Policy Study: Gas-fired Power Generation in China

(Synthesis Report)

Preface

Natural gas is important primary energy for China to secure a high-quality and diversified energy supply. With the economy in the middle of industrialization and the people's living standards constantly rising, China's overall energy demand is growing rapidly, putting ever greater pressure on its coal-dominated energy supply. When the room is limited for large-scale development of hydro, nuclear and renewable energy and the import dependency of petroleum is getting higher than ever, speeding up the development of natural gas will provide an important substitute and supplement for coal and oil. Given the overall energy structure of China, it is imperative to set up a natural gas market of a considerable scale, which is more urgent in the relatively more developed regions along the southern and eastern coastlines.

Experiences of natural gas market development in many developing countries have shown that the success of the whole project hinges upon that of gas-fired power generation. At present, China's natural gas development is in the initial stage, when gas-fired power generation serves as a pillar for large pipeline and LNG projects. In LNG projects of China's Guangdong Province, over 50% of the gas is used in power generation, and the figure in Fujian Province is as high as over 80%. However, under the current energy pricing system in China, the advantages of gas-fired power plants in low investment costs and high efficiency have not been able to offset the price edge of coal. CCGT is less competitive to coal-fired power generation, as gas-fired power plants have to, on the one hand, abide by the Power Sector Reform measures and upload electricity to the grid at competitive prices, and on the other hand, follow the international practice of take-or-pay in gas purchase. Both at the downstream of the natural gas industry and upstream of the power sector, these gas-fired power plants are faced with a dilemma.

A total of nearly 18 GW of installed capacity will be realized in the gas-fired power-generation projects under construction or will be carried out in China in the near future, of which the West-East Pipeline (WEP) in East China and offshore natural gas power projects take up about 10.50 GW, Fujian LNG project (FJLNG) 3.60 GW, and Guangdong LNG project (GDLNG) 3.85 GW. By the year 2020, the total installed capacity of natural gas in China will be about 60 GW. According to the overall requirements of the Power Sector Reform, all power generation projects, hydro and nuclear ones included, will have to compete in the future electricity market. Therefore, it is necessary to identify the position of gas-fired power generation in the national energy strategy and direction of its development and formulate clear policy measures, in order to solve the problems facing gas-fired power projects and provide policy guidance for future development of such projects.

Under such circumstances, the Energy Research Institute of National Development and Reform Commission (ERI/NDRC) and State Power Economic Research Center of State Grid Corporation of China (State Grid) jointly formed the research team on the subject of policy analysis for China's gas-fired power generation. Over a year, two international seminars have been convened on China's policy for gas-fired power generation. The team members have been to Shanghai, Zhejiang, Guangdong, Jiangsu and Fujian for survey and studies and held 13 meetings to solicit views from development and reform commissions of relevant provinces and cities, local grid companies, gas-fired power plants and energy group companies, etc. Many expert sessions have been held after the completion of the first draft of the Synthesis Report titled *Policy Study: Gas-fired Power Generation in China*, to solicit expert opinions from NDRC, State Electricity Regulatory Commission, development and reform commissions of Shanghai, Zhejiang, Guangdong, Jiangsu and Fujian, etc. A final draft has come out after many revisions. This report seeks to make comprehensive and well-structured studies on China's policy on gas-fired power generation and provide practical policy suggestions for government's reference in decision-making.

I. Importance of Developing Natural Gas Industry in China

Natural gas, a high-quality, efficient and clean energy source and material for chemical industry, plays an important role in optimizing the energy mix, protecting the atmospheric environment, easing the strained petroleum supply, improving energy utilization rate, promoting modernization of industries and commerce, and realizing the sustainable development of the national economy.

In recent years, the energy dependency of China's economic growth has increased considerably. The energy consumption elasticity was only 0.47 in 1980~2000, but it reached 1.19 in 2002, 1.42 in 2003 and 1.60 in 2004 respectively.

At present, natural gas only takes up 2.7% in China's primary energy consumption mix, far lower than the world average of 24% and the average level in Asia, which is 8.8%. Natural gas demand will grow at a greater speed than that of coal and oil in the decade to come, thanks to the gradual improvement of natural gas infrastructure and market development in China. It is estimated that natural gas demand will be 100 billion cubic meters (bcm) in 2010, 150 bcm in 2015, and 200 bcm in 2020. The share of natural gas in primary energy consumption will reach 6% in 2010 and around 9% in 2020.

1. Importance of Developing Natural Gas Industry in China from the Energy Supply Perspective

China's energy demand is rising sharply, putting ever greater pressure on the coal-dominated energy supply. With limited production capacity in coal and ever greater import dependency in petroleum, it is imperative to speed up the development of natural gas industry.

(1) China's coal production capacity cannot grow at the same pace with future economic growth, due to various constraints.

Though China is rich in coal resources, there are many obstacles in securing a clean, safe and economical coal supply. For example, most of the coal-rich areas have fragile eco-environment; coal and water resources are not located in a complementary manner; coal resources are usually stored in conditions not suitable for large and extra-large mining equipment; many safety hazards exist in the coal mines, where the working environment also tends to be bad; coal mining has seriously damaged the already tight supply of land resources; the coal-rich places are not the economically-developed areas and the bottleneck in long-distance transportation will exist for a long time; and high-sulfur coal is of a great percentage in the coal reserves and poses difficulties in the mining and use. According to some analysts, while ensuring the production safety and economic viability, the ceilings for China's coal development and production are both around 2.4 billion tons. In 2004, China's coal production was 1.96 billon tons and the 2005 production was already 2.11 billion tons, quickly approaching the production ceiling.

(2) In recent years, China's oil consumption grows rapidly and its import dependency gets higher and higher. Oil supply security has become an important matter for national economic security.

In the period between 1985 and 2004, Europe's oil consumption rose from 662 million tons to 771 million tons, an increase of 16.5 %; North America's oil consumption grew by 32.2% from 849 million tons to 1,122 million tons. Meanwhile, the oil consumption of the Asia-Pacific jumped from 499 million tons to 1,090 million tons, registering a growth of 118.4%. In this region, China has seen the fastest growth in oil consumption, a 249% increase from 91.688 million tons to 320 million tons. Ever since China became a net importer of oil in 1993, its net crude oil import increased from 2.2876 million tons to 117.32 million tons in 2004, growing by 14.38 million tons or 63.6% every year. Its crude oil import dependency has kept rising, reaching 40.2% in 2004, and is estimated to top 60% by 2020. The international oil price continues to climb and has reached US$ 70/barrel. The pressures and costs on China's oil supply are more and more rising, putting into spotlight the bottleneck effect of oil supply.

(3) Hydro, nuclear and renewable energy will have a limited contribution to satisfying new energy demands.

Though China's nuclear power is picking up speed, it can only reach an installed capacity of 40 GW in 2020, due to constraints in raw material, technology, costs and site selection. By that time, the installed capacity of hydro power will be 300 GW, with 60% of the technically developable and 75% of the economically viable resources already developed. In another word, most of the hydro power resources will be used up by that time. Also in 2020, installed capacity of the renewables (mainly wind, bio-mass, geothermal, solar and tidal power) will exceed 62 GW, or 6% of the total energy mix.

In all the primary energy sources, coal, oil and renewable energy are constrained to various degrees, and natural gas is the main energy source for China to secure a high-quality, clean and diversified energy supply. Speeding up the development of China's natural gas industry will serve as an important substitute and supplement to coal and oil and will be essential in achieving high-quality growth of the economy.

2. Importance of Natural Gas in Optimizing China's Energy Mix

(1) Compared with other countries, China's high-quality energy is too little in its energy mix. Increasing natural gas' share in the primary energy is the main approach to an optimized energy mix.

In China' energy consumption mix, coal takes up too big a share, shadowing oil, gas and other sources. Oil and gas play an important role in the economic activities of developed countries. Their oil consumption percentage was 40%~68% in early 1980s and 40%~50% in 2000, and it is estimated to remain at 40%~48% by the year 2020. Their natural gas consumption was 19% in early 1980s and 22% in 2000, and will approach 28% in 2020. For developing countries, the shares of oil and natural gas in primary energy was 45% and 9% respectively in 1980, 42% and 16% in 2000, and will reach 42% and 28% in 2020. China's oil and gas consumption was lower than the world average by nearly 20 percentage points.

Coal takes up nearly 70% of China's energy mix. There's hardly any other country that can rely on one energy source for so long. Optimizing the energy mix and increasing the share of high-quality energy is essential to China's march towards a moderately prosperous society. And increasing the share of natural gas is a strategic choice for this optimization.

(2) It is more urgent for the economically developed coastal regions in China to optimize the energy mix, and natural gas is of unique importance to the economic development of these regions.

East China and South China regions, located on the southeast coastlines or at the mid and lower reaches of the Yangtze or Pearl rivers, are economically more developed in China and serve as a window for its opening-up policy. In recent years, fast economic growth has caused a sharp increase in energy demand and power shortages. It is more and more difficult to increase power supply in these regions due to the following constraints: first, the shortage in coal transportation capacity; second, difficulties in obtaining land for coal-fired power plants; and third, limited environmental bearing capacity. In some places, it is explicitly forbidden to build new coal-fired power plants. Therefore, gas-fired power plants can enjoy better conditions and meet more urgent needs in the coastal areas.

3. Importance of Developing Natural Gas Industry in China from the Perspective of Environment Bearing Capacity and Environmental Protection

Coal burning has caused serious environmental problems in China and the use of natural gas can reduce the pressure on the environment.

In 2003, China's total SO_2 emission was 21.59 million tons, 12.0% more than that of the previous year. Of the total, 83.0% or 17.92 million tons were emitted by industries, rising 14.7% year-on-year. Of all the industrial emission, 46.1% or 8.26 million tons were from thermal power plants, growing by 24% over the emission of 2002. From a sector point of view, top five in the SO_2 emission in 2003 were: power industry, non-metal mineral products; chemical industry, ferrous metallurgy and non-ferrous metallurgy. Together the five industries emitted 13.89 million tons of SO_2, or 85.0% of the total of key enterprises in the statistics. And the power industry had an SO_2 emission intensity of 0.218 ton/ RMB10,000, 4～18 times higher than the other four. The SO_2 emission of the power industry will rise year by year with further development of coal-fired power plants in China. Talking about the environmental pressure resulted from coal-burning, coal-fired power generation is the largest contributor. Efforts must be stepped up in the power sector to have a clean energy supply.

Compared with coal-fired generation, gas-fired generation has obvious environmental advantages: SO_2 emission basically removed, CO_2 cut by nearly 1/3 and NO_x reduced by 95%.

Table 1 shows the comparison of SO_2 emission intensities of different power generation types.

With SO_2 emission in Shanghai, Jiangsu, Zhejiang, Guangdong and Fujian exceeding the national control targets, natural gas has become the first choice for power generation there.

Table 1 SO_2 Emission Intensities of Different Power Generation Types

Type	**Gas-fired**	**Coal-fired without Desulphurization**	**Heavy Fuel Oil**	**Coal-fired with Desulphurization**
SO_2 mission （g/kWh）	0~0.25	5~11	11	0.4~1

Besides, used as automobile fuel, natural gas is free of the cancer-causing substances like lead, benzene and aromatic hydrocarbon and low in CO and CO_2 emissions (only 3%-10% of that of fuel oil). In residential use, 10 bcm of natural gas can replace 30 million tons of coal and reduce the emission of SO_2 by 360,000 tons and dust by 30,000 tons. Therefore, the use of natural gas can greatly improve the environment of a city or region. By replacing coal and oil with natural gas in industrial and commercial fields can also promote their modernization and further improve the productivity and service quality.

4. Urgency in Developing China’s Natural Gas Industry from the Perspective of World Natural Gas Market Trends

A close look at world oil and gas reserves, market trends and prices shows that natural gas is of great appeal.

The total gas reserve in the world is 158.2 billion tons of oil equivalent, higher than that of oil, which is 156.7 billion tons. In terms of reserves allocation, natural gas reserve is nearly 4 times of that of oil in Europe and Eurasian Continent, and nearly 2 times in the Asia-Pacific. Under the current oil and gas exploration levels, oil reserve will last 41 years and natural gas, 67 years. It is evident that natural gas enjoys a greater potential of reserve increase and better resource backup.

Although gas prices are also subject to international supply and demand, it is less volatile than oil. For the same heat value, natural gas (LNG included) has a price edge over oil. The environmental advantages, lower investment costs and flexibility in use have made natural gas a preferred choice in many countries and regions.

Liquefied natural gas (LNG), a newcomer in world natural gas market, shows a strong growth momentum despite its relatively small share. With continuous improvement in liquefaction, transport and re-gasification technologies and overall cost reduction in LNG, many countries and regions have chosen LNG as an effective means to enhance their domestic energy supply. Many emerging economies in the Asia-Pacific, in particular, have regarded LNG as the energy for sustainable development in the 21st century. The world's annual LNG trading volume is 82 million tons, and is estimated to jump to 112-116 million tons by 2010, with China, India and Korea showing even greater increase in this respect.

In terms of oil replacement, increasing LNG/natural gas import is not only of great strategic importance, but also very economical. Even with the recent hike in LNG price, its economical advantage against crude oil is still obvious. Table 2 is a comparison of crude oil and LNG prices summarized from some LNG import deals in Korea and India. When the crude oil price was US$ 40/barrel (US$ 6.89/MMBtu), the average price of LNG was US$ 3.7 /MMBtu, or 54% of the oil price; and when the oil price was US$ 60/barrel, the average LNG price was its 33%. China's domestic oil resources are limited and oil imports rise year by year. Importing LNG can replace some crude oil import and ease the pressure.

Table 2 Current LNG Import Price in Korea and India Compared with Crude Oil Price

Crude Oil Price (US$/barrel)	Crude Oil (US$/MMBtu)	LNG (US$/MMBtu)
20	3.45	1.9
25	4.3	2.3
30	5.17	2.8
40	6.89	3.7
50	8.62	4.0
60	10.34	4.2

5. A better domestic policy environment is needed when there is increasingly fierce competition in international LNG market.

Recent deals in international LNG market reveal that Japan, Korea, the US and India, an emerging LNG consumer, are very active in securing LNG contracts, resulting in a fight for resources in the LNG market. The two biggest LNG importers in the world, Japan and Korea, now face the maturity of their long-term LNG supply contracts signed in 1970s and 1980s, which need to be renewed or replaced. As they both have strong purchasing power that can tolerate high prices and decades-old and developed LNG markets at home, Japan and Korea have become the markets of choice for LNG suppliers. It can be seen from the recent change of Chevron's Gorgon LNG project from supplying China's Zhejiang to signing contract with Japan.

The development of European and American natural gas markets has also, to a large degree, aggravated the LNG resource competition in the Asia-Pacific. European countries have long been committed to a multi-source gas supply, so as to reduce dependency on Russia. The Russia-Ukraine gas dispute in early 2006 further strengthened EU's resolve to reduce dependency on Russian gas through LNG supply. The US is the largest natural gas market in the world. But it also looks to LNG import for solutions as its domestic production and Canada import lack the room for further growth. According to the US Energy Department, its LNG import will reach 47 million tons (65 bcm) in 2010. LNG import will take up 10% of the US natural gas use in 2010, instead of less than 3% in 2004. By 2020, LNG import will meet 18% of the US gas demand. The US now has 7 LNG receiving terminals, which will be expanded to have an import capacity of over 30.2 bcm. More LNG vessels will arrive on the American coast from the Asia-Pacific and the Middle East.

India, though not as good as China in overall market environment, has learnt the lesson of Dabhol LNG project (which was stranded since 1996 due to problems in LNG power generation), and formulated clear rules of game for other projects in the country. Now India runs two LNG terminals successfully.

In terms of overall international market conditions, the best historical opportunities for developing LNG market like in 1998-2003 will never come by again. Under the new market conditions, China should make timely decisions on LNG import on the basis of analysis of long and mid-term gas supply and demand. It should adopt proactive and flexible countermeasures in LNG contract negotiation and try to secure more LNG resources to optimize its energy mix. Meanwhile, China should create a better policy environment for LNG development at home and reduce policy risks to the extent possible, to make up for the risks of a not-so-mature market.

II. Importance of Gas-fired Power Generation to Natural Gas Industry and Power Industry Development

1. Important Support Role of Gas-fired Power Generation to Natural Gas Industry Development

There were two ways for early developments of natural gas in other countries:

First is a gradual approach with focus on residential and commercial uses, such as those of North America and developed European countries, where the residential and commercial uses took up 37.5% and 45.5% in their early gas consumption mix. At that time, these countries and regions had complete pipeline networks for city gas (coal gas), large natural gas reserves, low development costs and closeness between production base and market, thus enjoying rapid development in natural gas use. Since gas-fired power generation technology had not been transferred from military to civilian use at that time, and these countries implemented, in the aftermath of the first Oil Crisis, an energy policy of limiting the use of natural gas in industrial fields, gas-fired power generation did not play a big role in the initial stage of natural gas market development there.

The other approach is of leap-frog development focusing on developing large industrial users (mainly power generation). The use of natural gas jumped to a new level with the completion of each gas-fired power generation project. This model is represented by Japan and Korea. All LNG imports to Korea were used for power generation in the early stage, and on this basis, gas transmission trunk-lines were built in steps and phases, to introduce natural gas to big cities like Seoul. The development of residential gas use has in turn speeded up the development of natural gas market. In today's world, new gas pipelines usually take a large end-user as the starting point, on which the market can be set up and gradually expanded. In developing countries in Africa and South America, 30% or even over 40% of the natural gas is used for power generation. Gas-fired power generation projects have played a pillar role in the natural gas development of these countries.

China is in the initial stage of natural gas market development. Major provinces and cities like Shanghai, Guangdong, Zhejiang, Jiangsu and Fujian are in dire need of natural gas supply. However, due to the lack a complete natural gas pipeline network and slow progress in city gas network expansion and replacement, many cities cannot eat up the designed gas volume of large gas projects (LNG projects in particular). Therefore, the development of natural gas market in these areas should be based on large industrial users (such as gas-fired power generation). Then the urban pipeline network will be gradually formed and gas consumption in the city increased on this basis. This is the way to speed up the natural gas market development.

In the long run, no matter domestic pipeline gas, or imported LNG or pipeline gas, should be used as city gas and high-value-added industrial gas, especially in cities and regions dependent on imported gas. Moreover, to ensure safety and continuity of natural gas supply, major cities need multiple gas sources. Normally, the surplus in gas supply will be used for power generation, and when the supply is tight, the gas will be used as city gas. In this way, with further improvement of urban pipeline network in the future, gas-fired power generation can help to adjust city gas supply, especially for big cities. Of course, it needs the coordination between the gas supply contract and the electricity sales contract of the gas-fired power plant.

In summary, when the Chinese natural gas market is not mature, developing gas-fired power plants of a considerable scale is important to ensure success of large pipeline projects (WEP and imported Russian gas, etc.). WEP will have an annual gas supply of about 12 bcm, of which 50% is planned for power generation. Large and stable in gas consumption, gas-fired power plants are most important customers for launching and supporting the natural gas market and ensure the economic viability and feasibility of gas transmission projects. When city gas is more widely used, the newly-added natural gas supply will be used more as city gas. And whereas allowed by the long-term gas supply contracts, existing gas-fired power plants may also play a greater peak-shaving role for city gas. Gas-fired power plants need to find a balance between grid peak-shaving and city-gas peak-shaving, which requires a special arrangement in gas supply price for these power plants.

2. Importance of Gas-fired Power Generation to Improving China's Power Supply Structure and Power Grid Safety

At present, China relies on coal as the main primary energy for power generation. Hydro power takes up a certain share and nuclear power generation is still in the initial stage. It is not feasible to have large-scale power generation by wind, solar and other renewable energy. Moderately developing gas-fired power generation is in the interest of optimizing and adjusting the energy mix for power generation and gradually realizing its diversification.

With rapid economic development and rising living standards, each power grid has seen the trend of widening gap between the peak and the valley and the decreasing load factor. In order to ensure safety and stable operation of the system and meet peak-shaving needs, the grids need some flexible power plants with good peak-shaving abilities. Gas-fired units characterized by quick start and flexible operation are a good choice for it. Nonetheless, the gas-fired power plants must be set up in line with local conditions, and CCGT should not be applied where it is not suitable. Even when CCGT is chosen for some plants, no uniform requirement of operating timeframe or annual operating hour should be adopted for all.

In terms of optimization, given the current natural gas prices, SCGT units enjoy certain advantages in different power grids. SCGT usually operates at the peak positions in the system, with several hundred hours of annual use. CCGT gas-fired power plants are not competitive against coal-fired power plants. Constrained by the energy mix, load features and supply & demand of specific grids, CCGT power plants are not fixed in their operating positions.

In thermal-centered grids, the system needs flexible sources for peak-shaving. Gas-fired power is more flexible but more expensive than coal-fired, so it is suitable for the peak position. If the grid also has considerable hydro power or capacity to accept large amount of hydro power from outside, then in high-water periods, hydro power can operate at base-load position and gas-fired power will do the peak-shaving; and in low-water periods, gas-fired power can move downward in position and take up the mid-load as well as the peak-load.

In hydro-rich power grids, it is relatively difficult to analyze the operating position of gas-fired power. In general, hydro power operates at base-load in high-water periods and gas-fired can replace coal-fired power to adjust the peak, thus enhancing peak-shaving capacity of the grid and reducing power waste in water discharge. In low-water periods, coal-fired power plants operate at base-load, hydro power adjusts the peak, and gas-fired power serves as backup or operates at mid-load.

Different power demand & supply scenarios also have a major impact on the operating position of gas-fired power plants. When the supply is ample, gas-fired power is less competitive due to higher price and usually operates as the backup or for very limited hours on the grid. But when the supply is tight, gas-fired power, with its technical advantage of flexibility, can do the peak-shaving for the grid or operates at mid-load position.

Flexible and efficient, gas-fired units are an effective means to improve the quality of grid operation. Besides, in major cities and their surrounding areas, where the construction of traditional power projects is strictly limited due to environmental concerns and urban land-use regulations, gas-fired power plants can be built close to the load centers, as they require far less land, water and other conditions and produce far less pollution. It also reduces the pressure on grid transmission and grid construction, and improves stability of the grid operation.

Gas-fired power generation can also, directly or indirectly, drive the application and development of gas turbine, shipbuilding and clean coal technology (CCT) in China. If gas-fired power generation is applied in scale, it will help the independent R&D on and localized production of gas turbines; and with more imported LNG, the localized manufacturing of LNG vessels will also be promoted. Indirectly, gas-fired power generation will drive the development of the CCT.

3. Unique Features of Gas-fired Power Generation

The fundamental differences between large natural gas projects and other large energy projects are: natural gas projects require huge initial investments; the product cannot be cheaply stored in large amount; and there are no customers at the end of the value chain who have to use the product. Therefore, in the initial stage of the natural gas market, especially when the downstream market is immature and cheap alternative energy is available in large quantity, it is necessary to consolidate mutual commitment at every link of the value chain with strict take-or-pay contracts, in order to ward off risks and provide confidence for the huge investments thereon.

In terms of value chains of different energy industries, gas-fired power plants are a link in the LNG value chain, a chain that is rather rigid and requires large investments. This value chain is connected and guaranteed by long-term business contracts at every link. In contrast, other power plants need neither long-term take-or-pay contracts for the fuel, nor huge investments.

Gas-fired power plants are essential to the whole LNG project, but they are not the end of the LNG value chain. To be able to honor its commitment in the take-or-pay fuel contract, a plant must ensure enough power uploaded to the grid in every year of the fuel contract. So it must sign long-term power purchase agreements (PPA) with grid companies. The key here is matching the PPA with the take-or-pay contract. The take-or-pay contract signed by a power plant is valid for 25 years. For each year there is a minimum take-or-pay gas consumption requirement, and for each month, week and day, there are strict regulations on gas consumption (which need to be reflected in the parallel operation agreement of the power plants). The power plant pays the gas supplier once every two weeks, for LNG cost, LNG transport and pipeline transmission. The unit prices of these three charges are fluctuating in a certain range according some indexes (such as oil price in the international market). Then the PPA between the power plant and the grid company needs to include the following as well:

(1) 25-year take-or-pay power purchase agreements;

(2) Minimum annual power purchase-sell quantity matching that of the minimum gas consumption quantity pledged by the power plant.

III International experiences on gas-fired power generation

1. Gas-fired power generation in the world: at present and in the future

The world electricity demand and electricity production have been increasing continuously. The annual growth rate of electricity production was 2.63% during 1990-2003. According to Energy Information Agency (EIA) of United States, the world electricity demand would reach, with an annual growth rate of 2.3%, to 23072TWh in 2025 from 13290TWh in 2001, while the growth rate in the developing countries would be 3.5%. Natural gas-fired power generation has been boosted since 1990s. Gas power generation grew by 6.9% annually from 1970 to 2001 and the share of gas power generation rose from 12.1% in 1973 to 19.1% in 2002. Following the same trend in the next 20 years, the world gas power generation in 2025 will double the volume of 2001 and gas consumption for power generation will increase by 3.3% (see Table 3), according to EIA. The International Energy Agency (IEA) has projected that world natural gas consumption will reach to 4900bcm in 2030 from 2600bcm in 2002, in which gas consumption for power generation shares 59%, increasing by 2.3% annually.

The rapid growth of gas-fired power generation is mainly attributed to the additional proven reserve of natural gas, the advance of gas turbine and combined cycle technology and more severe environmental legislation. The worldwide liberalization of electricity markets since 1990s has offered opportunities for gas-fired power producers. Relatively small-scale Independent Power Producers (IPPs) are able to enter the electricity markets. Gas-fired power plant has been the favorite choice of IPPs due to its low investment costs, short construction time, high efficiency and environmental advantages.

Table 3 World outlook of energy for power generation (unit：10^{15} Btu）

	2001	2010	2015	2020	2025	annual growth rate 2001-2025，%
coal	61.1	73.0	79.5	86.9	96.7	1.9
natural gas	29.6	37.7	44.9	54.1	65.2	3.3
nuclear power	26.2	29.8	31.4	31.8	30.4	0.6
oil	12.2	14.5	15.5	16.7	17.0	1.4
renewable energy	31.5	38.6	42.5	45.9	49.4	1.9
total	160.5	193.6	213.9	235.5	258.6	2.0

The gas industry, electricity industry and gas-fired power generation in the world have been at a turning point. The increase of gas demand is mainly driven by power generation. The international gas market turns to a seller’s market and the gas price and its fluctuation have kept going up linking with oil price. Meanwhile, the introduction of competition into electricity market has resulted in lower electricity price and higher fluctuation of electricity price. Therefore, although the increase trend of gas-fired power generation is shared commonly, this prospect is uncertain along with the following impact factors: 1) high natural gas price and fluctuation, competition with other fuels, especially with coal; 2) CO_2 price and emission trading. The EU Emission Trading Scheme went into effect in January 2005 followed by many uncertainties in its implementation, such as allocations and CO_2 trading price; 3) The policy for nuclear power; 4) The risks of import dependence, and so on. These factors enlarge the risks of gas power investment. Nevertheless, with the concern of the environmental problems, the limitations of resources and the phase out of nuclear power plants, many countries, especially the developed European countries, do not have many available options except gas-fired power generation. Actually, the price fluctuation is inevitable in the open market, and it follows the long-term equilibrium of supply and demand. Subject to resource availability, the rise of price may lead to demand reduction and additional supply. The demand may shift to substitute fuels and the price may go down. Besides, the price risks can be hedged through various financial instruments. Therefore, our basic argument on gas-fired power generation in the future is that it will increase in the fuel mix of power generation but the increase will be slow down. The gas power investors are facing great risks.

2. International experiences and lessons on gas-fired power generation

The evolution path of gas-fired power generation generation is particular for each country depending on its natural gas resource and infrastructure, the structure of energy industry and the competitiveness of gas power plants. There are both successful experiences and lessons to learn. There are basically three kinds of models representing respectively the way of European and American countries, Japan and Korea, and South America.

(1) Experiences of the European and American countries

The development of gas industry and gas-fired power generation in the European and American countries are successful. The gas industry has experienced the process from monopoly to competitive markets. At the beginning of the gas industry, it is mainly for satisfying the residential and commercial gas demand and the gas networks were built up gradually. The US government had adopted preferential tax policies to the gas chain from production to consumption for attracting investment and promoting gas infrastructure construction. The European countries had accomplished the rapid switch from coal to natural gas. The European gas industry is characterized by long-term take-or-pay contract, comprehensive cooperation along the gas value chain and 35-50 years of franchise for the distribution system. Before the gas power generation appeared in the gas market, the gas industry has had a relatively long history, the gas network has been well established and efficiently operated under qualified market mechanism. The rapid increase of gas-fired power generation is driven by demand because the combined cycle gas turbine is more competitive than other types of power plants because both of its investment and operation costs are lower. In the European and American countries, the gas power generation is relatively more competitive than that of others, main reasons include, (1) the gas price is relatively low in 1990s, e.g., in UK, the gas price is comparatively lower than coal and it is independent of the European gas market before the UK gas network is interconnected with other European countries in 1998, (2)the raised emissions(SO_2 & CO_2) tax, and (3)the public's uneasy attitude towards nuclear power.

In the process of gas power generation in European and American countries, there are both policy interference and market reason. They all experienced a process, from limited to open. Because of the shock of the Second World Oil Crisis and the imminence to substitute oil, the United States issued the Power Plant and Industrial Fuel Use Act (FUA) in 1978 to prohibit the use of natural gas-fired power generation generation. This restriction was lifted due to the increased proven natural gas reserve and the environmental performance of gas power plants. Consequently the IPPs have constructed a great number of gas power plants after 1990. Similarly the EU has restrained natural gas use from power generation in its directive in 1975. The restraint was removed in 1991 followed by the commitment of many gas power plants. Most of these power plants have signed long-term power purchasing agreements. In the UK, the Government published a White Paper on the fuels for power generation in 1998. The White Paper identified significant distortions in the operation of the electricity market. These distortions had artificially encouraged a rash of new investment in gas-fired power generation, mainly at the expense of existing coal-fired plant. The UK Government decided to apply a stricter consents policy for gas-fired plants since October 1998. New gas power plants have not been allowed to build until the lifting of the stricter consents policy in November 2001. At present, the construction and operation of gas-fired power plants are mainly left to the market. Different from the situation in Europe, most of the IPPs in the United States own CCGT plants and few of them hold long-term power purchasing agreements. These IPPs have encountered financial difficulties because of the substantial rise of gas price in recent years. The West European countries strongly rely on the importation of natural gas due to limited domestic resource. The security of supply is guaranteed through long-term take-or-pay contracts. Nevertheless, the gas supply and gas power generation are inevitably influenced by the rising gas price.

More and more natural gas are used to generate electricity in the open electricity market and gas market. It is worth to mention that many of the players in the gas market are electricity companies who build the LNG terminals, import LNG and sign contracts directly with the gas suppliers. They usually negotiate more flexible gas supply contracts and apply new pricing models in order to mitigate the risks. There is also an integrated business-running model between the electricity transmission companies and gas transportation companies. Many countries have combined the operation of transmission systems of electricity and gas into an integrated company. The National Grid Transco (NGT) of UK, e.g., owns, operates and builds the principal electricity and gas transmission systems.

(2) Experiences of Japan and Korea

The energy supply in Japan and Korea depends basically on the LNG import due to deficient domestic natural gas resource. The LNG import projects are usually large in scale for its high risks in exploration and production. In the initial stage of the gas industry, the pipeline system has not been complete and the residential and commercial demand is limited. The implementation of large-scale LNG import projects have to be supported by large industrial consumers, such as gas power plants. Therefore, different from the models of the European and American countries, the gas power generation is driven by the supply of LNG and the power plants play the role of supporting LNG import projects. In the early years of LNG import in Korea, the long-term take-or-pay contracts are mainly carried by power plants. The IPPs signed long-term power purchasing agreements with electricity suppliers and large electricity consumers. The share of gas use in power generation in total gas consumption is rather high at this stage. Along with the completion of gas infrastructure and the increase of residential and commercial use of natural gas, the share of gas-fired power generation decreased gradually.

It is proved that this model is successful in Japan and Korea. There are other successful experiences such as diversified gas suppliers, more flexible supply contracts, and so on. The power generation mix in Japan is diversified. Although about 70% of natural gas is consumed for power generation, this part is only 23% of the total. About 40% of gas-fired power plants are dual-fuel. The situation is the same in Korea with about 53% of dual-fuel gas-fired power plants. This system guarantees the flexibility and security of the operation of power plants.

(3) Experiences and lessons of South America

There are large proven natural gas reserves in the region of South America. The gas consumption was 89 bcm in 2002 in which 23 bcm is used for power generation. The natural gas is mainly consumed in Argentina, Brazil, Chile, Colombia and Venezuela. The South American gas market is substantially influenced by the policy and geo-political factors and the situation of the countries are various. In Argentina, natural gas resource is abundant. The gas-fired capacity has steadily increased during the last decade. But the economic and social consequences and the policy fallout of the financial and debt crisis that shook the country in 2002 have brought all new private investment in gas production, transmission and power generation to a standstill. In Brazil, the private investment is restrained by the absence of a clear government policy for the gas and electricity sectors. There is strong interest favoring hydropower although the gas sector and power producers argue the utmost importance of gas to power for the development of the gas industry. Chile imports natural gas from Argentina. Power generators have invested heavily in gas-fired power plants. However, the Argentine government has frozen the gas price during the economic crisis in 2002. This resulted in the shut down of gas production and shortage of gas supply. As a consequence, Chile could not obtain the contract quantity of gas and the gas power plants have to be shut down. The Chile government may reconsider their gas power plans in the view of security of supply. In Colombia, a comprehensive gas sector policy have allowed the development in less than a decade of a thriving gas sector and boosted gas use in a hydro-dominated power system. However, lower than expected electricity demand in the last few years due to economic recession have reduced the scope for competition for gas-fired generation and many existing gas-based plants are experiencing financial problems.

The principal challenges for gas power producers in South America are mainly as follows: 1) the gas markets are underdeveloped in South American countries except Argentina. The little heat demand results in small demand for gas in the residential and commercial sectors. Only the power plants, as big gas consumers, could ensure the payback of the huge investment of the gas industrial chain. However, the take-or-pay gas supply contract has limited the flexibility of gas power plant's operation. Once the electricity demand is getting lower, the power system dispatching will firstly cut down the production of gas power plants. This brings big problems to gas power plants because they have signed long-term take-or-pay contracts and are not allowed to resell the gas; 2) The gas power generation is uncompetitive to hydropower so that the utilities and the large consumers are not willing to sign long-term power purchasing agreement with the gas power plants. Without long-term power purchasing agreement the gas power plants endure great risks; 3) security of gas supply; 4) The uncertainties of electricity demand growth；5) Effective policy and regulation framework for gas and electricity industry.

The flexible gas supply contracts in South America provide useful references. For example, in the early stage of Argentine gas market, the gas suppliers agree to deliver the quantity of gas according to the buyer's need within one year before signing the take-or-pay contract. In Colombia, in order to promote gas power in the hydropower dominant system, Ecopetrol has signed the gas supply contracts of low take-or-pay quantity（25%）with the power producers, and this quantity can be modified with the increase of demand. In the early gas market, the long-term take-or-pay and ship-or-pay contracts prevail. Currently the spot market and secondary market have emerged in Argentina, Chile and Colombia in which the market players negotiate certain agreements over specific items, such as interruptible gas supply contracts and interruptible shipping contracts.

The South American gas markets are mainly based on pipeline systems where LNG is less important. Some lessons can be drawn from the South American experiences.

1) Restrained by incomplete gas network and limited gas demand for city use, large-scale gas project is not feasible without gas power plants. A project well-known as the first cross-border pipeline between two developing countries, Bolivia and Brazil, was not fulfilled due to the failure of launching the relevant gas power generation project.

2) The public authority should clarify the status of gas power plants and formulate explicit policies. In most South American countries, the last 5-10 years have been characterized by a generally low level of policy involvement in the energy sector and the reliance on market forces for investment decisions. The investors believe that the absence of clear and stable energy policy is the key barrier to private investment. In Brazil, the policy is not clear on many aspects related to gas-fired power generation, such as the role of private capital, the role of state-own companies, the structure of electricity, gas markets, the market rules, and the function of gas

power plants in the power system, etc. There is a lack of policy and law in the gas industry either. The restructuring of electricity sector has been progressing in the absence of reasonable regulation framework and market rules. These factors have delayed the gas projects in Brazil. Currently the governments are more involved in the market. Taking the example of Argentina, the electricity market is a spot market while gas market is based on long-term contracts. This brings contradiction because the two markets are interrelated through gas power generation. For avoiding the confliction, the government modifies the market rules to establish secondary gas market and to enhance the long-term contracts in the electricity market. The Colombia government has also reconsidered the regulation framework of gas and electricity markets concerning the financial feasibility of gas power plants.

3. Evolution of international gas trade

The gas industry in the world has been undergoing a significant change indicated by the deregulation and introduction of competition and expanded international gas trade, especially LNG trade. In such environment the form of gas trade has evolved as well. At the beginning of LNG trade, the contract is usually bilateral. The purchaser regards the security of supply as the primary concern so that the long-term contracts are preferred. The traditional LNG contracts are characterized by (1) long-term contract of more than 20 years; (2) Ex-ship contract;（3）high take-or-pay quantity, e.g. above 85%；（4）price linked closely with oil（5）strict delivery point；（6）little flexibility of seasonal gas quantity. In recent years, the LNG suppliers are diversified. The purchasers' major concern turns from supply security to optimal benefits and risk mitigation. The investment of upstream developers has been gradually recovered through depreciation. The contract items are less rigid. The traditional LNG contracts are replaced by more flexible ones. For example, Japan has signed a portfolio of contracts including long-term, medium-term, short-term and spot contracts in order to adapt to the demand change and to hedge the risks. The new trade agreements and pricing mechanisms also appear in Europe, e.g., to link the LNG price to the electricity price. The gas producers in the Middle East has created the conventions for spot LNG trade that provides a standard contract system for spot LNG trade. The new LNG contracts are distinguished from the traditional ones by (1) reduced time of less than 15 years, with increased number of medium-term contracts of 5 to 8 years; (2) price linked to the local major competitive fuels such as coal or electricity;（3）FOB contract, the buyer can control the shipping and adjust the gas volume according to the demand; (4) reduced take-or-pay quantity ;(5) some contracts allow resell of LNG;（6）in the past the investment is usually downwards from producers to the downstream, now the buyers of LNG start to invest in the gas fields.

In the deregulated gas markets in the American and European countries, with the introduction of third-party access, at some locations, where several pipelines meet and where storage facilities and consumption centers are both close by, a marketplace for gas is set up, i.e., a hub, for example, Henry Hub in the United States and NBP （Notional Balancing Point）in the UK. The spot market and futures market for gas are gradually established in which the gas price fluctuates reflecting the balance of supply and demand. The futures market provides reference for the long-term contracts and instruments for hedging risks.

4. Concluded international experiences and Lessons

The development process of world gas industry has provided helpful implications for the start-up Chinese gas industry.

(1) The government policy and the market should both play important roles in the gas industry. The evolution of market price and international trade patterns have to be sufficiently paid attention. In addition, as a important part of the whole energy supply, the decisions in gas industry have impacts on the energy structure, energy security and environment, even the whole economy. Therefore, these decisions cannot completely follow the market. China should avoid the failure in South America caused by the absence of clear policy, should clarify promptly the position and the direction of gas power in the national energy strategy, should formulate reasonable policies in time to provide solutions for the barriers encountered in the ongoing gas projects and provide indicative instructions for the future gas projects.

(2) The suitable way for developing gas industry depends on the local resources and infrastructure. In the region of scarce gas resource and incomplete network, the gas power projects are necessary to ensure the realization of the large-scale international gas projects. In a different way, the smaller-scale domestic projects based on the local resources may gradually complete the network and build up the market without gas power projects. The gas industry is at the initial stage in China. Gas power projects are necessary for the large-scale LNG projects and pipeline gas import projects in the regions with immature gas market and incomplete infrastructure.

(3) The advantages of gas power generation are apparent compared with others. Although the uncertainties raise the economic risks of gas power plants, as a clean energy source, gas power generation will take an important position in the future world energy supply. As indicated by the international experiences, the long-term contracts are essential for the large-scale LNG projects because of the huge investment accompanied by great risks, and because of the unequal risk hedging capabilities in different countries and regions. Corresponding to the long-term take-or-pay gas supply contracts, the power plants have to sign long-term power purchasing agreements with electricity purchasers. In the United States, the gas power plants without long-term power purchasing agreements suffer serious financial difficulties when gas price rises and the new gas power plants require the long-term contracts. China is at the beginning of electricity deregulation and the preliminary stage of gas industry, the gas power plants are uncompetitive to coal power plants. The long-term electricity purchasing contracts between gas power plants and

electricity purchasers may be a reasonable option.

(4) The power purchasing agreement should be accepted by the utility and the consumers. The first LNG project in India failed because the electricity price of the gas power plant was not accepted by the consumers. There are different forms of power purchasing agreements between the power plant and the utility. In Thailand, for example, the utility supports gas power generation through directly undertaking the power plant’s obligation of take-or-pay gas purchasing. In Philippines the gas power plant has signed long-term contract with the utility. In Singapore, the long-term power purchasing agreement is guaranteed by the government. The electricity price includes two parts of capacity price and energy price. In the first 7-8 years, 50% of the capacity price is determined by the long-term marginal cost of the plant of best performance in the system while the energy price is determined by the system marginal cost.

(5) There are various ways for gas power plants to deal with the uncertainties and to manage the risks. For example, to negotiate flexible contracts and portfolio of contracts (combination of long-term, short-term and spot contracts), to apply favorable type of pricing model, to build different types of power plants and to combine them for flexible bidding in the electricity market. With the gradual establishment of electricity market in China, the introduction of new market products, such as ancillary services and futures contracts, will provide more instruments for the gas power producers to enhance their competitiveness and to hedge the risks. Therefore, in the condition of practical policies, the investors should face the risks and find the ways to hedge the risks.

(6) In the countries that deregulated the gas and electricity sectors it appears the integrated companies with the gas and electricity. The combination is demonstrated by the aspects of technology (natural gas is used for power generation), trade (gas power producers have the chance of arbitrage between gas market and electricity market)and integrated operations. The combination may improve the flexibility of gas power plants, mitigate the risks and enhance their competitiveness.

(7) The condition of energy resources and the energy industries in China are different from the other countries. The challenges facing by the gas power generation are not the same as in other countries. To some extent, the situation of gas power in China is similar to that of Brazil in the sense of rapid growth of electricity demand and lack of competitiveness of gas power. However, hydropower shares more than 90% in Brazil while China consumes mainly coal. There are abundant natural gas reserves in the South America as well as in Brazil. Therefore the two countries are incomparable. The situation in China is also different from the American and European countries where the gas and electricity markets are established with effective mechanisms, the network is sufficient, the residential, commercial and industrial gas markets are mature. The role and survival of gas power generation is determined by the market. The strict emission restriction, the uncertain policy for nuclear power and the limited coal resources suggest that natural gas is the key option of power generation in these countries. However, it is possible that the gas power

plants could not survive financially in the case of high gas prices. Yet in China the natural gas resource is deficient, the gas price is high while the coal reserve is abundant. The dominance of coal-fired power generation in the electricity industry would not change in the near future. In the primary stage of gas industry development and the reform of electricity market, gas power projects are necessary for supporting large-scale LNG import projects; in a long-term, gas power plants can be used to adjust the gas use to ensure the security of city gas supply and can be peak plant in the power system. Therefore the practical policies and measures have to be formulated for the gas power plants to effectively realize their functions, for the social welfare and the benefits of both gas industry and electricity industry.

IV. Main Problems for Gas-fired Power Generation in China

1. Lack of Competitiveness

A major problem facing gas-fired power generation is its economic viability, especially its competitiveness against coal-fired power generation. In today's China, though the market environment for each planned gas-fired power plant may be different, the conclusion on their economic viability is the same: their on-grid tariff is higher than that of the coal-fired plants with desulphurization in the same region.

If the unit static investment for a gas-fired power plant is calculated as an average RMB 3,300/kw (an average with package bidding for turbine equipment), gas price is RMB 1.3/m^3 (net calorific value as 8,100 kcal/m^3) and annual use time is 3,500 hours, to ensure an internal rate of return (IRR) of 8%, the on-grid tariff of the gas-fired power plant will be RMB 0.407/kwh (tax not included) or RMB 0.476/kwh (tax included). But the current on-grid tariff (target tariff) of newly built gas-fired power plants in eastern coastal areas is usually RMB 0.38 - 0.43/kwh (tax included). Fuel cost is over 60% of the power generation cost of gas-fired plants, while the percentage for coal-fired plants is only 40%. Therefore, on-grid tariff of gas-fired plants is more subject to fluctuations in fuel prices.

One can use relevant technological and economic parameters of a coal-fired unit and a CCGT unit to compare the competitiveness of the two power generation methods. The unit static investment of a gas-fired power plant is taken as RMB 3,300/kw and that for a coal-fired plant is RMB 4,000/kw, and the annual generation use time is 3,500 hours. To ensure basically the same competitiveness (same on-grid tariff and same IRR), the critical price ratio between natural gas and coal (standard coal) will be 2.4 for the same heat value; When the annual generation use time is 5,000 hours, the ratio is around 2. When the real gas to coal price ratio is higher than the critical ratio, gas-fired power plants are not competitive against coal-fired ones.

The average price of standard coal is around RMB 350/ton in the eastern coastal region in recent years. Given this, China's natural gas and standard coal price ratio is above 3. At present, the LNG factory-gate price is preliminarily set at RMB 1.54/m^3 (net calorific value 8,940 kcal/m^3) in gas-fired power plants in Guangdong, while the average standard coal price for coal-fired power plants is around RMB 480/ton, forming a price ratio of 2.5 between natural gas and standard coal. In East China, the natural gas price is about RMB 1.3/m^3 (net calorific value 8,100 kcal/m^3), and the standard coal price is around RMB 400/ton, forming a ratio of 2.8. In general, the price ratios between natural gas and standard coal in the economically more developed eastern regions of China are always above 2.5, higher than the critical ratio.

Therefore, given the present energy prices in China, the advantages in low investment costs and high efficiency of gas-fired power plants have not offset the price advantage of coal, and CCGT is not competitive against coal-fired power generation.

2. Gas-fired power generation faces double pressures from take-or-pay contracts and taking part in power market competition.

Natural gas and LNG industries are on a special business chain with the upstream and the downstream being an integrated whole. According to the international practice in LNG trading, in emerging natural gas markets, the supply and demand sides should sign a long-term take-or-pay gas purchase contract, thus forming a business chain of risk-sharing and risk-transfer. In WEP, GDLNG and FJLNG projects, the gas-fired power plants have all signed such long-term contracts with the gas suppliers.

In the implications of the Power Sector Reform, the long-term power purchase agreements signed between grids and power plants should be abolished and competition introduced to the power market. The regional power markets in China at present and in the next few years are in the primary stage, where the power sellers are usually coal-fired plants of a considerable scale and with centrally allocated coal, and the sole power buyers are provincial grid companies. The products traded are yearly and monthly quantities of electricity. And the trading method is usually contract for difference (CFD). In the second stage of power market in the future, market players and products will be gradually diversified and the support service market will be introduced. The future power market will have both contract and spot trading, whereas the contract method will be divided into authorized contract and self contract. Authorized contracts are to carry out the national policy and sign power purchase contracts on verified tariffs with different types of power plants (such as those using renewable energy, featuring combined heat and power (CHP) or runoff-type hydro plants).

Without any policy support, gas-fired power generation will lack competitiveness against its main competitor in the domestic power market, coal-fired power. And the on-grid electricity volume and tariff of gas-fired power plants will be largely unstable.

China's natural gas industry has only taken its initial steps and needs support and nurturing in a certain period. But the power industry has been mature and competition is the inevitable trend there. It has put the gas-fired power plants, both at the downstream of the natural gas industry and the upstream of the power sector, in a dilemma.

3. The gas supply model constrains the operation of gas-fired power plants

In the real operation of power systems in various regions, with improvement in technical performance of coal-fired units and greater system automation, there is no technical obstacle to peak-shaving and the crux is in the economic viability of it. Gas-fired units have the technical advantages of flexible operation and fast start and stop, and will, to the extent economical and rational, be greatly beneficial to peak-shaving and safe and stable operation of the grid.

However, if gas-fired power plants operate for peak-shaving, it will require a reliable gas source, stable supply and great flexibility in gas supply to meet the needs of daily peak-shaving and seasonal changes. Therefore the gas supply side must be able to mobilize a sizeable reserve (like having gas storage facilities), to handle the changes in gas supply. Meanwhile, gas-fired power plants should purchase gas at the city-gate or gas trunk-line to the extent possible, so as to reduce costs and avoid interference between residential and power-plant gas uses.

For the complementary gas-fired power plants to WEP, their take-or-pay contracts have evenly divided the annual contract amount of gas to 365 days of the year, with no guarantee for gas use exceeding the daily contract amount. It has resulted in limited daily peak-shaving capability of these power plants. Two gas storage tanks were built in Phase I of GDLNG, but it still cannot meet the monthly and seasonal peak-shaving needs of the grid. Since gas supplier cannot provide gas as needed in power generation, the generation and peak-shaving capacity of gas-fired power plants are greatly constrained.

V. Main Conclusions and Policy Recommendations

1. Main Conclusions

The following 8 conclusions have been drawn from the above analysis:

(1) China must vigorously develop its natural gas market. With ever greater pressure on energy supply, China's coal supply is constrained by production capacity, transportation, safety and environmental concerns, and the room for large-scale development of hydro, nuclear and renewable energy is limited. Besides, coal takes up nearly 70% in the energy consumption mix, wherein the share of high-quality energy is too small, resulting in huge environmental pressures. It is more urgent in the economically more developed coastal areas to optimize the energy mix and improve the environment. Natural gas, a high-quality, efficient and clean energy source and material for chemical industry, plays an important role in optimizing the energy mix, protecting the atmospheric environment, easing the strained petroleum supply, improving energy utilization rate, promoting modernization of industries and commerce, and realizing the sustainable development of the national economy. China's eastern coastal regions have a stronger demand for natural gas as they have faster economic growth, greater energy shortage and higher environmental requirements. Increasing the share of natural gas in China's primary energy (especially in the coastal regions) is not only a practical choice for optimizing energy mix and improving the environment, but also an important supplement to the sustainable energy supply and a major approach to enhance energy quality.

(2) In developing the natural gas market in China, it is inevitable to use some natural gas in power generation, in particular in the initial stage of large commercial gas projects. Countries in the world are different in resource availability, infrastructure and energy mix, and they are not identical in the development path and consumption structure of the natural gas industry. But in general, large customers like gas-fired power plants are needed to quickly launch the natural gas market without the presence of a complete pipeline network. When the percentages of residential and industrial gas use are greatly enhanced, more natural gas may be applied as city gas and high-value-added industrial gas. At that time, the designers of gas-fired power plants should give more thoughts to help adjusting the source and volume of city gas. From the overall and long-term perspective, we do not encourage the use of large amount of natural gas in purely conventional power generation in China. But from the perspective of power system operation, in particular power supply security at the receiving end, it is necessary to develop some gas-fired power plants. In areas with huge power demand, we should not rely solely on coal-fired power generation and should add some other power sources, such as gas-fired power generation.

(3) Gas-fired power generation is important for the diversification of power sources in China. It helps to adjust and optimize the power source mix. It is conducive to peak-shaving and safe operation of the grid. Besides, it can serve as an important power source in the load center, the large and medium cities where environmental and land regulations are more strict, to provide short-distance power supply and improve grid stability. However, commercial gas-fired power is a new industry in China. Not only the power sector lacks experience in it, the government organs also do not have relevant policies to reflect the uniqueness of gas-fired power generation. Especially when a competitive power market and its market rule have yet to be established, it is imperative to formulate relevant policies for gas-fired power generation in line with the development of both the natural gas industry and the power industry.

(4) The policy for gas-fired power generation should not be "one size for all". No uniform operating hour and gas price should be set for the whole country, because a gas-fired generation project is at the converging point of a natural gas project and the power system, which each has its own features. The scale and deployment of gas-fired power generation, its role in the natural gas project and its operating position in the local grid, should be determined through consultation between the sponsor of the natural gas project and the local government.

(5) The success of a natural gas project hinges upon the success of the gas-fired power generation project. Natural gas industries in Japan and Korea developed on the basis of LNG power generation projects. India's first LNG project in Maharashtha failed due to obstacles in its complementary power project. Failures of gas-fired power generation projects in South America also hindered the development of the natural gas industry. A notable example is the failed cross-border natural gas pipeline linking Bolivia and Brazil, as a result of inability to launch the complementary gas-fired power project. China's natural gas market is in the infant stage, when gas-fired power projects will play a vital role to the development of the whole natural gas market, the LNG market in particular.

(6) Based on the manufacturing costs of gas and coal turbine units, for the same heat value, the critical price ratio between natural gas and coal is 2~2.4 (annual generation use time is 5000~3500 hours). When the gas-coal price ratio is higher than the critical ratio, gas-fried power is not competitive against coal-fired. In recent years, China's gas-coal price ratio has been above 3, and the current natural gas price in the eastern regions (WEP and imported Australian LNG prices) has a ratio of over 2.5 against coal, both higher than the critical ratio. It is evident that the low investment costs and high efficiency of gas-fired power plants have not offset the price advantage of coal. CCGT is less competitive than coal-fired generation. With international LNG prices rising continuously and upward adjustments of domestic natural gas price, the competitiveness of gas-fired power generation will be further weakened. At the same time, China has yet to reflect in its pricing mechanism the environmental advantages of gas-fired power plants, and it is unreasonable to let the gas-fried power compete with the coal-fired under such conditions.

(7) Compared with other power sources, gas-fired power generation has many unique features. As an important component of the natural gas industry, these plants need to sign long-term take-or-pay contracts with the gas suppliers and take part in the power market competition. In today's market environment, gas-fired power generation is not competitive against coal-fired power generation and it cannot survive in the competitive power market without policy support. Falling with the gas-fired power plants will be the large natural gas projects supported by them and the Chinese natural gas industry still in its infancy. For the natural gas projects which involve larger investment and higher risks than other power sources, there must be long-term contracts to ward off risks. Corresponding to the long-term take-or-pay contracts on gas supply, power plants need to secure long-term sales contracts with the electricity buyer.

(8) Analysis of the international gas market changes shows that China will face increasingly fierce competition from the rest of Asia, the US and Europe and higher natural gas and LNG prices. China is no match to developed countries in terms of gas market maturity and price tolerance. The Chinese Government should proceed from energy supply security of the country and the overall energy strategy, make clear as soon as possible its strategic arrangements for imported natural gas /LNG and other clean and efficient energy, and actively create a favorable domestic environment for the use of natural gas resources home and abroad, so as to attract long-term natural gas supply.

2. Policy Recommendations

Based on the above conclusions, we believe importance should be attached to natural gas/LNG industry development and the related issue of gas-fired power generation, as overall national energy strategy and global market competition requirements. We suggest, on the basis of this study, that the China Government should adopt the following policies and measures:

(1) To speed up the development of the natural gas market. We must strengthen the exploration, development and use of domestic natural gas resources, step up the import of pipeline natural gas from Russia and Kazakhstan, facilitate the construction of the LNG projects in Guangdong and Fujian and the implementation of their supply contracts, and where conditions are ripe, build in other coastal provinces and cities LNG projects of suitable scales and affordable prices.

(2) To speed up natural gas market development does not mean to vigorously develop gas-fired power generation. It will be of greater strategic significance, in terms of environmental protection, economic feasibility, security and stability, to use China's limited natural gas supply in replacing fuel oil and coal in various sectors than to generate power. But in the initial stage, large gas projects need the support of gas-fired power generation, and the power system indeed can and need to accept some gas-fired power plants. Therefore, China should moderately develop gas-fired power generation and let the gas-fired power plants, the gas suppliers and power departments make proposals through joint studies on the scale, site, operating position and time of construction of such plants in light of the available gas resources and features of local grid.

(3) To set up pricing mechanisms for on-grid tariff and gas price for power generation

1) In accordance with the principle that gas-fired power plants must fully comply with the rules of the local power market and take part in the tariff competition for on-grid electricity, it is clear that the on-grid tariff of gas-fired power plants should be determined by the market in a scenario of full market competition. But before the competition rules in the power market are complete, the on-grid tariff of gas-fired power plants may be set as the weighted average of the on-grid tariffs of the local grid, or peak and valley tariffs in line with the local peak and valley on-grid tariffs. The operating model, annual generation use time, relevant arrangements for power generation and upload to the grid, and other technical requirements and commercial arrangements that need to match the requirements of take-or-pay contracts signed with gas suppliers, should be worked out by the electricity seller and buyer through business negotiations and clarified in the power purchase contract.

2) The gas supply contract, including gas supply model, factory-gate price and validity period of the contract, between a gas-fired power plant and the natural gas supplier should be worked out by the two sides through business negotiations.

3) Solutions to the difference between the gas price arrived at through net-back from on-grid tariff (the generation price) and the factory-gate price set by the contract:

① Relevant provincial government organs, the gas-fired power plant and the gas supplier will set the generation price of the year in accordance with the average on-grid tariff of the previous year;

② The local government will provide subsidies to the gas supplier as previously agreed to cover the difference between the contract price and generation price of the year;

③ Sources for local government's price subsidy: with approval of competent national authorities, the local government may apply a surcharge on the direct-sale power (not including the contracted power sold directly by the power plant to the user) of grid enterprises of the province; Local governments may also use their budgets to cover part of the price subsidy, if they can afford it.

(4) To reduce gas price for power generation and improve the competitiveness of gas-fired power generation

1) More preferential tax policies for development and use of natural gas

① For enterprises engaged in natural gas exploration and development, to allow the exploration investment to have a larger tax discount (of a certain percentage) on taxable income than usual;

② For enterprises engaged in gas pipeline transmission, to exempt them from income tax and turnover tax in the period starting from the day of putting into operation of the pipeline and the day of return of all investment and repayment of all loans; and to collect only half of the turnover tax after the return of investment;

③ For imported LNG projects, to reduce or exempt the import tariff, and refund the import value-added tax (VAT) upon collection;

④ For enterprises in gas-fired power generation, to exempt the income tax and refund the VAT upon collection.

2) To adopt reasonable classified gas prices

We should formulate reasonable classified gas prices for users of different types and sizes, as well as different timeframes (peak or valley), set up a pricing mechanism that favors fair burden-sharing and reflects the user and load characteristics, guide natural gas consumption, and optimize gas use structure. For residential and commercial gas uses, where the market is hard to establish, the peak-valley gap is wide, and the gas supply safety requirements are strict, a higher price should be applied. For industrial users, the larger the scale of gas use, the lower the gas price should be; and the more stable and balanced the gas use, the lower the gas price. Customers for whom the gas supply may be cut off should enjoy the lowest gas price. Gas prices should also change with the seasons, with higher price for the peak and lower prices for the valley.

3) To fix the pipeline tariff in a rational way

Sticking to the principle of "breakeven and meager profit", we should set a rational pipeline tariff (for long-distance pipeline and urban pipeline network) and strictly supervise it, through measures like reducing project return on investment (IRR should be controlled at 10%) and extending the period of depreciation of pipelines (from the current 10~15 years to 30~40 years), in a bid to reduce the price burden on gas users (in particular gas-fired power plants).

4) To use the natural gas resources in an comprehensive and optimized manner

Methane is the main content of natural gas. Natural gas is called “dry gas” if its methane content is over 95%. If there is about 10% (mol) of C_2 and C_3, as well as an extremely small amount of C_4, then it is called “wet gas”. According to an analysis, if C_2 is separated in an efficient and low-cost way using the cold energy of LNG (wet gas) and used to replace naphtha as cracking material in ethylene production, we can cut the investment by 30%, energy costs by 30%~40% and overall costs by 10%. In this way, the costs of natural gas may be reduced by RMB 0.3/m^3, and the competitiveness of LNG will be improved.

5) To introduce competition and technological innovation

In the construction of gas-fired power plants, we should reduce the investment costs and power tariff through tender bidding. We should encourage the use of diversified gas-fired power generation technologies and avoid the use of the same type of large CCGT unit everywhere. We should encourage the use of SCGT that is dual-fuel, good at peak-shaving and more economically competitive, as well as the small and mid-scale distributed CHP and combined cold, heat, power (CCHP) gas-fired power plants that are high in total energy efficiency. We should speed up the localization of the R&D and manufacturing of gas-fired generation equipment, so as to lower the equipment costs.

(5) Environmental discounts should be included in on-grid tariff of gas-fired power.

To reflect the environmental value of gas-fired power generation, its on-grid tariff should incorporate the environmental cost (benefit) in real money. For the short term, environmental discounts for SO_2 can be incorporated first.

(6) To clarify the way for gas-fired power plants to take part in the power market

Gas-fired power plants should take part in power market competition and follow the operation rules there. Before the power market mechanism is fully established and as a transitional step, gas-fired power plants may use the weighted average of the on-grid tariffs of the local grid as the tariff basis. With maturity of the natural gas market and enrichment of product types in the power market, and after the power market competition mechanism is fully established on the basis of improvement of the regional markets, gas-fired power plants should fully participate in the competition. These plants may participate in the contract and spot markets and sign suitable long-term power sale contracts with buyers; they may also ward off risks through products like financial contract. At the same time, gas-fired power plants, with features like fast start and stop and flexible operation, may benefit from the support service market to enhance their competitiveness.

(7) To enhance the flexibility of gas supply and operation of gas-fired power plants

In recent years, the trend in international natural gas contracts is the gradual relaxation of the terms and greater flexibility in business model. Specifically, the term of the contract has reduced from 20-25 years to 8-10 years, spot trading has increased, take-or-pay trading decreased and gas off-take at different timeframes has become more flexible. To solve the contradiction between gas supply model and gas turbine operation, gas supply companies should try to obtain more flexible gas supply contracts from the upstream, such as signing a packaged contract covering the long-term, mid-term, short-term and spot. The gas supplier and power plants should coordinate with each other to adapt the gas supply contract to the gas use by the power plants to the extent possible, so as to give play to the flexibility of these power plants and serve the peak-shaving needs of the grid. Gas-fired power plants may also use dual fuels to improve flexibility and profit-making capability in the power market.

(8) To encourage oil and gas enterprises to have controlling shares in gas-fired power plants

As a gas supplier for power generation and a big power consumer, oil and gas enterprises should penetrate into the power generation field as well as the production, transportation and sales of natural gas, in order to form an integrated business chain between the supplier of natural gas/ LNG and power plants. It can avoid the division between gas supply and power generation, reduce the trading costs, improve the competitiveness of gas-fired power generation and simplify the business negotiations on the whole chain of gas-fired power generation.

Postscript

This project has been carried out under the auspices of Bai Rongchun, former Inspector of the Energy Bureau of NDRC, at a time when the Chinese natural gas market is not yet mature and a complete set of systematic solutions and policy measures for gas-fired power generation does not exist. The study has been co-sponsored by the Energy Foundation, BP (China), Shell (China), TOTAL (China), Chevron (China), China National Off-shore Oil Corporation (CNOOC). Members of the research Team include: Zhou Dadi, Yang Qing, Yang Yufeng, Li Ji, Xue Xinmin, Geng Zhicheng and Jiang Xinmin from the Energy Research Institute of NDRC (ERI/NDRC), Jiang Liping, Wang Yaohua, Bai Jianhua, Zhao Jing from the State Power Economic Research Center of State Grid Corporation of China (State Grid) and Dong Jun from North China Electric Power University. The Synthesis Report has been written by Bai Rongchun, Yang Yufeng, Wang Yaohua, Jiang Liping and Dong Jun, with Yang Yufeng responsible for the organization of Sub-report One and Wang Yaohua responsible for Sub-report Two. The organizer and contact person for this study is Yang Yufeng.

During the course of the study, a team of energy experts from the co-sponsors, including Yang Fuqiang, Xavier Chen, Wu Ruhu, Jia Jizhong, Guo Li, Li Xu, Qiu Tieyan, Wang Wanxing, Zheng Hongtao and Du Lian, have given their valuable comments. Dr. Xavier Chen made important contributions to revising the Synthesis Report.

Wang Jun, Wu Guihui, Zhang Yuqing and Hu Weiping of the Energy Bureau and Li Caihua of the Price Department of NDRC gave important opinions on revising the report; Zhu Chengzhang (China Electricity Council), Tang Zhenhua (CNOOC). Liu Baohua (State Electricity Regulatory Commission), Yang Kun (South China Electricity Regulatory Commission) and Ouyang Changyu (State Grid) made valuable suggestions on revising the report.

Development and reform commissions of Shanghai, Guangdong, Zhejiang, Jiangsu and Fujian, as well as relevant grid companies, gas-fired power plants and energy group companies made important contributions to the report in the process of studies and view-soliciting.

Office of China-EU Energy and Environmental Projects (EEP) and Dr. Dick De Jong of International Natural Gas Association also provided support to the study.

Members of the research team wish to express most sincere thanks to all officials, experts and scholars who have given their care and support to the study!