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THE STATUS, DEVELOPMENT AND APPLICATION OF NATURAL GAS

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ABSTRACT

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As one of the modern clean energy, the importance of natural gas is gradually discovered. Natural gas is the general term of the mixture of hydrocarbons existing in the underground rock reservoir. Natural gas is mainly composed of alkanes, in which methane accounts for the vast majority and is insoluble in water. There are many causes of natural gas, such as organic, inorganic. It has the characteristics of environmental protection, economy, practicality and safety.

It has gradually become the main clean energy and has been popularized in people's life. Natural gas has been widely used as a kind of clean energy. In this process, research and production are still going on, but there are still problems such as insufficient production, insufficient storage capacity and insufficient emergency support. Because natural gas is still unable to meet its demand, it is still necessary to strengthen the relevant technical capacity.

Its application also needs to continue to strengthen the promotion. In terms of application, according to the way of application, natural gas can be used as industrial fuel, and its role in process production, natural gas chemical industry and urban gas industry can be used to make compressed natural gas vehicles and strengthen natural gas. In the application of products, liquefied gas, compressed gas, artificial gas can be applied to life.

At the same time, according to the current situation of natural gas, more research is needed for the future development of natural gas.

Key words
Natural gas, status, application, exploitation, development, future

CONCEPT DEFINITIONS

LNG	Liquefied natural gas
CNG	Compressed natural gas
LPG	Liquefied petroleum gas
CNG	Compressed natural gas

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1 INTRODUCTION

Natural gas is used to describe the mixture of hydrocarbon gases. It is a kind of mineral fuel, which is mainly composed of methane, colorless and tasteless. It also contains a small amount of ethane, propane, nitrogen and butane. Methane is rich in hydrogen but it is a lack of carbon. Natural gas has many uses and can be used in most energy sectors: residential, commercial and industrial. In recent years, liquefied natural gas (LNG) is transported to distant countries by sea, and it can also develop rapidly.(Johannes et al.,2012)

With the extensive use of clean energy, China's natural gas industry has begun to develop rapidly, and the status of natural gas is also rising. It is predicted that China's natural gas production will grow rapidly and become a more important energy source than oil. Therefore, great importance should be payed to the to the development of natural gas, plan its industrial development more reasonably, and make full use of it in domestic and foreign markets.(Johannes et al.,2012)

2 CONCEPT AND CONTENT OF NATURAL GAS

Natural gas is the general name of the mixed gas existing in the underground rock reservoir with hydrocarbon as the main body, with a specific gravity of about 0.65, lighter than air, colorless, tasteless and non-toxic characteristics. Natural gas is mainly composed of alkanes, in which methane accounts for the vast majority, and a small amount of ethane, propane and butane. In addition, hydrogen sulfide, carbon dioxide, nitrogen and water vapor, a small amount of carbon monoxide and a small amount of rare gases are commonly found.(Temple 2007)

TABLE 1 Natural gas composition (Liu, 2010)

Composition of natural gas	Proportion (%)
methane	85%
ethane	9%
propane	3%
nitrogen	2%
butane	1%

Natural gas is insoluble in water, under standard conditions, methane to butane exists as gas, and above pentane is liquid. Methane is the shortest and the lightest hydrocarbon molecule. Organic sulfide and hydrogen sulfide are common impurities, which must be removed in advance in most cases of natural gas utilization. Methane accounts for 75-99% of the total composition, while ethane, propane and other components generally exist in low to medium amounts, and the natural gas liquid will be formed after separation and liquefaction from methane.(Temple 2007)

2.1 Cause of formation

The origin of natural gas is various. The formation of natural gas runs through diagenesis, plutonesis, epigenesis and metamorphism. Various types of organic matter can form natural gas. Sapropel type organic matter generates both oil and gas. For example, its causes include biological, inorganic, organic and so on. Next is a general introduction.(Chen ,2018)

2.1.1 Biology

In the early stage of diagenesis, biogas was formed by microbial fermentation and the synthesis of sedimentary organic matter in the shallow biochemical zone. Rich organic matter and strong reducing environment are the premise of biogas formation. There are two main ways of biogas formation: acetic acid fermentation and carbon dioxide reduction. The nature of oxidants in sediments determines the reaction process. If there is free oxygen, it is mainly decomposed by oxygen, and then nitrate reduction plays a major role. The single molecule compounds decomposed by various microorganisms are reduced to form methane. Due to the limitation of oxidants in sediments, the main reactions of organic matter decomposition are sulfate reduction and methane formation.(Liang et al.,2017)

2.1.2 Organic genesis

Sedimentary organic matter, especially sapropel organic matter, forms natural gas together with oil in the process of thermal degradation into oil, or natural gas formed by thermal cracking of organic matter and early formed liquid oil in the post formation stage is called oil type gas, including wet gas (oil associated gas), condensate gas and cracking gas.(Liang et al.,2017)

Natural gas generated by evolution of coal measure organic matter (including coal seam and dispersed organic matter in coal measure strata) is called coal type gas.Coal gas is a multi-component mixture, in which the main hydrocarbon gas is methane, usually dry gas, but there may be moisture. Sometimes it may contain more steam and nitrogen.(Liang et al.,2017)

2.1.3 Inorganic origin

Inorganic gas or abiotic gas is produced by the decomposition of inorganic salts in rocks, and it may also be produced in metamorphic rocks. This kind of gas is mainly composed of methane, and sometimes it contains CO2, N2, H2S, etc. There are many causes for this gas, such as inorganic synthesis, volcanic activity and dehydration.(Chen et al.,2018)

2.1.4 Carbon dioxide

High CO2 content in natural gas, like high hydrocarbon gas, also has important economic significance. For CO2 gas reservoir, natural gas with CO2 content > 80% (volume concentration) has economic value, which can be widely used in industry, agriculture, meteorology, medical treatment, catering industry and environmental protection.(Chen et al.,2018)

2.2 Characteristic

Natural gas is a safer fuel. It contains no carbon monoxide, is lighter than air and does not easily accumulate to form an explosive gas. It is relatively safer than other fuels.Using natural gas as an energy source can reduce the consumption of coal and oil, reduce the emission of sulfur dioxide and dust by nearly 100%, carbon dioxide by 60%, and nitrogen oxide by 50%, which can help reduce the formation of acid rain, slow down the global greenhouse effect and fundamentally improve the quality of the environment.(Howarth et al.,2011)

In China, when natural gas is used as vehicle fuel, it has the advantages of small exhaust pollution, reliable supply and low price, which has become the development direction of clean fuel for the world vehicles, while natural gas vehicles have become the fastest developing and most used new energy vehicles. However, for the greenhouse effect, natural gas, like coal and oil, will produce carbon dioxide. Therefore, natural gas cannot be used as a new energy source. (Howarth et al.,2011)

It has many advantages, such as green environmental protection, less carbon dioxide produced by natural gas combustion than other fossil fuels, and low greenhouse effect, which fundamentally improves the environmental quality. And it is safe and reliable, natural gas is non-toxic, lighter than air , and not easy to accumulate into explosive gas, so it is a relatively safe gas. But the natural gas content in the air reaches a certain extent, it will suffocate people. Natural gas is essentially harmless to human body. However, if the natural gas is in a high concentration, it will cause death.(Howarth et al.,2011)

Although natural gas is lighter than air and easy to diffuse, when it accumulates in closed environment such as houses, it will cause a strong explosion when it reaches a certain concentration. When the concentration of natural gas in the air is in the range of 5% - 15%, it will explode in case of fire. The explosion of compressed natural gas to be used in the engine of natural gas vehicles requires the use of external forces to maintain the concentration of natural gas between 5% and 15% to trigger the explosion.(Howarth et al.,2011)

2.3 Composition classification

Natural gas can be divided into free state, dissolved state, adsorbed state and solid hydrate. Only natural gas in free state can be developed and utilized after accumulation. Natural gas can be divided into associated gas and non-associated gas. Associated gas is the natural gas produced simultaneously with crude oil and associated with crude oil. The associated gas is usually the volatile part of crude oil, which exists in the form of gas above the oil-bearing layer. Non-associated gas, including pure gas field and condensate gas field, exists in the formation in the form of natural gas. (Wang et al.,2009)

According to the state of natural gas reserves, it can be divided into structural natural gas, water-soluble natural gas and coal mine natural gas. Structural natural gas can be divided into wet natural gas produced with crude oil and dry natural gas without liquid component.(Wang et al.,2009)According to the cause of formation， natural gas can be divided into biogenic gas, oil type gas and coal type gas.According to the occurrence of the natural gas underground, it can be divided into oilfield gas, gas field gas, water-soluble gas, and solid gas hydrate and so on.(Wang et al.,2009)

3 THE STATE OF NATURAL GAS

Nowadays, the global energy structure is changing to the direction of low-carbon environmental protection, in which the consumption of natural gas is increasing, and the global demand for natural gas is also growing rapidly. In China, as a clean and efficient low-carbon fuel, natural gas is very important. Due to the increasing demand for energy and environmental issues, it can be predicted that it will remain very important in the next few decades. According to the data, the consumption of natural gas in China increased from about 1.1 billion cubic meters in 1965 to 1973 billion cubic meters in 2015 (see Figure 1), which shows that it has increased nearly 180 times.(Yang et al.,2019)

At this stage, China's natural gas market is not very complete, the regulation is strict, and the price is not clear. These reasons lead to serious restrictions on the development of natural gas. Therefore, in order to increase the demand for natural gas, China has been looking for a pricing system for natural gas. During the period of natural gas development, the reform has experienced three periods: single government pricing period (1965-1993), mixed government pricing and government guided pricing period (1994-2005) and government guided pricing period (2006 to present) (Figure 1). In view of the problems in this process, China has issued the reform plan. Therefore, the final effect has important theoretical and practical significance. (Boersma et al.,2017)

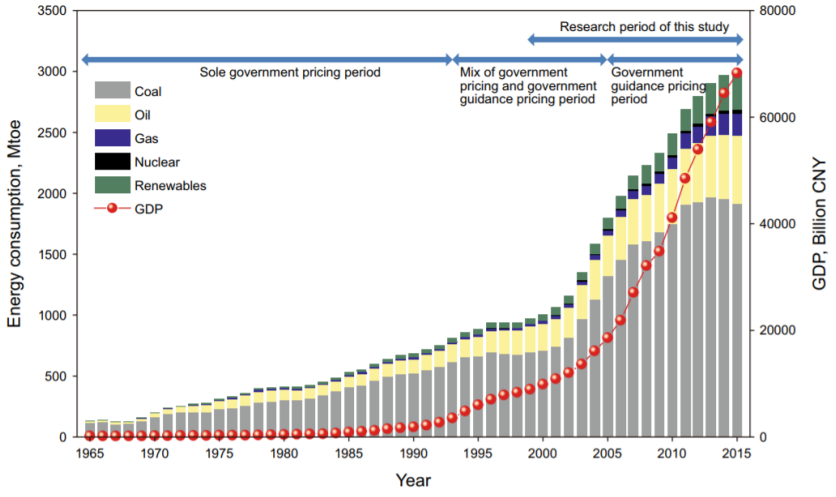

FIGURE 1 Primary energy mix,GDP, and natural gas price reform milestones from 1965 through 2016 in China.(BP (2017), Dong et al.)

In the United States, natural gas is more environmentally friendly than traditional energy because of its low carbon dioxide emissions, low energy cost and sufficient domestic supply. However, due to the pricing of facilities and other issues, the use of natural gas as an important energy source in the United States is more restricted. Economically, unlike oil, natural gas is an infrastructure driven industry. This means that its price depends on a range of regional markets, and the independent development of these markets depends on the nature of the infrastructure and existing regulations. As a result, natural gas suppliers are more likely to face the risk of disruption than oil producers.(Boersma et al.,2017)

However, the risk degree of this temporary supply shock should not be exaggerated, because different users have different supply demands. On the other hand, generators with changing demand need more power supply, but the most respected groups are still residents, public service or commercial consumers who have no alternative ability.(Boersma et al.,2017)

Around 2017,natural gas price dynamics in Europe show that, to some extent, regional price differences are close to transportation costs. With the increasing number of global importers and exporters, market liberalization and the ability to enter the global LNG market mean that the number of buyers and sellers in the European natural gas market is also increasing, which reflects the trade of organized market transactions. With the maturity of European market and the overall decarburization of European energy industry, the natural gas market and its current regulatory system are facing many challenges.(Boersma et al.,2017)

4 APPLICATION OF NATURAL GAS

For natural gas, after the discovery of its production and function, its application has gradually developed. Previously, there were many categories of natural gas, and the different kinds of natural gas produced according to these categories also have their related applications. These applications also have different directions, such as the form of application and related products. It will be based on these two aspects.(Liang ,2012)

4.1 Application mode

Natural gas also has a lot of utility in the years when it has been widely used. According to the form of natural gas, different aspects of its application are also introduced. For example, natural gas can be used as fuel in industry or residential life, in process production, in power generation, as automobile fuel instead of traditional petroleum fuel, etc, Next, it gives a brief classification and overview of this aspect.(Han et al.,2004)

4.1.1 Industrial fuel

Natural gas is used instead of coal for heating factories and making boilers. The natural gas power generation can alleviate energy shortage and reduce environmental pollution. From the perspective of economic benefits, the use of natural gas in power generation makes less investment, short construction period and strong competitiveness. Natural gas also has better uses for the environment in industrial applications and power generation, including:(Han et al.,2004)

TABLE 2 Comparing the GHG emissions of several fossil fuels(Chemistry Central Journal,2012)

Pollutant(pounds per billion btu of energy input)	**Natural gas**	**Oil**	**Coal**
Carbon dioxide	117,000	164,000	208,000
Carbon monoxide	40	33	208
Nitrogen oxides	92	448	457
Sulfur dioxide	1	1,122	2,591
Particulates	7	84	2,744
Mercury	0.000	0.007	0.016

At first, It can be seen from table 2 that according to the material comparison of natural gas, oil and coal after combustion, we can know that natural gas emits less greenhouse gases and is more environmentally friendly. Secondly, natural gas can be added to coal-fired or oil-fired boilers to reduce pollutant emissions. The natural gas releases a small amount of sulfur dioxide, reducing the amount of sludge produced in the industrial process. And the preferred fuel for its equipment is natural gas, fuel cells and combined cycle generation.(Liang ,2012)

4.1.2 Natural gas chemical industry

Natural gas is the best raw material for nitrogen fertilizer production, with the characteristics of less investment, low cost and less pollution. Chemical products are produced from natural gas. Natural gas can be made into synthetic ammonia, ethylene and acetylene by purification, separation and oxidation. In the world, 80% of synthetic ammonia, 90% of methanol and more than 75% of acetylene are produced from natural gas.(Chang,2005)

4.1.3 Urban gas industry

In particular, domestic fuels for residents include conventional natural gas and unconventional natural gas such as coal-bed methane and shale gas. It is mainly used for daily use after natural gas production. The economic benefit of natural gas as civil fuel is also greater than that of industrial fuel. In residential life, public buildings and commercial enterprises, gas is used for hot water and food preparation, drying, heating, refrigeration and air conditioning.(Liu et al.,2009)

4.1.4 Compressed natural gas vehicle

Replacing automobile oil with natural gas has the advantages of low price, less pollution and safety. Natural gas is a high quality and efficient clean energy. Carbon dioxide emissions are only half that of coal, and other serious pollutants are almost zero. For the development and utilization of natural gas, countries all over the world also attach great importance to this. Globally, the amount of natural gas resources is far greater than that of oil, and the development of natural gas is guaranteed by sufficient resources.(Han et al.,2004)

4.1.5 Enhanced natural gas

It is a new type of energy-saving and environment-friendly industrial gas, which is based on natural gas and mixed by gas agent intelligent mixing equipment and natural gas synergist. Its combustion temperature can be raised to 3300 ℃, and can be used for industrial cutting, welding and crevasse making. It can completely replace acetylene gas and propane gas. It can be widely used in steel plants, steel structures and shipbuilding industries, and can be safely used in the cabin.(Liu et al.,2009)

4.2 Product application

Natural gas is an important energy, which is widely used as city gas and industrial fuel; however, the so-called natural gas only refers to a kind of hydrocarbon rich combustible gas stored in the deeper strata, and the natural gas symbiotic with oil is often called oilfield associated gas. Natural gas fuel is one of the earliest alternative fuels widely used, which is divided into compressed natural gas (CNG) and liquefied natural gas (LNG).

4.2.1 Liquefied gas

When natural gas is cooled to - 162 ℃ under normal pressure, it changes from gaseous state to liquid state, which is called liquefied natural gas (LNG). The main component of LNG is methane, with a small amount of ethane, propane and nitrogen. Natural gas is further purified in the process of liquefaction. Methane has higher purity, almost no carbon dioxide and sulfide, and is colorless, tasteless and non-toxic. The main component of natural gas is methane, and its critical temperature is 190.58k. Natural gas liquefaction and storage technology has gradually become a major advanced technology. There are many advantages of liquefied natural gas, for example, compared with natural gas, liquefied natural gas has the advantages of convenient storage and transportation, good safety, environmental protection and so on. (Chem. Soc. Rev., 2021,50, 2984)

Liquefied petroleum gas (LPG) is one of petroleum products. It is a colorless and volatile gas obtained by pressurization, cooling and liquefaction of refinery gas or natural gas (including oilfield associated gas).Liquefied petroleum gas (LPG) is a kind of petroleum tail gas left in the process of refining gasoline, kerosene, diesel, heavy oil and other oil products. By using certain procedures, the oil tail gas is recycled, and the measures of pressurization are taken to turn it into the liquid and put in a pressure vessel. It is mainly composed of ethylene, ethane, propane, and a small amount of pentane and sulfur compounds. Once it flows out, it will vaporize into combustible gas about 250 times the original volume, and it is very easy to diffuse, and it will burn or explode when encountering open fire.(Chem. Soc. Rev., 2021,50, 2984)

The corresponding reserves of coal-bed methane in China are very large, and the reserves are basically the same as that of natural gas. Its basic component is methane. In addition to cheap chemical raw materials, it is mainly used as fuel. It can not only be used as the fuel for residents' life, but also as the fuel for vehicles such as automobiles and airplanes. The use of coalbed methane after liquefaction has the advantages of economy and safety. (Chem. Soc. Rev., 2021,50, 2984)

4.2.2 Compressed gas

Compressed natural gas (CNG) is a kind of natural gas which is pressurized and stored in a container in gaseous state. Besides natural gas from oil fields and natural gas fields, compressed natural gas can also be used to produce biogas (mainly composed of methane).The components of compressed natural gas and pipeline natural gas are the same, and the main component is methane (CH4). Compressed natural gas can be used as vehicle fuel. Compressed natural gas (CNG) can be used to make liquefied natural gas (LNG). This kind of vehicle using compressed natural gas as fuel is called NGV. Liquefied petroleum gas (LPG) is often confused with compressed natural gas (CNG). In fact, there are obvious differences between them. The combustion gas sources in people's life are roughly divided into three categories: liquefied petroleum gas, artificial gas and natural gas.(Chem. Soc. Rev., 2021,50, 2984)

4.2.3 Artificial gas

Coal gas is made from coal or coke and other solid raw materials by retorting or gasification. Its main components are carbon monoxide, methane and hydrogen. Therefore, it can be divided into the following three types according to the different production methods: retort gas, gasified gas and oil gas. Therefore, the gas is toxic and easy to form explosive mixture in the air, which should be paid great attention to when it is used.(Chem. Soc. Rev., 2021,50, 2984)

5 NATURAL GAS EXPLOITATION

Methane hydrate (or gas hydrate) is composed of water molecules containing methane (the main component of natural gas). They may be one of the largest carbon-based fuel storage depots in the world. However, due to the abundant resources of conventional natural gas and shale gas, there is no economic power for the development of natural gas hydrate resources, and there is no commercial scale exploitation technology.(U.S. Department of Energy,2012)

Gas hydrates can be found under permafrost in the Arctic, or on the seafloor. They can also be formed during drilling and production. However, so far, gas hydrate has provided more problems than solutions during this period. Gas hydrate formed in deep water production will hinder operation; for decades, it has been a challenge to manage or prevent the formation of gas hydrate in deep water oil and gas wells and pipelines. To solve the problem of gas hydrate is an important part of deep-water drilling and production planning. However, at some point in the future, gas hydrate may become a potential source of natural gas. When a cubic foot of gas hydrate returns to the earth's surface, it releases 164 cubic feet of gas.(U.S. Department of Energy,2012)

According to the U.S. Geological Survey in 2012, natural gas hydrates in the world may contain more organic carbon than coal, oil and other forms of natural gas combined. Estimates of gas hydrate resources range from 10000 trillion cubic feet to 100000 trillion cubic feet. Using these resources will require a lot of additional research and technical improvements. The U.S. Department of energy recently selected 14 gas hydrate research projects to receive funding, which is based on a successful experiment in early 2012 to extract stable natural gas flow from natural gas hydrates on the northern slope of Alaska. Japan is also studying the production of gas hydrates from deep-water basins near its coast.(U.S. Department of Energy,2012)

Taking shale gas as an example. Shale is a common fine-grained sedimentary rock rich in organic matter, containing low concentrations of radioactive nuclide, which are adsorbed on organic matter and clay minerals (Smith 2011). During burial, in shale, some of gases can then be produced by hydraulic fracturing of rocks. (Keshavarzi et al. 2012)

The hydraulic fracturing process requires the use of fracturing fluid. When the fracturing fluid is pressurized, it will produce fractures and invade the shale reservoir, and then return to the surface through the well-bore after fracturing (Anderson et al. 2010; Gregory et al., 2011) . This is referred to as a reflux fluid. Flow-back fluids are usually highly salty and contaminated with dissolved and suspended solids, heavy metals, fracturing chemicals, and different concentrations of natural radioactive materials (NORM) (Edmiston et al., 2011; Warner et al., 2013). Many sedimentary shale formations may contain high concentrations of radium, uranium and so on (Walter et al. 2012).

The uranium content in many shale formations ranges from 0.01% to 0.02% (McKelvey and Nelson 2006). Radium 226 and radium 228 are usually the most abundant radioactive nuclide in the backwater (Abdeen and Khalil, 1995; Barbot et al., 2013). Radium is more soluble than most of the fixed uranium and thorium isotopes, so it can be dissolved in pore water and hydraulic fracturing fluid (Smith, 1992; Abdeen and Khalil, 1995), which can then flow back to the surface after hydraulic fracturing (Edmiston et al., 2011).

Similarly, radon is a relatively short daughter product of radium decay (radon has a half-life of 222 – 3.8 days and radium has a half-life of 226 = 1601 years). Therefore, although radon is usually present in groundwater (e.g., Mullinger et al., 2009), radon has not been detected in the analysis of back-flow fluids. Radioactive nuclide is the source of ionizing radiation, the source of ionizing radiation is naturally produced food, water, medical exposure, cosmic rays. It is very common in daily life. (World Health Organization, 2012) For example, the average radon level in 17000 homes in Carrick, Cornwall, is 145 Bq m − 3 (Becquerel per cubic meter), almost seven times the average of 21 Bq m in the UK (UK health protection agency, 2012).

Due to the existence of these radioactive substances, more attention should be paid in the mining process, otherwise it will cause more serious pollution. In this process, the fracturing fluid used also contains potential hazards. Since fracturing fluid formulations are usually tailored to specific reservoirs, it is necessary to conduct on-site assessment of the potential hazards of each fracturing fluid. Evaluating two fluids used so far in shale gas and coal-bed methane reservoirs in Germany. By evaluating the two kinds of fluids (slippage water and gel fluid improvement) that may be applied to shale gas reservoirs and coal-bed methane reservoirs, the plan improvement of fracturing fluid is considered.(Bergmann et al., 2014)

Table 3 Comparison of two fracturing fluids(Environmental Sciences Europe ,2014)

Function	Fracking fluid used at Damme 3				Planned improvement of a slickwater fluid			
	Additive	Dissolved concentration in fracking fluid	Risk quotient based on toxicological assessment	Risk quotient based on eco-toxicological assessment	Additive	Dissolved concentration in fracking fluid	Risk quotient based on toxicological assessment	Risk quotient based on eco-toxicological assessment
Clay stabilizer	Tetramethyl-ammonium chloride	520 mg/L	1,733,000	Database insufficient (>2,600,000)	Cholinium chloride	750 mg/L	< 43	210
Friction reducer	Hydrotreated light petroleum distillates	220 mg/L	2,200	55,000	Butyl diglycol	350 mg/L	40	6,600
Surfactant	Ethoxylated octylphenol	36 mg/L	120,000	20,000	Polyethylene glycol monohexyl ether	130 mg/L	743	760
Biozide	Isothiazolinone derivative	4 mg/L	7,520	72,000	(Ethylenedioxy)-dimethanol	1,000 mg/L	10,000,000	Database insufficient (139,000)

Table 3 compares the potential hazards of slick-water fluids used in shale gas reservoirs in 2008 to the composition of planned improvements. The assessment concluded that the oil and water slick used in 2008 had high toxicological and ecotoxicological potential hazards. The fracturing fluid was then modified, but the three additives used were replaced with less dangerous alternatives. Just because of the high concentration of formaldehyde, there is still a lot of risk in the modified liquid. For this fungicide, there is very little data to evaluate.(Bergmann et al., 2014)

For the three dangerous additives that were still in use in 2008, they were evaluated to see if they could be replaced by other substances. But their assessment data still exist, suggesting that service companies in the past had not considered the possibility. Progress in reducing the use of additives and finding alternatives to dangerous substances such as highly toxic mutagenesis suggests that progress is possible.(Bergmann et al., 2014)

6 THE DEVELOPMENT AND FUTURE OF NATURAL GAS

Since 2000, China's natural gas production and consumption has been growing rapidly. In 2014, its output reached 134.5 billion cubic meters, while its consumption reached 185.5 billion cubic meters (BP 2015). It shows that China's natural gas industry has entered a stage of rapid development. Its role has gradually become more important. Therefore, reasonable prediction of natural gas development is of great significance.(NEA 2013)

In the aspect of prediction, many scholars have studied it. In this aspect, Jebaraj and Iniyan have made great contributions. They have made a detailed introduction and classification for research of prediction, which makes our understanding of this aspect have great benefits. In the aspect of natural gas prediction, scholars have made great achievements in Europe, Asia Pacific and other regions (Szoplik, 2015; Aguilera et al., 2014; Demierre et al., 2015), and Italy, Turkey, etc. (Bianco et al., 2014; Primoz et al., 2014).

In this process, the most famous prediction model used abroad is Hubbert model. In China, Weng model will be used to predict the development status of natural gas. Since then, based on China's development in this field, various forecasting models have emerged. At present, HCZ model (Hu et al., 1995) and generalized Weng model (Chen, 1996) based on Oilfield statistics are the most popular models. In addition, there are also studies on the various cycle Hubbert model (Feng et al., 2010; Boqiang and Ting, 2012).

At the same time, there are also some predictions based on different models, which are combined to carry out the prediction research on natural gas production (Yuan et al. 2007; Li et al. 2009;Granger and Ramanathan 1984).Although the combination model can improve the accuracy in some ways, In people's real life, the combination model will lead to the uncertainty of the overall combination model because of the uncertainty of the results of each model, which leads to a large margin of error in the forecast.(NEA 2013)

In order to solve the problem of climate change, China plans to achieve the peak of carbon dioxide emissions around 2030, and try its best to reach the peak ahead of time, while reducing the emission intensity by 60% - 65% from the level of 2005.But at present, coal is still better than natural gas in economic development. In 2012, nearly half of China's carbon emissions came from coal-fired power generation. (NEA 2013)

In Europe, the process of natural gas market liberalization and the establishment of a single natural gas market started with the first reform in England and Wales around 1990. From then on, some European countries began to implement it, in order to let all EU member states establish a single natural gas market together. In 2016, the price of natural gas in Europe is gradually unified, which also shows that the development of natural gas related commodity market is better than before. (Review of Industrial Organization,2019)

According to the comparison between the forecast results of IEA's world energy outlook 2015 and BP's energy outlook 2035, the forecast of China's natural gas production is shown in Table 4. These two forecasts are generally optimistic. The average annual output increases by 4.1%, 5.1% and 4.4% respectively. BP is expected to grow fastest from 2030, when unconventional gas is expected to grow significantly in China.(Chemistry Central Journal,2012)

TABLE 4 Comparison of natural gas production forecast(Chemistry Central Journal,2012)

	2020	2025	2030	2035
IEA	1720	2120	2600	3090
BP	1812	2324	2981	3822
Forecast in this work	2037	2587	2987	3159

National natural gas production is on the rise rapidly. By 2014, China's total natural gas production was 1.5 trillion cubic meters, with great potential for growth. As shown in Figure 2, the growth trend of national natural gas production can be obtained from the superposition of regional production. This shows that China's natural gas production will continue to grow rapidly. In 2020 / 2030 / 2036, the production will exceed 2000 / 300 / 323 billion cubic meters respectively, and then gradually decline.(Pet. Sci. ,2016)

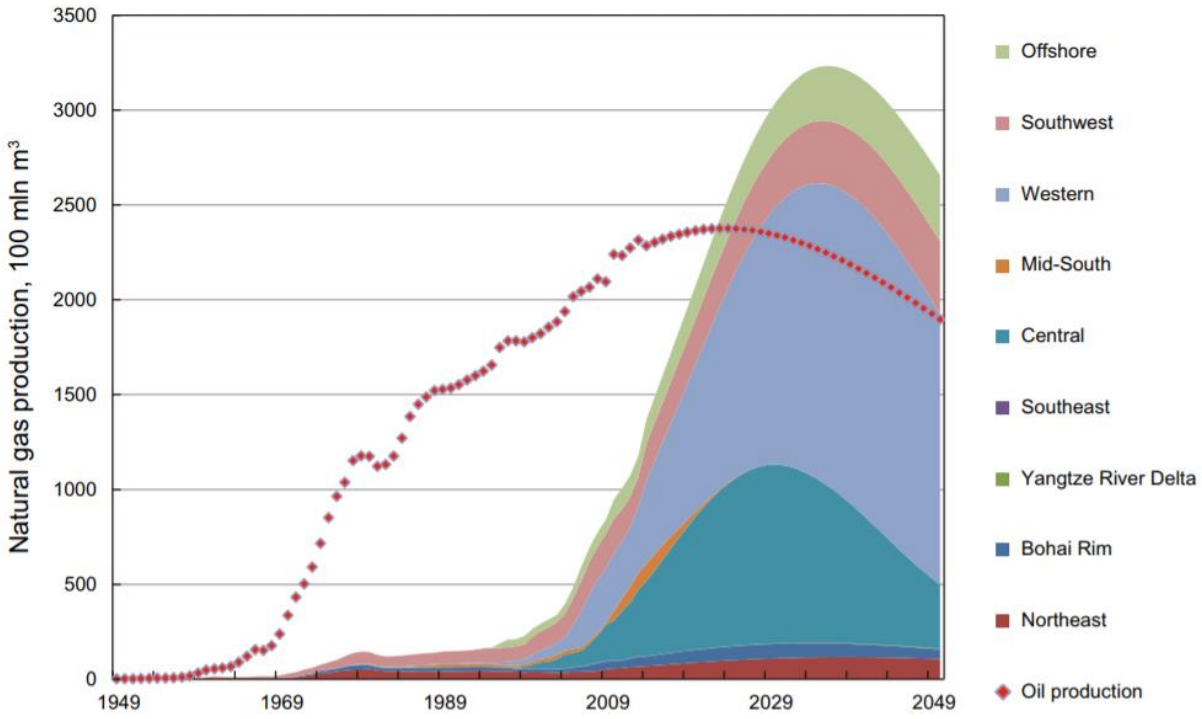

FIGURE 2 Past and forecast annual natural gas production in China and comparison with that of oil(Pet. Sci. ,2016)

In addition, China's natural gas production will triple that of 2014. It is estimated that from 2030 to 2044, China's annual natural gas production will remain at more than 300 billion cubic meters for 15 consecutive years, which will become an important energy source for China's economic and social development. Using the same method as natural gas prediction, the oil production in China is predicted, and the results are shown in Figure 2. The forecast shows that China's oil production will continue to grow, reaching peak production of 214 million tons or 237 billion cubic meters of natural gas equivalent per year by 2024. (Pet. Sci. ,2016)

However, China's oil production growth potential is relatively small, and the growth is relatively moderate. According to the current growth trend of natural gas, China will enter a new stage around 2020, in which oil and natural gas will play a role together in energy, and natural gas will also play a more important role in China's energy industry. In other words, natural gas will provide more abundant energy for China's economic and social development in the future.(Pet. Sci. ,2016)

7 CONCLUSION

Starting from natural gas, this paper expounds the basis, current situation and development of natural gas as clean energy. At present, natural gas has been widely used all over the world. There is no doubt that natural gas has good use value. Compared with oil, natural gas will be reused gradually due to less pollutants released by environmental protection. The natural gas demand forecast has a great influence on planning.

At the same time, it points out that if the problems in the planning stage are not properly solved, there may be the risk of mismatching the development of natural gas supply and demand infrastructure in time and space. For natural gas, the market pricing mechanism should be adopted as far as possible to realize the optimal gas distribution strategy and minimize the total supply cost. Scientific prediction of future natural gas demand is conducive to better infrastructure planning.

At the same time, China's natural gas production has great potential for growth, and the natural gas production in most regions will maintain long-term growth; in addition, the rapid growth of natural gas production will help China enter the stage where oil and natural gas jointly dominate the energy structure and provide rich sources for China's energy consumption. Therefore, more attention should be paid to the development of natural gas, which is also very beneficial. In the future, natural gas will get better development.

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