on ten years' fast development, emphasize demonstration and design of key indicators and strengthen progressive planning study

After the past decade's fast development, China's natural gas industry has obtained great achievements. And now, as one of the major natural gas production and consumption countries in the world, its effect and position in global natural gas markets becomes more and more important. Ten years' exploration and development experienced success and failure. In the new situations, it plays an instructive role for the future exploration and development to summarize the experience and lessons on ten years' fast development. First, sort out the cases of ten years' fast development of natural gas industry and select the typical ones which will be analyzed deeply in terms of experience or lessons for reference or warning. Second, summarize the variation rules of key indicator (e.g. reserves, production, investment and cost) of different types of gas fields, evaluate the adaptability of exploration and development technologies of different types of gas reservoirs, and propose the direction and targets of technical innovation. Third, summarize and analyze the performance of planning index and the issues during the operation, so as to make decision procedures and key index determining methods more rational. And finally, combined with external macrosituations, emphasize demonstration and design of key indicators of natural gas exploration and development, strengthen progressive planning study, improve the flexibility and performability of planning programs, so as to instruct faster and healthy development of China's natural gas industry in the long term.

Fund project

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