

China's fuel gas sector: History, current status, and future prospects



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ABSTRACT

China has a unique urban pipeline network of three types of fuel gases: manufactured gas (coal gas), Liquefied Petroleum Gas (LPG), and natural gas. Manufactured gas, which is often seen as an outdated technology in the western world, is still widely used in Chinese cities. LPG is distributed through community-based pipelines in many Chinese cities, in addition to its distribution in cylinders and canisters in rural areas. Natural gas consumption is increasing throughout China, particularly as a cooking fuel. Expanding the production and supply of natural gas in China faces many challenges. In particular, China's controls on natural gas prices have deterred investment in exploration and natural gas imports. However, recent price decontrols of unconventional natural gas (defined in China as shale gas, coal-bed methane, and coal-to-natural-gas), and recent pricing reforms, appear likely to increase natural gas use. The prospect for increased exploration is promising but will still depend greatly on the future of institutional reforms. In the near term, regulatory reforms toward a more market-driven system will be the most critical issue in the development of China's fuel gas sector.

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1. Introduction

Gaseous fuels comprise a small but growing share of China's energy system. In most countries, household gas from a pipeline is generally synonymous with natural gas. In contrast, China's urban pipeline network of fuel gas is supplied by three major gas types: 1) manufactured gas, mostly hydrogen (H₂), carbon monoxide (CO), methane (CH₄) and other hydrocarbons; 2) natural gas, primarily methane; and 3) petroleum gas, primarily propane (C₃H₈) and butane (C₄H₁₀). Manufactured gas was widely used in U.S. and European cities in the nineteenth and early twentieth century (Tarr, 2004). China deployed manufactured gas extensively during the latter half of the twentieth century, after the western world had started to phase it out. In the United States, for instance, natural gas quickly gained market share and replaced manufactured gas during the 1930s–1950s (Hatheway, 2012). Many other countries converted from manufactured gas sometime in the mid-to-late twentieth century (Wang and Gao, 2008).

China's fuel gas sector was underdeveloped throughout most of the 20th century. From the 1950s to the 1970s, China had a planned economy and endured slow economic development. Unlike the United States, which decontrolled natural gas prices in the 1980s,

China has maintained price controls on natural gas through today. Not surprisingly, artificial price controls have led to chronic shortages and market distortions in China (Rockoff, 2008).

Since U.S. natural gas prices were decontrolled in the 1980s, natural gas has evolved from a resource that was scarce in the United States to one of its most abundant energy resources. Inspired by the U.S. experience, China has recently initiated regulatory reform and partial price decontrols to encourage the development of unconventional gas. Just as it was for the United States in the 1970s–1980s, China's natural reform of natural gas pricing has been a slow and politically difficult process (Zhao, 2011a, b). Although there has been progress in recent years, the prospect of future reform remains uncertain.

To our knowledge there has been no systematic examination of the historical developments and unique regulatory environments of China's fuel gas utilities. The prevalence of manufactured gas use in China and the 20-year deployment of urban LPG pipeline networks with envisioned eventual conversion to natural gas is largely unknown outside of China, as is the evolution of institutional restructuring and price controls for natural gas there. Although China's fuel gas sector is largely controlled by the government, it is gradually moving towards deregulation, a change that will result in the phasing out of some antiquated technologies and the adoption of more advanced ones. By tracing historical developments, and using history to understand the current status and future prospects of fuel gas in China, we analyze the fuel gas sector in a way that

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should benefit energy and environmental policymakers as well as entrepreneurs and technical experts.

Here, we examine the three main types of fuel gases – manufactured gas, LPG, and natural gas – currently supplied in China’s urban gas pipeline networks. Each type has a unique history of development and is encountering different challenges. Manufactured gas is still widely used in hundreds of cities, although many cities are now converting their manufactured gas systems to natural gas. LPG currently serves the most people in China as the most widely accessible cooking fuel in cities and villages. Natural gas is the fastest growing of the three gas types and is the focus of current regulatory reform, a topic we examine in detail. The pace of pricing and regulatory reform will likely determine how quickly China’s fuel gas sector develops.

2. Historical development of fuel gas in China

A number of historical developments have led to China’s current unique structure for its fuel gas sector. This background provides important insights into how China’s fuel gas infrastructure became well established on the demand side but underdeveloped on the supply side. As described above, manufactured gas is still an important part of China’s energy economy. The widespread pipeline networks used for delivering manufactured gas for the retail market can be easily converted to deliver natural gas. Such retail delivery networks are capital intensive to build. Without the existence of the manufactured gas networks, China’s retail demand for natural gas would not be able to expand at such rapid speed.

The natural gas industry is, in our view, the most regulated and least flexible energy sector in China. Price-controls and a national monopoly on natural gas industry and mineral rights have stymied exploration and production for decades. Reform has been slow and unbalanced, focusing primarily on unconventional gas but overlooking the potential of underexplored conventional natural gas.

In contrast to the tightly controlled natural gas industry, LPG in China is a more market-driven commodity. The commercial success of pipelined LPG provides a showcase for what a deregulated natural gas market could be. The market-driven LPG systems provide sufficient supply at market prices that are higher than the controlled manufactured gas and natural gas, but the higher prices have proven to be commercially viable. The on-going pilot pricing reforms on imported LNG is increasing the supply of natural gas and allows many coastal cities to convert from pipelined LPG to cheaper imported natural gas.

2.1. Manufactured gas

Manufactured gas, also known as coal gas or town gas, was widely used in the United States and Europe before the mid-twentieth century. Today, China still employs manufactured gas in hundreds of cities. China’s national standard on manufactured gas (GB 13612–2006) classifies two types of manufactured gas. Type 1 is made from the pyrolysis of coal, while Type 2 is made by reacting steam with diverse fossil fuel sources, including coal, oil, LPG, or natural gas. Manufactured gas contains a mixture of hydrogen, carbon monoxide, methane, and other volatile hydrocarbons. The proportion of these component gases varies depending on the specific technology and feedstock materials used locally.

British entrepreneurs built China’s first manufactured gas factory and pipeline delivery system in 1865 in the Shanghai International Settlement, a joint colony of European countries and the United States (Shanghai Gas, 2008). The Japanese South Manchuria Railway Company then built manufactured gas systems in eight cities in Japanese-controlled Manchuria (Northeastern China) between 1907 and 1934 (Dalian Gas, 2002). By the end of WWII,

Shanghai and the eight northeastern Chinese cities were the only cities in China with pipeline gas supplies (Gu, 1998).

After the People’s Republic of China (PRC) was established in 1949, the PRC government nationalized the manufactured gas facilities and continued their operation. We were able to find little information on the development of manufactured gas from 1949 to 1978 in China, the era of PRC’s strictly planned economy. One article indicated that deploying urban manufactured gas had been included in the economic plans since the first five-year plan (1952–1957) (Li, 1994).

Between 1949 and 1978, manufactured gas use expanded rapidly under the planned economy, despite a Chinese economy that was largely isolated from the western world and whose economic growth rates were low. The total supply of manufactured gas in China grew from 0.34 million cubic meters in 1949 to 1725 million cubic meters in 1978 (Li, 1994; MOHURD, 2011).

In 1984, the State Council, China’s chief administrative authority, decided to promote urban fuel gas systems to replace coal burned for cooking (Wang, 1996). The use of gaseous cooking fuels greatly reduces indoor air pollution and improves public health. Cooking with pipelined manufactured gas was also more convenient and energy efficient than conventional solid cooking fuels such as biomass and coal briquettes (Edwards et al., 2004). The 7th Five-Year Plan (1986–1990) therefore stipulated that cities should actively deploy manufactured gas. By 1994, 147 cities had manufactured-gas pipelines, while only 51 cities used natural gas (Zhang, 1996). Manufactured gas continued to be the most popular gas fuel used for cooking in Chinese cities throughout the 1990s. Fig. 1 show the length of pipeline networks for manufactured gas, LPG, and natural gas in major Chinese cities and county seats (small towns that serve as administrative centers of rural counties) (MOHURD, 2011).

Manufactured gas production continued to grow throughout the 1990s and up to 2009. However, some cities had already started to convert manufactured-gas networks to natural-gas ones (Wang and Gao, 2008). In 2006, for instance, Beijing completed its transition from manufactured to natural gas. Shanghai is expected to complete its conversion by 2015.

Manufactured gas systems are typically locally-owned public utilities. Local governments’ pricing bureaus set the prices of manufactured gas according to a cost-based principle. However, local policymakers sometimes prioritize political over fiscal concerns and set the retail price below the cost of production (Hou, 2009). That tendency, coupled with volatile coal prices in recent

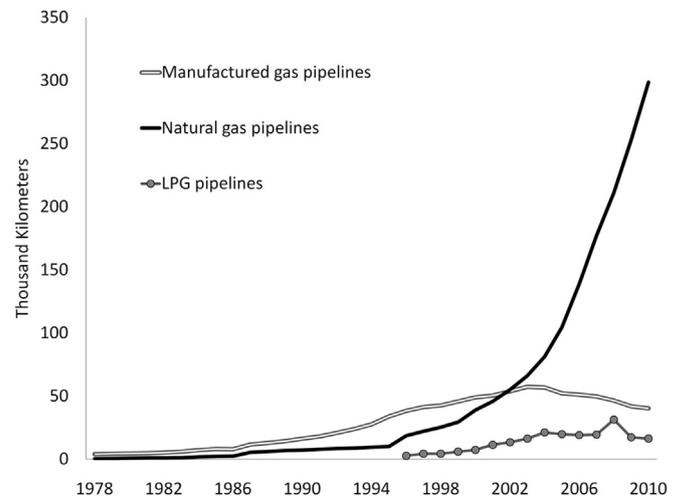


Fig. 1. Urban fuel gas pipelines in China (MOHURD, 2011).

years (Yang et al., 2012), has resulted in financial losses for manufactured gas utilities in many cities (Zhu et al., 2012; Hou, 2009).

Fig. 2 shows the total supply and residential consumption of manufactured gas in China (MOHURD, 2011). An interesting feature is that, although residential consumption started to decline in the early 2000s, the total supply has nevertheless increased rapidly. We suggest that this continued growth comes primarily from industrial uses, including the production of methanol and other coal-based chemicals (Yang and Jackson, 2012).

According to the China Urban-Rural Statistical Yearbook (MOHURD, 2011), manufactured gas systems are not only widely deployed in cities, but also in many rural areas. Chinese statistics distinguish urban and rural regions according to clear-cut administrative jurisdictions. Many county seats or rural towns in China's administrative-denominated "rural" regions are nevertheless fairly urbanized and may be equipped with manufactured gas networks. We do not know exactly how many independent manufactured gas systems exist in China today, but the number is likely to be at least hundreds and possibly thousands.

The vast number of manufactured gas facilities in China presents a challenge for environmental remediation. In light of the U.S. experiences in remediating former manufactured gas sites, such sites often remain hazardous for years after manufacturing is abandoned. The loss of records and data for abandoned sites presents additional difficulties in site characterization for remediation efforts in the United States (Hatheway, 2012). Currently, China is converting many manufactured gas systems to natural gas ones and shutting down gas-manufacturing facilities. We are unsure whether or how these shutdown sites are remediated.

2.2. Natural gas

Historical records indicate that the Chinese drilled deep boreholes and utilized natural gas in the Sichuan basin as early as the 11th century. In ancient China, the discovery of natural gas was mainly accidental, resulting from drilling for brines. Natural gas was used primarily to boil brine to produce salt (Vogel, 1993; Zhou, 2008).

Modern Chinese natural gas production began as a byproduct of oil exploration and production. From 1949 to 1978, China's government departments directly owned and managed the oil industry. The government's focus was predominantly on oil development, and it devoted few resources to natural gas

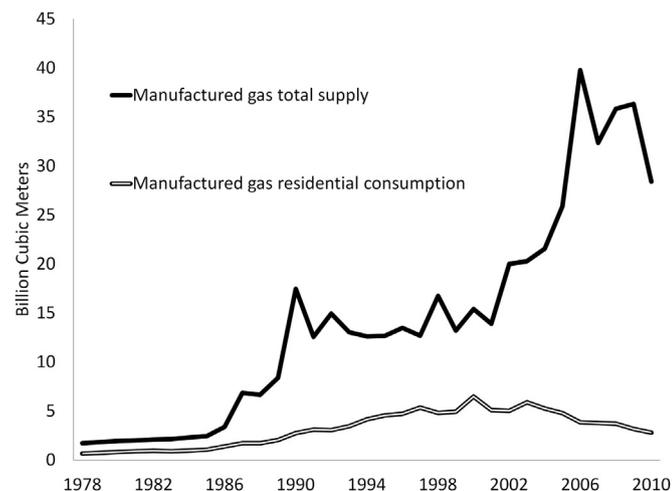


Fig. 2. Manufactured gas supply and residential consumption in China by year (MOHURD, 2011).

exploration. Moreover, the limited supplies of natural gas that were available were designated primarily for industrial purposes (Zhou, 2008). Before the mid-1980s, for instance, residential consumption accounted for less than 1% of China's total natural gas consumption (Fig. 3) (NBS, 2012). Since then, residential consumption of natural gas has been increasing rapidly. Natural gas also serves as an important transportation fuel in major cities, thanks to successful government programs for natural gas vehicles, primarily buses and taxis.

Before 1982, the Chinese government directly managed all oil and gas exploration and production in China. Since economic reform began in 1978, the government decided to separate business from government administration more fully. The Ministry of Oil Industries' assets were incorporated into three major national oil companies – PetroChina, Sinopec, and CNOOC – which now dominate China's oil and gas sector. The natural gas sector continued as a sideline business of the oil companies (Table 1).

All three companies are major players in China's oil industry and in setting energy policy (Downs, 2008). Although the National Development and Reform Commission (NDRC) technically controls the prices of gasoline and diesel, its pricing scheme is sufficiently flexible to mimic market prices approximately and to avoid serious market distortions. Therefore, despite gasoline and diesel price controls, China's oil sector has remained profitable.

China's natural gas pricing is in our view the least flexible and has endured the longest period of price control among all major commodities there. For example the Chinese government never allowed any segment of the natural gas market to be sold at international prices until 2012. The government's controlled prices have always been much lower than the prevailing market price in East Asia.

Between 1949 and 1987, the government set a single wellhead price for all natural gas in China that was only adjusted seven times during this period (Fig. 4) (Zhou, 2008). A dual-track pricing system for natural gas began in 1978. Unlike dual-track pricing for other commodities, where producers were allowed to sell their excess output (i.e., beyond the government's designated quota) at market prices, the natural gas dual-track pricing did not allow free market prices. From 1987 to 1992, natural gas producers delivered their planned quota at a government-set price (¥130/1000 m³), but the output beyond their quota received a higher, though still government-set, price of ¥260/1000 m³. Both prices are much lower than market prices in East Asia, such as Japan's LNG import price as a common benchmark. For comparison, ¥260/1000 m³ is

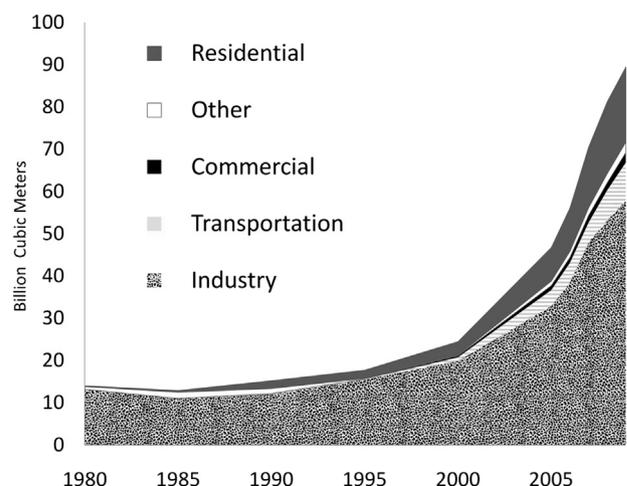


Fig. 3. Breakdown of natural gas consumption in China by sector (NBS, 2012).



Fig. 4. Wellhead prices for natural gas in China 1950–1992 (Zhou, 2008).

about US\$1.82/GJ, while Japan's LNG import cost was US\$3.54/GJ in 1987.

In 1992, China's national planning commission implemented a more complex pricing scheme for natural gas. The pricing differed not only according to whether it is within a planned quota, but also what the use of the natural gas was, including fertilizer, residential, commercial, and industrial applications. These prices continued to be much lower than East Asian regional market prices (roughly \$3.8/GJ in 1992) (Table 2) (Zhou, 2008).

China's national planning commission adjusted natural prices again in 1994, 1997, 2002, and 2005. Each time the pricing scheme became increasingly complex. The prices not only differed due to plan or out-of-plan and user categories, but also according to which gas field it came from. Additionally, a few minor additional pricing reforms were implemented. In 2003, the NDRC began to allow the West-East pipeline to adjust its natural gas prices within $\pm 10\%$ of the government's directive prices; then in 2004 the Zhongxian-Wuhan pipeline was also allowed this same $\pm 10\%$ pricing flexibility. In 2005, the flexibility was extended to all producers. Since 2005, natural gas prices have been adjusted annually. However, government-directed prices remain much lower than East Asian's regional market prices (roughly \$11/GJ in 2010). Table 3 shows the price adjustment on June 1, 2010.

A big breakthrough in China's pricing reforms for natural gas occurred in 2012. The Chinese government not only decontrolled

Table 1
Evolution of China's natural gas institution.

Year	Managing entities of China's natural gas sector
1949–1955	Ministry of Fuel Industries
1955–1970	Ministry of Oil Industries
1970–1975	Ministry of Fuel and Chemical Industries
1975–1978	Ministry of Petrochemical Industries
1978–1988	Ministry of Oil Industries
	Spinoff of state-owned industries from government administration occurred during this period.
	1982: China National Offshore Oil Corporation (CNOOC) was established.
	1983: China Petroleum and Chemical Corporation (Sinopec) was established.
	1988: China National Petroleum Corporation (PetroChina) was established.
	Ministry of Oil Industries was abolished.
	1998: Provincially-owned Shaanxi Yanchang Petroleum Corporation was incorporated.
1988–	PetroChina, Sinopec, CNOOC, Yanchang

Table 2
Natural gas price adjustment in 1992 (Zhou, 2008).

User category	Chinese Yuan/1000 m ³		US\$/GJ	
	Plan price	Out-of-plan price	Old price	New price
Fertilizer	¥ 130	¥ 220	\$0.62	\$1.04
Residential	¥ 160	¥ 280	\$0.76	\$1.33
Commercial	¥ 210	¥ 480	\$0.99	\$2.27
Industry		¥ 240		\$1.14
Other		¥ 330		\$1.56

(Note: US\$1 = ¥5.5146 as in 1992).

the prices of unconventional natural gas, including coal-bed methane, shale gas, and coal-to-natural-gas, it also began an experimental, market-referenced pricing scheme in two coastal provinces: Guangdong and Guangxi. Technically, in these two provinces natural gas prices will still be set by the government, but the government will set the prices according to market prices of alternative fuels. The government also announced its intention to increase the frequency of price adjustments. In these two provinces, natural gas prices will at first be adjusted once a year, but the frequency of adjustment may increase to twice yearly or even quarterly in the future. In June 2013, the NDRC made another breakthrough by revising the price-setting rules for non-residential natural gas from the previous cost-plus principle to market netback principle. This revision has in fact extended the market-referenced pricing scheme to all non-residential natural gas in China. The pace of on-going pricing reform appears to be accelerating.

2.3. LPG

LPG is a product from petroleum refineries and accounted for ~6% of Chinese refinery outputs by energy content in 2009 (NBS, 2012). China's petroleum industry is dominated by three major national oil corporations. Technically, the Chinese government exercises price control on selected pivotal petroleum products such as gasoline and diesel. The wholesale prices of domestically produced LPG are subject to a price cap that is pegged to government-set gasoline prices. In contrast, imported LPG is not subject to any price controls. The government-set gasoline prices, however, are adjusted frequently to stay largely consistent with international market prices. Because of the relatively flexible price control, LPG is traded essentially as a market commodity. In consequence, LPG does not suffer the same shortages that natural gas supplies do in China.

LPG is primarily used as a domestic cooking fuel and comprised 1.2% of China's total energy consumption in 2009 (NBS, 2012). Fig. 5 shows the breakdown of LPG uses in China (NBS, 2012).

LPG is conventionally distributed through cylinders and canisters, while manufactured gas and natural gas are typically delivered to households through pipelines in China and globally. The different modes of distribution can be explained by the physical features of the fuels. LPG can be more safely and economically stored as a liquid than manufactured gas and natural gas can. While LPG is typically more expensive than competing gases, its ease of liquefaction enables it to reach markets without pipeline infrastructure. In contrast, where pipelines are available, LPG is largely uncompetitive in price. LPG is by far the most widely available gaseous cooking fuel in China, serving both urban and rural markets (MOHURD, 2011).

Some planners for new urban regions also prefer LPG to manufactured gas because LPG is safer and cleaner than manufactured gas, which often contains toxic carbon monoxide (CO) and produces more air pollution, waste water, and soil contamination during manufacture. Many cities with existing manufactured gas

Table 3
Natural gas price adjustment in 2010.

Gas field/pipeline	User category	Chinese Yuan/1000 m ³		US\$/GJ	
		Old price	New price	Old price	New price
Sichuan-Chongqing gas field	Fertilizer	¥ 690	¥ 920	\$2.64	\$3.52
	Industry	¥ 1275	¥ 1505	\$4.88	\$5.76
	Urban industry	¥ 1320	¥ 1550	\$5.05	\$5.93
Changqing oil field	Urban non-industry	¥ 920	¥ 1150	\$3.52	\$4.40
	Fertilizer	¥ 710	¥ 940	\$2.72	\$3.59
	Industry	¥ 1125	¥ 1355	\$4.30	\$5.18
Qin Hai gas fields	Urban industry	¥ 1170	¥ 1400	\$4.47	\$5.35
	Urban non-industry	¥ 770	¥ 1000	\$2.94	\$3.82
	Fertilizer	¥ 660	¥ 890	\$2.52	\$3.40
Xinjiang gas fields	Industry	¥ 1060	¥ 1290	\$4.05	\$4.93
	Urban industry	¥ 1060	¥ 1290	\$4.05	\$4.93
	Urban non-industry	¥ 660	¥ 890	\$2.52	\$3.40
Dagang, Liaohe, Zhongyuan oil fields	Fertilizer	¥ 560	¥ 790	\$2.14	\$3.02
	Industry	¥ 985	¥ 1215	\$3.77	\$4.65
	Urban industry	¥ 960	¥ 1190	\$3.67	\$4.55
Other gas fields	Urban non-industry	¥ 560	¥ 790	\$2.14	\$3.02
	Fertilizer	¥ 710	¥ 940	\$2.72	\$3.59
	Industry	¥ 1340	¥ 1570	\$5.12	\$6.00
West-East pipeline	Urban industry	¥ 1340	¥ 1570	\$5.12	\$6.00
	Urban non-industry	¥ 940	¥ 1170	\$3.59	\$4.47
	Fertilizer	¥ 980	¥ 1210	\$3.75	\$4.63
Zhongxian-Wuhan pipeline	Industry	¥ 1380	¥ 1610	\$5.28	\$6.16
	Urban industry	¥ 1380	¥ 1610	\$5.28	\$6.16
	Urban non-industry	¥ 980	¥ 1210	\$3.75	\$4.63
Shaanxi-Beijing pipeline	Fertilizer	¥ 560	¥ 790	\$2.14	\$3.02
	Industry	¥ 960	¥ 1190	\$3.67	\$4.55
	Urban industry	¥ 960	¥ 1190	\$3.67	\$4.55
Sichuan-Shanghai pipeline	Urban non-industry	¥ 560	¥ 790	\$2.14	\$3.02
	Fertilizer	¥ 911	¥ 1141	\$3.48	\$4.36
	Industry	¥ 1311	¥ 1541	\$5.01	\$5.89
Sichuan-Shanghai pipeline	Urban industry	¥ 1311	¥ 1541	\$5.01	\$5.89
	Urban non-industry	¥ 911	¥ 1141	\$3.48	\$4.36
	Fertilizer	¥ 830	¥ 1060	\$3.17	\$4.05
Sichuan-Shanghai pipeline	Industry	¥ 1230	¥ 1460	\$4.70	\$5.58
	Urban industry	¥ 1230	¥ 1460	\$4.70	\$5.58
	Urban non-industry	¥ 830	¥ 1060	\$3.17	\$4.05
Sichuan-Shanghai pipeline		¥ 1280	¥ 1510	\$4.89	\$5.77

(Note: US\$1 = ¥6.8275 as June 1, 2010).

infrastructures nevertheless have embedded incentives to continue operating their manufactured gas facilities. In fact some cities use LPG or even natural gas as a feedstock to produce manufactured gas, so they can avoid the costs of retrofitting pipeline systems and appliances (Hou, 2002; Shen and Li, 2003).

Because LPG is much more expensive than other fuel gases, though, the per capita consumption of LPG is lower. Fig. 6 compares the total residential consumption of LPG, natural gas, and manufactured gas in term of heat value (MOHURD, 2011).

As a result of the price controls in China, chronic shortages of natural gas created a niche market for the development of urban pipeline LPG for household distribution. Shenzhen was the first city to pioneer this mode of development, and its success has been emulated in many cities since the 1990s (See Fig. 1 for the expansion of LPG pipelines).

In 1981, the Shenzhen Special Economic Zone was established and began to plan for its urban gas system. A proposal for building a manufactured gas system was considered but eventually rejected. The city policymakers chose LPG instead because it is safer, has higher heat content, and requires lower initial investment than for manufactured gas (Xinhuanet, 2004). In 1983, a community-scale LPG pipeline network serving 15,000 households began service in Shenzhen.

The Ministry of Housing and Urban-Rural Development promoted the “Shenzhen Model” of building pipeline networks and supplying them with LPG before natural gas was widely available. The pipelined LPG networks were quickly adopted in many Chinese cities (Cheng, 2008).

From the start, most LPG pipelines were deployed with a vision of eventual conversion to natural gas. In the mid-1980s, with the historic discovery of China’s largest offshore natural gas reserve in the South China Sea (Yacheng 13-1) (Xie et al., 2008), natural gas was seen to be abundantly available in the nearby Guangdong province in the future. By 1986, most cities in Guangdong had established an ad hoc office to make plans for using this natural gas resource (Lai, 1996). Shenzhen’s city planners were no exception. As that time, natural gas was not yet available in Shenzhen but was projected to become cheaper and more abundant soon. LPG, on the other hand, is relatively expensive but was already widely available. The city planners envisioned an imminent conversion from LPG to natural gas and started to deploy pipeline infrastructure. Pipeline-distributed LPG was an interim strategy (Lai, 1996). Unfortunately, the output of Nanhai Yacheng 13-1 was only enough to supply Hainan Island and Hong Kong. Shenzhen waited for 20 years before natural gas (imported LNG) eventually became available.

The deployment of LPG pipelines not only provides infrastructure that could eventually be retrofitted to distribute natural gas, it also facilitates market penetration of LPG in urban areas. Chinese fire safety regulations forbid LPG cylinders in high-rise buildings. Building-wide or community-wide piping networks enable dwellers of high-rise apartments to use LPG where large cylinders can be safely placed outdoors to distribute the gas. LPG is typically gasified and often blended with air to prevent condensation before being fed into the pipelines. Because LPG has a higher heat content than natural gas, stoves and burners for LPG may need adjustment

Table 4
China's natural gas targets in 12th five-year plans.

Gas type	2015 Target (billion cubic meters)
Total domestic natural gas production	176
Conventional natural gas	138.5
Coal-bed methane	16
Synthetic natural gas (SNG)	15–18
Shale gas	6.5
Natural gas import	93.5

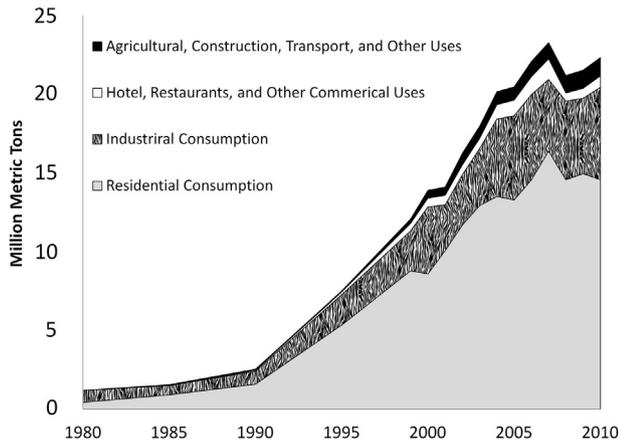


Fig. 5. Breakdown of LPG uses by sector (NBS, 2012).

or retrofiting when the networks are converted to natural gas. Some LPG/air blending intentionally mimics the heat content of natural gas in anticipation of future natural gas conversion.

The success of pipelined LPG distribution suggests that Chinese urban consumers can afford higher prices for natural gas than those controlled by the government. If policymakers garner the political support to decontrol natural gas prices, natural gas consumption is likely to grow even more rapidly than it is currently in China.

3. Prospects

Regulatory reforms will likely be the overarching variable in the future of China's fuel gas sector. The sector remains largely under government control with substantial market distortions from price

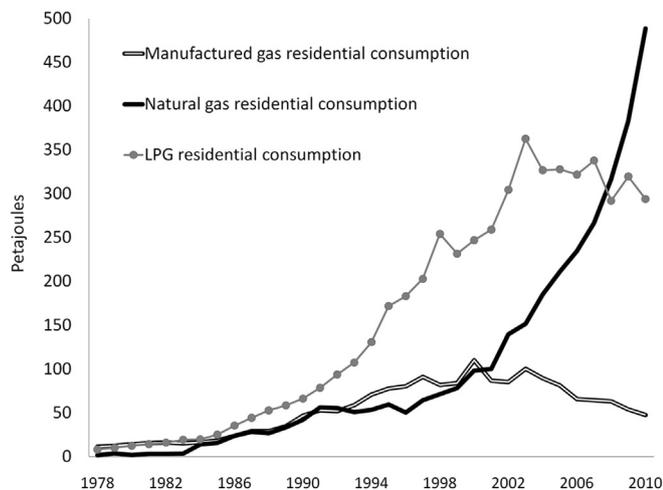


Fig. 6. Residential consumption of major fuel gases (MOHURD, 2011).

controls. Urban fuel gas systems are locally-owned public utilities. Manufactured gas, LPG, and natural gas each has a different pricing mechanism. Municipal governments' pricing bureaus set the prices of manufactured gas and adjust those prices according to the costs of production. The NDRC in the central government sets ex-factory (wholesale) prices of natural gas while local governments set retail prices. In contrast, LPG prices are largely market-driven. Although there has been some progress in regulatory reform, the process of reform has been slow and uneven - by region and by gas type.

In the following sections, we discuss recent developments and prospects of pricing reform and then analyze some challenges and opportunities for each type of fuel gas.

3.1. Pricing reform

Considerable Chinese research has examined natural gas pricing reform since the 1990s (Li and Qi, 1994; Zhao, 2011a; Zhang et al., 2009; Liu and Han, 2012). In general researchers have suggested that price controls have been a major impediment to developing natural gas in China. The actual progress in pricing reform, as discussed above, has been slow.

Because price decontrol is politically challenging in China, as elsewhere, partial decontrol is often pursued as a compromise. For example, in 1979, the United States decontrolled the prices of "new" natural gas (discovered after 1977) as a compromise prior to full price decontrol ten years later. In 2012, China decontrolled the price of unconventional natural gas, defined as shale gas, coal-bed methane, and coal-to-natural gas technologies. The decision to decontrol shale gas prices is likely inspired by the U.S. success in shale gas development. Surprisingly, tight gas, although considered to be a source of unconventional energy in the United States, is classified as conventional gas in China and therefore does not benefit from the price decontrol (Zhang and Zhang, 2012; Zhang, 2012).

The two provinces of Guangdong and Guangxi chosen for piloting a market-pegged pricing scheme of natural gas are located in regions with few natural gas resources and with no access to major natural gas pipelines. Because of the lack of resources, the pilot reform will have very low impact on domestic natural gas producers. Fuel gas consumers in Guangdong and Guangxi currently rely predominantly on LPG, which is significantly more expensive than natural gas. Because both Guangdong and Guangxi are coastal provinces, they have access to seaborne LNG imports. The market netback pricing reform announced in 2013 will likely have huge implications nationwide. The recent pricing reform will likely increase natural gas imports and encourage more investments in exploration.

3.2. Manufactured gas

Many cities have already begun converting their manufactured gas networks to deliver natural gas. The total length of manufactured gas pipelines has been declining since 2000 (Fig. 1), but the total consumption of manufactured gas continues to grow until 2006 (Fig. 2), likely driven by industrial applications.

In the past, manufactured gas from coal was a cheaper and widely available alternative to natural gas. However, rapid increases in coal prices in recent years have weakened the competitive advantages of manufactured gas. With increased awareness of pollution and concerns for safety, city policymakers will likely continue to pursue conversions from manufactured gas to natural gas wherever natural gas becomes available. We therefore expect residential consumption of manufactured gas to continue to decline in the future. The prospect for industrial use of manufactured gas, however, is less clear. China has witnessed very rapid growth in

coal-based chemical production in recent years (Yang and Jackson, 2012). Gasification is in most cases the first step in the processes of coal-to-chemicals. Modern coal-to-chemical facilities are usually large-scale and located near coal resources and relatively far from residential areas. Some decommissioned manufactured gas equipment may be relocated and reused for coal-based chemical industry, which may effectively lower their capital costs.

In the coming years, we expect many urban manufactured gas facilities to be decommissioned and the coal gasification industry to be increasingly separated from the urban fuel-gas sector. A former manufactured gas site will require considerable remediation before it can be used safely for other purposes. We recommend that the Chinese government compile a complete inventory of all former manufactured gas sites and existing facilities, as well as collect and preserve historical records of these sites and facilities.

3.3. LPG

Even though China has experienced rapid economic growth and urbanization in recent decades, roughly two thirds of its population still has no access to any type of fuel gas. These people typically burn dirty solid fuels such as coal and biomass for cooking and heating and endure greater indoor air pollution and likelihood of lung disease. In these cases, LPG provides the most readily available alternative to solid fuels. Although many coastal cities are converting from LPG to LNG, the reduced demands for LPG in these cities will likely be more than compensated by the increased demand in the vast rural regions and less developed towns and cities. As the rural economy grows, we expect the demand for LPG to increase rapidly in the foreseeable future.

3.4. Conventional natural gas

Not only are the prices of natural gas controlled below market levels in China, but access to conventional natural gas mineral rights is also strictly limited. Unlike the free-market system in the United States, only the three national oil corporations and one provincially-owned Shaanxi Yanchang Petroleum Corporation are entitled to explore for natural gas in China.

In the past, price controls and limited access to mineral rights have deterred investments in natural gas exploration. Conventional natural gas resources in China are abundant but underexplored and underdeveloped (Liu et al., 2008). Fig. 7 shows the trend of growth in proven conventional natural gas reserves in China (BP, 2012).

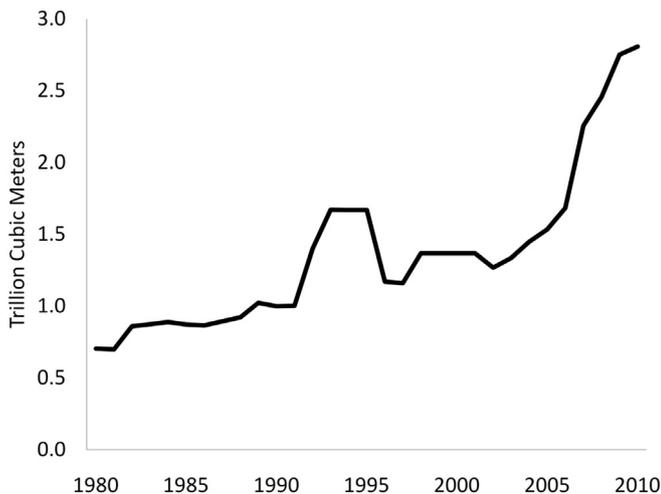


Fig. 7. Proven natural gas reserves in China (BP, 2012).

Since the early 2000s, proven reserves have been increasing quickly, likely as a result of more frequent upward natural gas price adjustments since 2005.

The prospect of future conventional natural gas development in China will depend greatly on pricing reforms and increasing access to mineral rights. Currently, most of the occurred reforms have a limited scope. The prospects for decontrolling conventional natural gas remain unclear.

An open-access pipeline network is also essential for creating a competitive market for natural gas in China (De Vany and Walls, 1994). Currently, PetroChina and Sinopec control all of China's long-distance gas pipelines. These pipelines mainly serve to transport gas from western China and central Asia to coastal cities. China is building more pipelines, both to increase the capacity of west-to-east delivery and to connect coastal city networks. With China's unique public land ownership system and the national oil companies' semi-governmental status, the siting and construction of pipelines usually proceed very quickly. China will likely have little difficulty in establishing a national gas network. Whether independent gas producers will enjoy open access to the network, however, is less certain.

China's 12th Five-year Plans (2011–2015) projected a rapid increase of natural gas production in the coming five years (Table 4). The total domestic natural gas production is expected to grow from 96.8 billion m³ in 2010 to 176 billion m³ in 2015. While China's economic planners still expect conventional natural gas to constitute the largest share, they have set ambitious targets for increased natural gas imports and extraction of unconventional gas.

3.5. Unconventional natural gas

Although conventional natural gas resources are far from exhausted in China, regulatory barriers often render them inaccessible or unprofitable to private investors. Unconventional resources are typically more expensive to explore and to develop but are relatively free from embedded political interests. Regulatory reforms for unconventional gases are thus occurring much faster than for conventional gas.

When the NDRC announced the piloting scheme of pricing reform in Guangdong and Guangxi on December 26, 2011, the announcement also included price decontrols for unconventional natural gas (Bai and Chen, 2011). In January 2012, the Ministry of Land and resources decided to list shale gas as a separate mineral type and open its mineral right access to private and foreign investors (Xinhuanet, 2012). The development of unconventional natural gas nevertheless faces numerous challenges in China. For example, the access to pipeline transmission presents a potential barrier to independent unconventional gas producers. Currently, all long-distance natural gas pipelines are owned and operated by the three major national oil companies, and the Chinese government has not yet an open-access policy for pipeline transmission. Although the price decontrols and open access may encourage private investors to develop unconventional gas, these potential developers still face uncertainties in whether they will have fair access to market delivery.

Many of the challenges are specific to each individual type of unconventional gas. In the following sections, we discuss some of these challenges for each of the three major types of unconventional natural gas (CBM, SNG, shale gas).

3.5.1. Coal-bed methane (CBM)

Energy companies in the United States pioneered the development of coal-bed methane (CBM). In China, coal-bed methane has traditionally been viewed as a coal mine safety hazard. Inspired by the U.S. success, China has begun to develop coal-bed methane as a

resource (Niu and Chao, 2011). A national corporation specializing in CBM (China CBM) was established in 1996. Traditional oil and gas companies (i.e. PetroChina and Sinopec) are also major developers of CBM.

The development of CBM in China, however, generates a conflict between the mineral rights for coal compared to CBM. Unlike in the United States, where CBM is mostly withdrawn from a surface well while the CBM reserves are underground in either unmineable coal seams or unexploited coal mines, China's CBM mostly comes from operating coal mines. CBM from un-mineable coal seams is rarely explored in China.

With a rapidly growing demand for coal, owners of coal mineral rights often are unwilling to wait for the drainage of CBM to start mining for coal. In China, the mineral rights of coal are primarily allocated by local governments, while natural gas mineral rights, including coal-bed methane, are exclusively in the central government's jurisdiction. As a result, the mineral rights for coal and coal-bed methane from the same coal seams are typically split between different entities. Coal mining companies often start digging for coal and vent the CBM that they do not own. According to an estimate by the China Coal Information Institute, China's coal mines emitted 30 billion cubic meters of CBM into the air in 2010 (Wang, 2012). For comparison, in the same year, only 1.5 billion cubic meters of CBM were consumed in China (NDRC, 2011).

CBM mineral right owners blame the coal mining companies for violating their CBM mineral rights and prefer that coal mining companies withhold mining operations until the CBM is drained (Li, 2010). In contrast, holders of the coal mineral rights blame the CBM companies for trying to block their mining operation and for using CBM rights as a means to seek financial compensation.

Recognizing this conflict, local governments have urged the central government to combine coal and CBM mineral rights into the same entity. In 2010, Shanxi-provincially-owned Jincheng Anthracite Mining Group became the first coal mining company to be awarded with CBM mineral rights, breaking the national corporations' monopoly on CBM.

China's 11th five-year plan (2006–2010) for CBM set a target to utilize 10 billion cubic meters of CBM by 2010, but only managed to reach 1.5 billion cubic meters (NDRC, 2007, 2011). The 12th five-year plan set an even more ambitious target of 16 billion cubic meters. How or whether China will resolve the issues with conflicting coal and CBM mineral rights will be an important factor in determining whether it reaches its target.

3.5.2. Synthetic natural gas (SNG)

Since 2005, and encouraged by more frequent price increases that the government set for natural gas prices, many Chinese companies have begun to invest in synthetic natural gas projects (Feng, 2011; Tang, 2011). As of June 2013, the NDRC has approved nine SNG projects, with total planned capacity of 37.1 billion m³/year. By comparison, the Great Plain Synfuels project in the United States has an SNG capacity of roughly 1.5 billion m³/year (Yang, 2009; Yang and Jackson, 2013).

Although China conducts coal gasification more widely and at a much larger scale than any other country, its gasifying activities are used predominantly for manufactured gas. The SNG technology requires more processing steps and much higher investment than for manufactured gas. From a strictly financial perspective, SNG would certainly be uncompetitive in cost with manufactured gas. However, SNG provides several advantages. SNG does not contain poisonous carbon monoxide and is therefore safer than manufactured gas. Large-scale SNG production can be located near coal mines and far from urban population centers, while manufactured gas facilities are mostly located within the cities.

The future of SNG in China will largely depend on government policies. As long as government planners decide to convert manufactured gas systems to natural gas (including SNG) and allow SNG producers to charge profitable prices, SNG should remain financially viable.

3.5.3. Shale gas

Inspired by the U.S. experience, China has initiated a plan to develop its shale gas resources. In the 12th five-year economic plan, China set the 2015 shale gas production target as 6.5 billion m³ and its 2020 target as 60–100 billion m³. All three national oil companies have partnered with foreign companies to explore for shale gas. Although the Chinese government technically has opened the access to shale gas mineral rights to independent developers, it is still unclear whether private developers, which tend to be smaller in China, will be able to compete with the national corporations.

Because of the diverse geology in China, shale gas technologies developed in the United States will likely need to be altered somewhat in China. China's potential shale gas reserves are often deeper and have more complex structure than their U.S. counterparts (Zhoi et al., 2012). They are also mostly located in remote mountainous regions, where drilling operations will be more difficult and expensive (Zhoi et al., 2012). A great deal of technological innovation will be required to commercialize shale gas in China.

The U.S. oil and gas industry is composed of numerous competing private companies, including specialized drilling and other service providers as well as technology developers (Rogers, 2011). Small independent developers, who tend to be more flexible, quick to adopt new technology, and risk-prone than large corporations, have pioneered shale gas development in the United States. In China, the three national oil companies have monopolized natural gas mineral rights historically. Private investors have only recently been allowed to explore for shale gas in China. Whether the recent reforms will lead to a competitive market and encourage innovations is still too early to tell.

The national oil companies monopolize conventional natural gas resources, which are cheaper to develop than unconventional gas. Recently, the national corporations have shown enthusiasm for exploring shale gas production, in part attributable to successful U.S. experience. Whether this enthusiasm will sustain long-term efforts in developing shale gas is uncertain. The price decontrol of unconventional gas has provided some incentive for the national oil corporations to prioritize unconventional resources over conventional ones. The partial price decontrol in fact has added another distortion to an already distorted market. The Chinese political economy is a complex and opaque system that is difficult to predict. Currently, the Chinese government's initiatives to develop shale gas focus primarily on acquiring the technology, and relatively little on replicating the business environment that created the U.S. shale gas boom in the first place.

3.6. Imports

China's natural gas market remained isolated from the rest of the world until 2006, when China's first LNG receiving terminal was completed in Guangdong province. China only started to import pipelined natural gas from Turkmenistan in 2010. Although imports began only recently, they have grown rapidly. In 2011, imported natural gas (LNG and pipelined) accounted for 23.6% of total natural gas consumption in China.

Since 2006, China has built new LNG terminals in Fujian, Shanghai, and Dalian, with many more terminals under construction. All the LNG receiving terminals are owned by one of the three

national oil corporations. The experimental pricing reform in Guangdong and Guangxi will likely trigger conversion from LPG to LNG. If the experiment is successful, the pricing reform would likely be extended to other coastal provinces. The overall direction of the reform is toward more market-referenced pricing and lesser government control. Although it is impossible to predict the future schedule of reform, LNG imports are likely to increase at whatever speed policymakers deem acceptable.

4. Conclusions

In spite of its relatively small share of China's existing energy mix, the fuel gas sector is growing quickly. Existing manufactured gas and LPG pipeline networks provides easily convertible infrastructure for the expansion of natural gas distribution. The ease of conversion from manufactured gas and LPG to natural gas explains why the residential demand for natural gas could increase at such a rapid speed. China's natural gas consumption has been increasing exponentially and will likely continue growing for many years. The limiting factor for more cities to convert their systems to natural gas is whether they can secure natural gas supplies.

The supply side of natural gas faces the largest regulatory uncertainties. Further price reforms will likely set the pace of increasing natural gas supply in China. Conventional natural gas resources still present huge growth potentials, as long as their prices continued to be adjusted closer to market levels.

The development of unconventional gas (CBM, SNG and shale gas) faces various institutional and regulatory hurdles. The vast CBM resources in China is largely underutilized or even wasted. Chinese governments should sort out the conflict between national and local interests and design an institutional arrangement to facilitate CBM development and reduce waste. For instance, the Chinese government may consider imposing a cost on venting methane to encourage CBM utilization. The future of SNG will depend on both the government's natural gas pricing policy and industrial policy for coal-based chemicals, particularly whether to approve more SNG projects (Yang and Jackson, 2013). There is currently political enthusiasm for shale gas development. Whether the enthusiasm will lead to viable production is still uncertain. The Chinese government still needs to resolve numerous regulatory and institutional barriers before unconventional gas can be commercially viable in China.

Access to transmission pipelines remains a major uncertainty for independent unconventional gas producers. Without an open access transmission policy, national corporations can use their monopoly in pipeline transmission to leverage their price bargaining power over local and private gas developers. Furthermore, price decontrol of unconventional natural gas may not be sufficient to encourage development unless companies have fair access to the market. The Chinese government should consider an open-access policy for pipeline transmission in order to provide local and private unconventional gas producers fair access to markets.

The state-monopolized structure of the natural gas industry and mineral rights that are owned and administered nationally also present severe challenges for establishing a competitive natural gas industry. Whether the Chinese government will be able to restructure its industry and increase access to mineral rights and to the Chinese market will be key to introduce competition in the industry.

The recent pricing reform appears to be moving toward a market-pegged system. Such market-pegged pricing reform will likely greatly increase the demand for imports. A more market-driven natural gas sector in China will lead to natural gas representing a much larger share in China's future energy system.

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