

China's Search for Blue Skies

Understanding LNG's Role

Batt Odgerel
Research Associate

William Pack
Senior Research
Analyst

April 2019



ABOUT THIS REPORT

Bringing an LNG project to final investment decision has traditionally required addressing the large financial risks inherent in the massive capital commitments needed to construct an appropriately scaled liquefaction facility and organize an assured long-term supply of natural gas feedstock. LNG project development investors have historically addressed these risks through long-term contracts in which both the supplier and consumer provide adequate long-term commitments to overcome the financial risks from a lumpy investment.

Many consuming centers in Asia are potentially new buyers of LNG given its effective role in addressing air pollution concerns. These consuming centers remain cautious and risk-averse making agreements for long-term LNG purchase commitments difficult to conclude. At the same time, the U.S. and other potential producing centers offer the potential to provide long-term and stable supplies of LNG at competitive prices. In response to these concerns, LNG suppliers are working through strategies to expand supply volumes under these new market conditions.

Although China has made long-term commitments for LNG imports, the country is also very active in the short-term or “spot” market. China’s potential as a very large LNG demand center remains uncertain. Estimating long-term LNG demand from China faces two unique challenges. First, China is a very large consumer of natural gas which is supplied from domestic production, overland pipelines, and LNG. Understanding the interrelationship of these supply sources is not straightforward. Second, because of the size of the Chinese market, relatively modest shifts in national priorities and government policy can have an outsized outcome on LNG demand in Asia leading to volatility in both prices and supply patterns.

This report examines China’s role as a demand center for LNG and evaluates how a range of conditions and policy initiatives could change the scale and scope of China’s demand profile in the Asian LNG market.

ABOUT EPRINC

The Energy Policy Research Foundation, Inc. (EPRINC) was founded in 1944, and is a not-for-profit, non-partisan organization that studies energy economics and policy issues with special emphasis on oil, natural gas, and petroleum product markets. EPRINC is routinely called upon to testify before Congress as well as to provide briefings for government officials and legislators. Its research and presentations are circulated widely without charge through postings on its website. EPRINC’s popular Embassy Series convenes periodic meetings and discussions with the Washington diplomatic community, industry experts, and policy makers on topical issues in energy policy.

EPRINC has been a source of expertise for numerous government studies, and both its chairman and president have participated in major assessments undertaken by the National Petroleum Council. In recent years, EPRINC has undertaken long-term assessments of the economic and strategic implications of the North American petroleum renaissance, reviews of the role of renewable fuels in the transportation sector, and evaluations of the economic contribution of petroleum infrastructure to the national economy. Most recently, EPRINC has been engaged on a joint assessment with the Institute of Energy Economics, Japan (IEEJ) of the future of U.S. LNG exports to Asia.

EPRINC receives undirected research support from the private sector and foundations, and it has undertaken directed research from the U.S. government from both the U.S. Department of Energy and the U.S. Department of Defense. EPRINC publications can be found on its website: www.eprinc.org.

© Copyright 2019

Energy Policy Research Foundation, Inc. 1031 31st Street, NW Washington, DC 20007

► +1 202.944.333 ► eprinc.org

TABLE OF CONTENTS

Executive Summary	1
History of LNG in Chinese Markets	3
Evolution of the Chinese Natural Gas Policy	5
Important Actors in the Sector	8
Bureaucracy	8
The Big Three and Other Enterprises	10
Local Authorities	13
Current Market Environment	14
Environmental and Climate Factors	16
Current Policy and Implementation	18
Projections Through 2020	19
Domestic Production and Shale Gas Potential	20
Natural Gas Supply and Storage Security and Capacity	22
Market-Based Reforms	27
Pricing Mechanism	27
Third-Party Access	34
Trading Hubs	35
Conclusion	36
Appendices	37
Appendix 1: Proposed LNG Receiving Terminals	37
Appendix 2: The NDRC Natural Gas Pricing Policy, 2010-2018	38
Appendix 3: Medium- and Long-Term LNG Contract	40
Appendix 4: Three Separate Phases of CNPC Planned UGSs Starting in 2022	41
Appendix 5: The “2+26” Key Cities Have Different Types of Natural Gas Heating Methods	41
Appendix 6: LNG Receiving Terminals and Storages Operating in China	42
Appendix 7: LNG Receiving Terminals and Storages Under Construction/Planned in China	43
Appendix 8: Natural Gas Distribution Pipelines and Supplies in Chinese Cities, 1998-2016 (km, bcm)	43
Appendix 9: Short-Term and Spot Market Trade in 2017	44
Appendix 10: Beijing Historical Weather, 2013-2017 (Celsius degrees)	45
Abbreviations	46
Bibliography	47

FIGURES AND TABLES

Figure 1: Natural Gas Consumption and Production in China, 2007-2017 (billion cubic meters)	3
Figure 2: LNG vs. PNG, 2011-2016 (bcm, %)	4
Figure 3: Average Annual Economic Growth and Energy Consumption Growth, 1991-2016 (%)	5
Figure 4: Average Annual Economic Growth and Natural Gas Consumption Growth, 1991-2016 (%)	6
Table 1: Natural Gas Production Planning and Performance (billions of cubic meters and percent)	7
Figure 5: Chinese Natural Gas Governance Structure	8
Figure 6: China’s Domestic Natural Gas Production by NOCs (2017)	10
Figure 7: China’s LNG Imports by NOCs (2017)	11
Figure 8: Composition of Energy Consumption, 1990-2016 (%)	14

TABLE OF CONTENTS continued

Figure 9: Natural Gas Consumption by Sector, 2000-2015 (bcm).....	15
Figure 10: PM 2.5 Air Pollution, Mean Annual Exposure in China (micrograms/cm).....	16
Figure 11: Bimonthly Domestic Gas Production 2013-2017 (bcm).....	17
Table 2: Natural Gas Provisions of the 13th Five-Year Plan Goals and Progress.....	18
Figure 12: China's Proven Natural Gas Reserves by Region (2006).....	21
Figure 13: Small-Scale LNG in Operation in 2015 (mtpa).....	25
Figure 14: Annual Average City Gate Gas Prices in the U.S. and China, USD/thousand cu.ft (2007-1H2018).....	28
Figure 15: Timeline of the Reforms in Non-Residential Natural Gas Pricing by the NDRC.....	29
Figure 16: Timeline of the Reforms in Residential Natural Gas Pricing by the NDRC.....	30
Figure 17: China's Natural Gas Pricing Composition.....	31
Figure 18: LNG Supply via Medium- and Long-Term Contracts in China 2006-2040 (mtpa).....	32
Figure 19: Monthly Imports and Average Values of LNG and PNG in China (Jan 2016 - Sep 2018).....	33
Figure 20: Short-Term and Spot LNG Imports in China, 2011-2017.....	34

EXECUTIVE SUMMARY

A small change in the Chinese natural gas sector can lead to an oversized impact on global markets. Indeed, China's "coal-to-gas" switching policy led to a spike in spot Asian LNG prices in the winter of 2017. The resulting opportunity for arbitrage attracted an unprecedented number of LNG vessels from the Atlantic Basin to the Pacific Basin, ushering in the beginning of a new era in the Asian gas industry. Driven by a rising political imperative to reduce air pollution, record growth has been observed in natural gas demand in China over the past decade. China surpassed South Korea as the second largest LNG importer in 2017 and is projected to surpass Japan as the world's largest natural gas importer in 2019. China's LNG import trends reflect official policy on improving air quality, concerns over energy security, the pace at which nuclear power and renewables can be deployed and the role of domestic supplies and foreign pipeline imports.

Key Findings

► **Political commitment to clean energy has driven growth in natural gas demand in China.**

The State Council, adhering to the guidance of the Communist Party, has put a great emphasis on natural gas in official government documents, including in its five-year plans and various "notices" and "opinions" as published by the Council. Despite the absence of a unified energy ministry, the Chinese economic planning agency, the National Development and Reform Commission (NDRC), has delivered strong results in promoting natural gas and LNG. In accordance with the 13th Five-Year Plan, the combined efforts of other state ministries as well as municipal and provincial governments are moving forward on national policy in this area. Even with growth in natural gas pipeline imports and continued expansion of domestic natural gas production, local and national policies will drive rising demand for LNG. Small scale LNG, expansion of LNG storage capacity, and the political imperative to improve air quality will likely drive LNG imports from 71.6 bcm in 2018 to 119 bcm by 2020. This is roughly equivalent to 90% of the expected U.S. export capacity by 2021 according to the EIA.

► **Despite the emergence of new players, national oil and gas companies (NOCs) will remain dominant in the natural gas and LNG sector.**

Beneath the bureaucracy lie more autonomous and commercialized state-owned oil and gas groups: CNPC, Sinopec and CNOOC. These monopolistic enterprises constitute the entire domestic gas production and natural gas imports by pipelines and fully or partially own over 90% of the total LNG receiving capacity in China. Against this backdrop, the National Development and Reform Commission (NDRC) and local governments pursued more competitive market policies, which prompted the emergence of the so-called "second-tier" players. Public utilities and private enterprises have begun engaging in the LNG business by leasing receiving terminals or constructing their own facilities. These second-tier players are advancing their presence in unconventional technologies such as small-scale LNG and LNG trucking. Independent entities are also engaging in spot markets to a greater extent than in the past, but these players only amount to a small volume of total Chinese LNG demand.

► **Environmental pollution and seasonal fluctuations are the biggest exogenous factors in both the long and short run, respectively.**

Air pollution in large cities has been the main cause of China's insistence on crafting clean energy policy. Along with other types of pollution, air pollution may determine the long-term growth of natural gas demand in the country. In the short run, however, seasonal fluctuations, especially winter temperatures, have demonstrated a direct impact on household consumption and the movement of LNG vessels.

Key Findings (continued)**► Chinese dependence on LNG and PNG imports will continue to grow unless major breakthroughs occur in shale gas technologies.**

China has shale gas reserves that could dwarf those in the United States. Unfortunately, due to technological barriers, geological difficulties, and lack of investment, the NOCs have not been able to tap into this potential. Unless major breakthroughs occur in shale gas, growth in domestic conventional and unconventional production will likely remain modest in the foreseeable future and lead to a growing dependence on LNG and PNG imports.

► LNG will be the main driver of growth in natural gas use through 2020; however, China faces substantial hurdles to increase the share of natural gas from its current levels to official guidance of 8.3%-10%.

China's natural gas policy can be divided into three components: substantial growth in natural gas use, security and stability of supply, and market-based reforms. Growth in natural gas use and LNG imports is projected to stay on track, but the 13th Five-Year Plan's goal to raise the share of natural gas in energy mix may slightly fall short of its planned percentage. This is largely due to China's insufficient growth in domestic output, the stalling of piped natural gas (PNG) pipeline projects and the country's overall limited upstream capacity. Imports are expected to constitute nearly half of total demand by 2020, with LNG driving that growth before the expected moderating effects of new PNG projects such as the Power of Siberia.

► Following a demand shock in 2017, official policies will be directed at obtaining supply stability through an improved storage and peak shaving system.

Approximately four million households switched from coal to gas or electricity for heating in the winter of 2017, contributing to extremely tight gas markets and high LNG prices. The transition came at the expense of societal wellbeing as a number of households and schools had to endure the winter without sufficient heating. To ensure supply security and stability, China is leveling up its storage and peak shaving capacity, particularly with regard to its underground gas storage facilities (UGSs) and LNG receiving stations and is implementing strict requirements and punishments for violations. An improved peak shaving system will smooth out the effects of seasonal variations and help to maintain a more robust LNG sector.

► Long-term LNG contracts will remain strong despite steady growth in spot trading.

Although the conventional view is that spot LNG markets are on the rise, the share of medium- and long-term contracts in total imports have remained at the same level due to recent deals with large companies such as Qatargas. This trend is supported by government policy to ensure national gas supply security.

► China has continuously shown progress in its market-based reforms, but it continues to trail far behind the gas markets in the United States and Europe.

China is striving towards more liberalized natural gas markets with improved pricing mechanisms, open access to infrastructure, and transparent gas trading hubs. The State Council has taken steps such as the unification of residential and non-residential gas prices and has initiated policy to open up third-party access (TPA) to LNG receiving terminals. China has established trading hubs in Shanghai and Chongqing to continue the liberalization of gas pricing and to set price benchmarks for Asian natural gas markets. Despite China's recent initiatives, Chinese gas pricing mechanisms are yet to be fully market-based and lag far behind those of the United States and Europe. That is, domestic gas prices remain pegged to alternative fuels and long-term LNG contracts are linked to oil prices in the Asian market; despite the first public TPA slot auction this year, it remains to be seen whether challenges stemming from a limited number of facilities and window periods could be addressed in the near future. The full maturity of Chinese trading hubs is likely to take a long time, with little interest generated internationally at the moment.

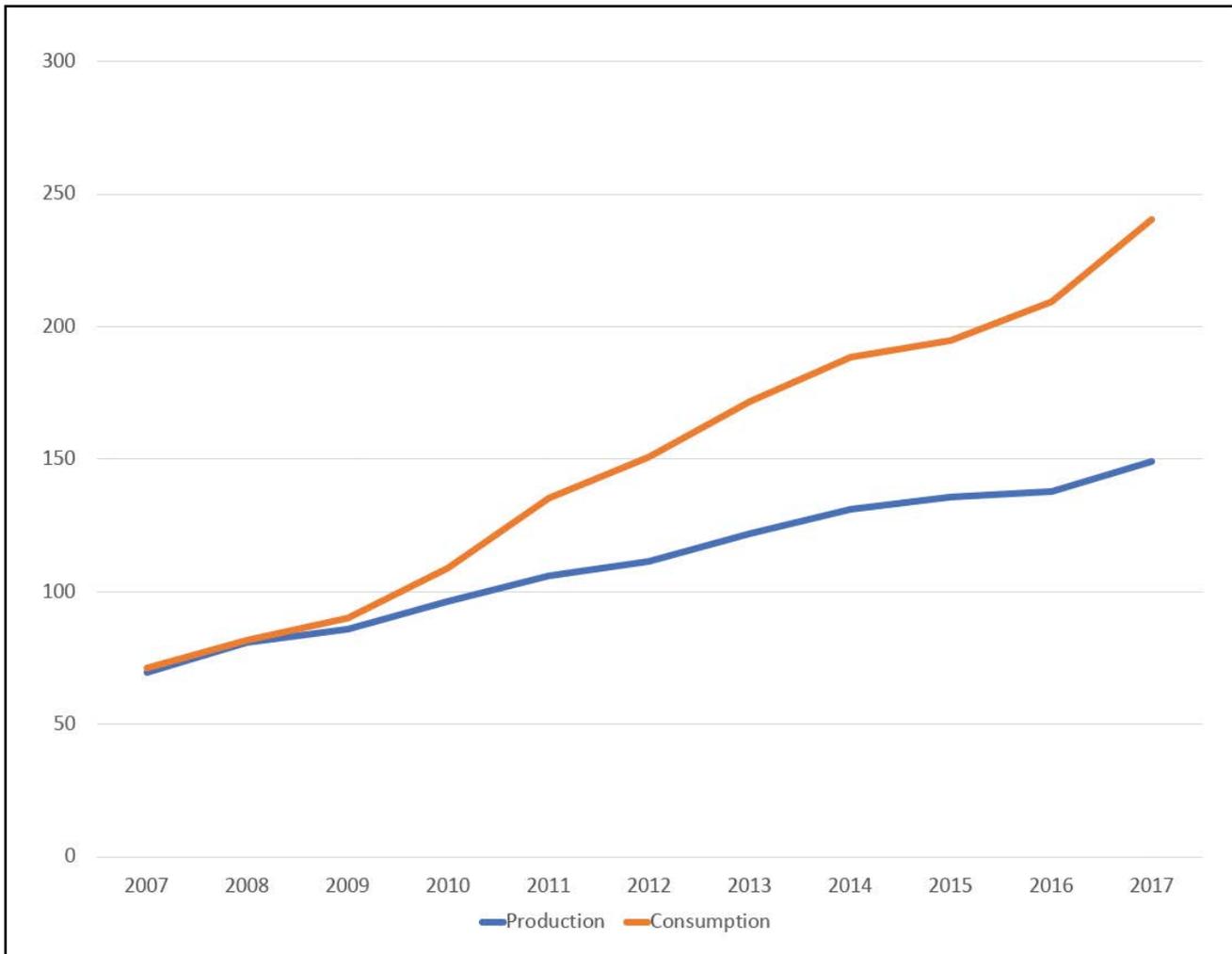
HISTORY OF LNG IN CHINESE MARKETS

Prior to its first LNG imports in 2006, China's natural gas governance emphasized domestic output, but the efforts were largely unsuccessful, and gas remained an insignificant proportion of China's energy mix. Up until the early 2000s, natural gas consumption accounted for less than 3% of the country's energy consumption.

As shown in Figure 1, China's energy mix started changing dramatically in the second half of the decade, and natural gas consumption in China grew at an annual average rate of 14.7% between

2007 and 2017. The rapid increase in Chinese natural gas consumption was in large part due to concerns over air pollution in large cities. In 2016, as some gains were achieved in domestic natural gas production, growing consumption required China to obtain additional supply by importing natural gas through pipelines and in the form of LNG.¹ By 2017, the share of LNG imports surpassed that of PNG, and natural gas imports nearly reached 40% of total consumption (Figure 2).

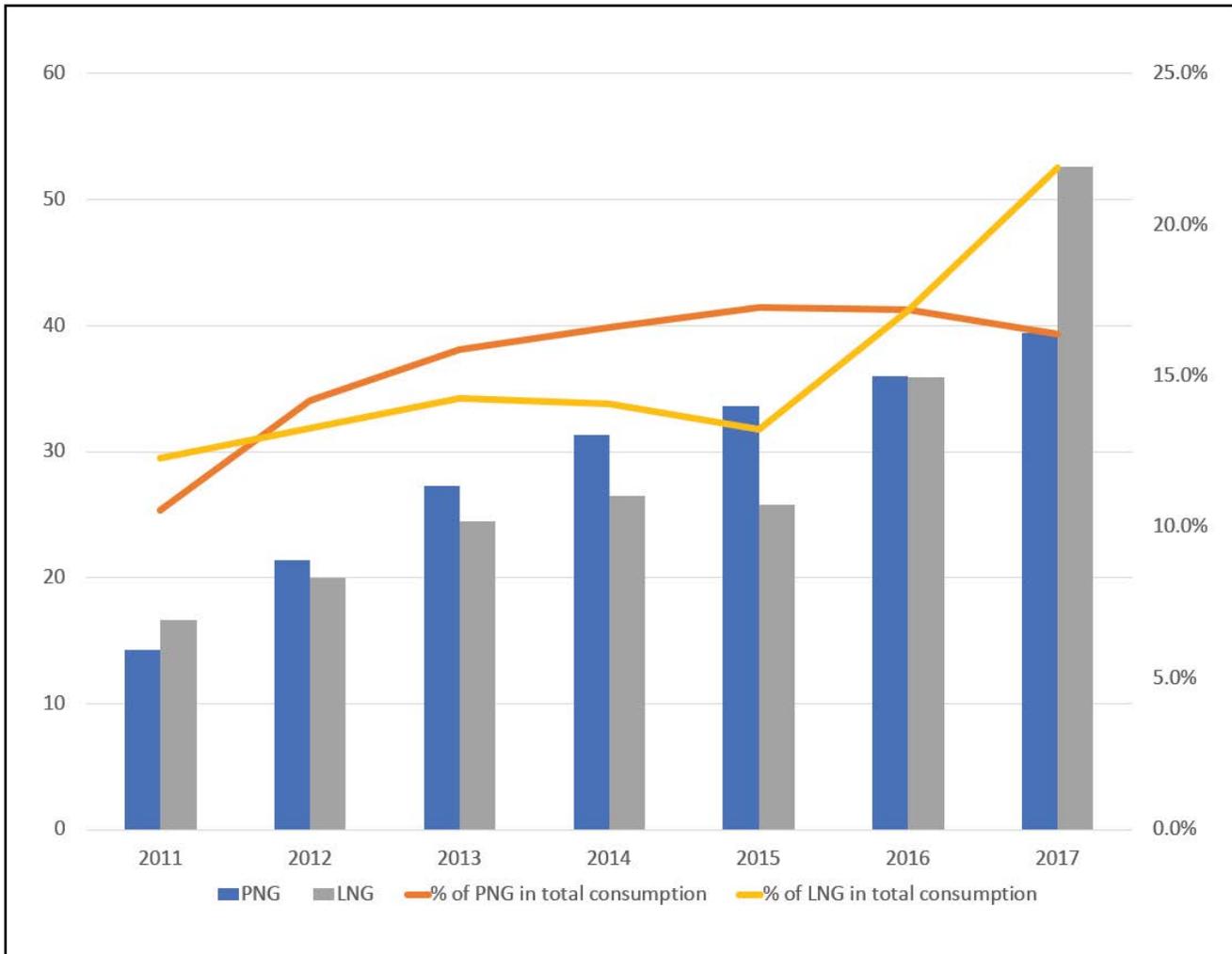
Figure 1
Natural Gas Consumption and Production in China, 2007-2017 (billion cubic meters)²



¹Higashi, Nobuyuki. June 2009. "Natural Gas in China: Market evolution and strategy." *International Energy Agency Working Paper Series*. p. 4.

²BP Statistical Review of World Energy, 2007-2017

Figure 2
LNG vs. PNG, 2011-2016 (bcm, %)³



In 1998, the State Council decided to introduce a pilot LNG project. This pilot project resulted in the establishment of Guangdong Dapeng LNG Co., Ltd. in 2014. The company is 33% owned by the large Chinese oil and gas state-owned

enterprise (SOE) CNOOC. After more than two years of negotiations with the Australian government and BP and the completion of the country’s first LNG receiving terminal, Dapeng LNG, the first LNG cargo arrived in Guangdong in 2006.⁴

³BP Statistical Review of World Energy Full Report 2013-2017.

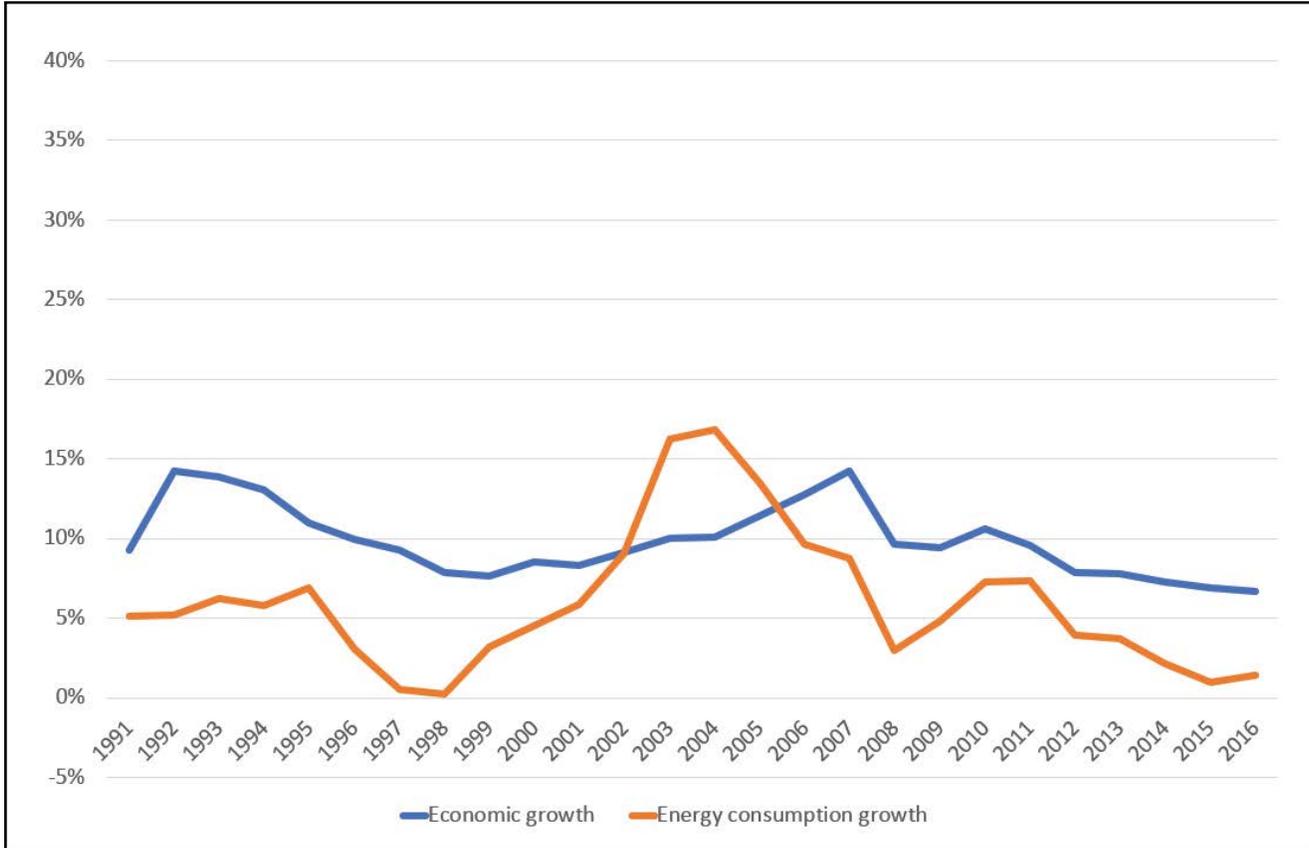
⁴Guangdong LNG. n.d. “Project Milestones” (in Chinese). <http://www.gdlng.com/static/gd-lng-milestrone.html>

Evolution of the Chinese Natural Gas Policy

In the absence of state policy, natural gas consumption in China would have had very modest growth or have been substantially constrained.

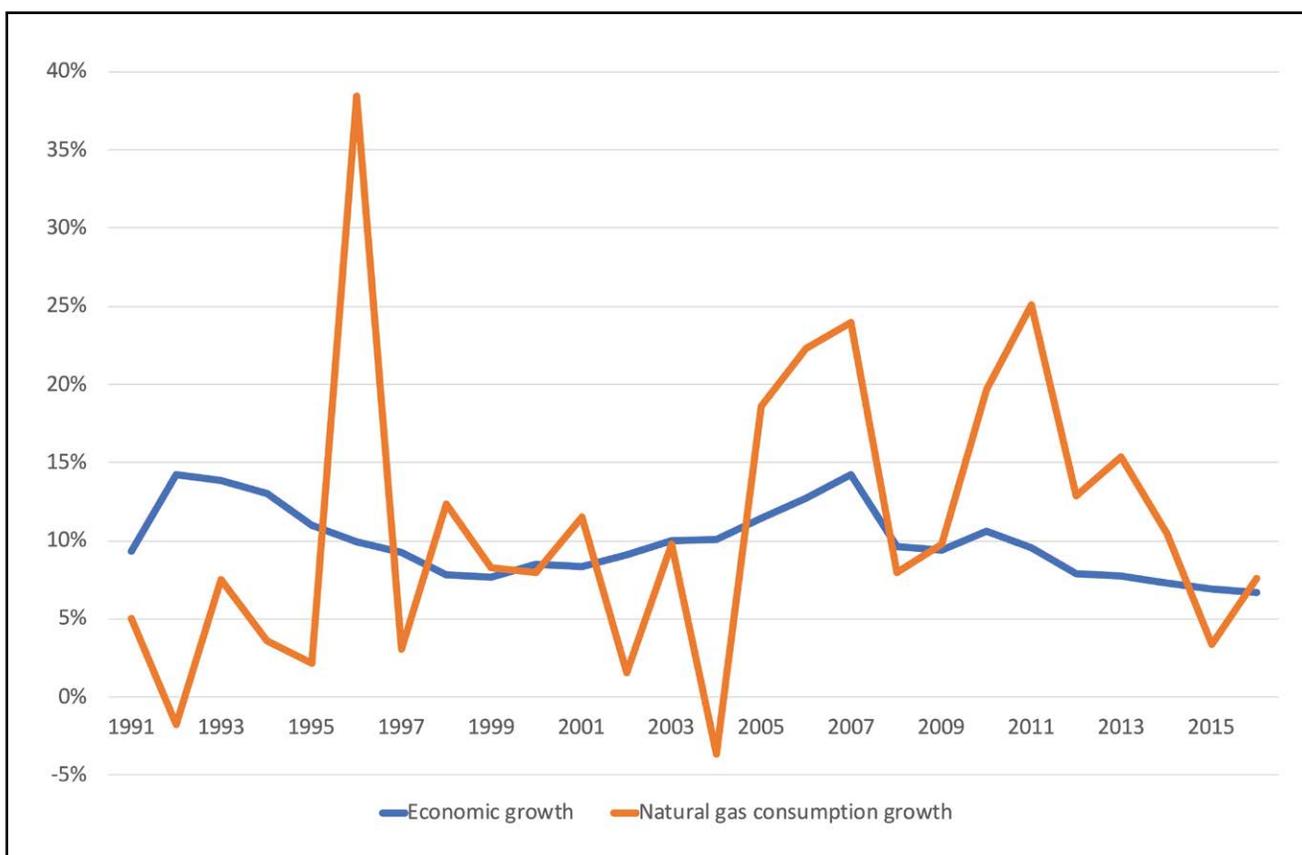
Instead of economic growth, state policy drove the changes towards increased natural gas consumption, as Figures 3 and 4 below show.

Figure 3
Average Annual Economic Growth and Energy Consumption Growth, 1991-2016 (%)⁵



⁵Data derived from the World Bank data on China’s economic growth, National Bureau of Statistics’ data on energy consumption, UN data on natural gas consumption, and BP data on natural gas consumption

Figure 4
Average Annual Economic Growth
and Natural Gas Consumption Growth, 1991-2016 (%)⁶



China’s natural gas policy has rapidly evolved since the early 2000s. This fact is reflected in China’s five-year plans and other state economic and development policies. The five-year plans before 2000 did not draw a distinct line between the oil and natural gas sectors; the ninth plan only briefly mentioned natural gas.

Starting with the 10th Five-Year Plan (2001-2005), China placed a greater emphasis on natural gas. The government acknowledged the lack of competition in the natural gas sector and even discussed reforming pricing mechanisms based on the market.⁷ The plan proposed developing clean technology to reduce environmental pollution and increase foreign collaboration on overseas oil and gas exploration. The 11th Five-Year Plan (2006-

2010) targeted an increase in the share of natural gas to 5.3% of total primary energy consumption in 2010. As a result, natural gas production showed the fastest growth rate after wind power during this period, averaging 14 percent.

LNG was first considered extensively in the 12th Five-Year Plan (2011-2015), which covered topics including LNG hybrid vehicles and ships. Annual LNG receiving capacity was planned to rise by over 50 million tons per annum (mtpa) and the number of LNG storage facilities were set to increase in coastal areas. Despite some achievements, the plan failed to fulfill its target of increasing the share of natural gas to 7.5% of total energy consumption by 2015.

⁶Data derived from the World Bank data on China’s economic growth, National Bureau of Statistics’ data on energy consumption, UN data on natural gas consumption, and BP data on natural gas consumption

⁷People’s Daily. 2001. “China’s ‘Tenth Five-Year’ Special Plan for Energy Development (Full Text)” (in Chinese). <http://www.people.com.cn/GB/jinji/31/179/20010813/533877.html>

During the 10th and 11th plan periods when China was more self-sufficient in natural gas, the planned production targets were fulfilled. However, in the 12th plan period implementation fell short of the goals, bringing forth an even greater production-

import ratio. Table 1 demonstrates that not all five-year plans were achieved within their timeframe, and when the actual production level failed to fulfill the planned level in 2010-2015, imported natural gas increased to a much greater extent.

Table 1
Natural Gas Production Planning and Performance
(billions of cubic meters and percent)⁸

Plan	Beginning level (year)	Planned achievement (year)	Planned annual growth	Actual achievement	Actual annual growth	Fulfillment
10th (2001-2005)	27.2 bcm (2000)	50 bcm (2005)	13.19%	49.3 bcm	12.63%	Almost
11th (2006-2010)	49.3 bcm (2005)	92 bcm (2010)	13.3%	95.2 bcm	14%	Yes
12th (2011-2015)	95.2 bcm (2010)	156.5 bcm (2015)	10.5%	135 bcm	7.2%	No
13th (2016-2020)	135 bcm (2015)	207 bcm (2020)	8.9%	N/A	5% (2017)	N/A



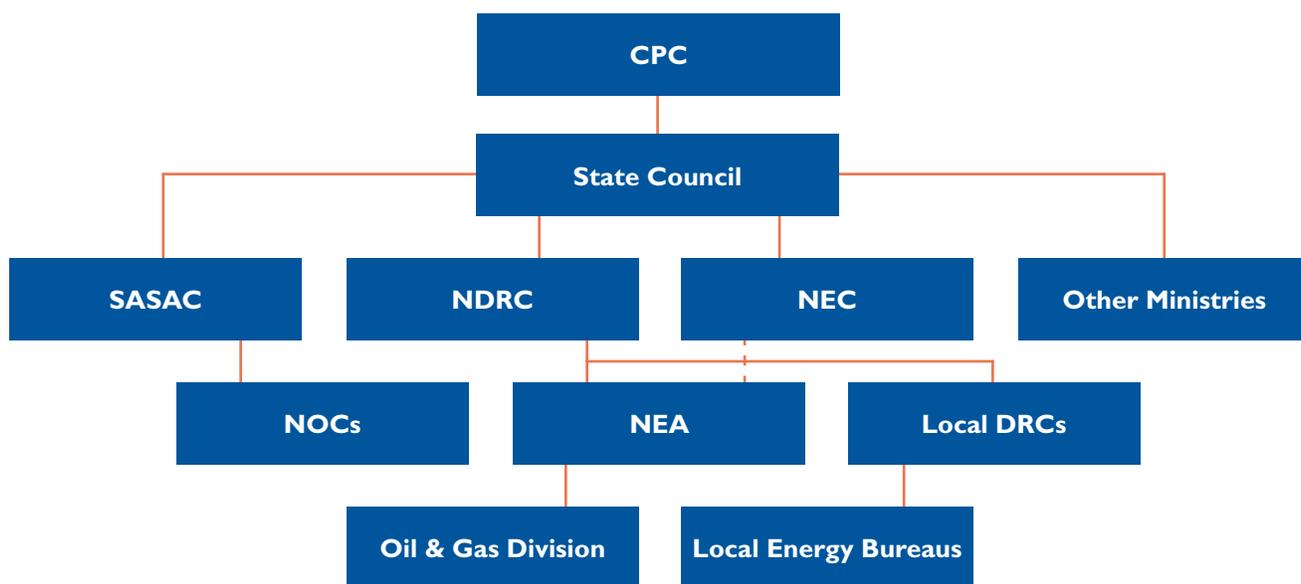
⁸Source: Five-Year plans from #10 to #13

IMPORTANT ACTORS IN THE SECTOR

China's gas sector development in the past decade can be attributed to state policy driven by social and health considerations rather than pure markets forces. The State Council and its agencies strive to fulfill the environmental ambitions of the Communist Party of China (CPC) and have shown unwavering support for the natural gas sector in recent years. Large state-owned enterprises

(SOEs) have dominated the entire sector with little competition from other public and private sector entities that have begun to appear in the gas markets lately. The governance of the natural gas sector in China reflects the government's hierarchical structure (Figure 5), but competing policies and interests exist at different levels of the national and local governments.

Figure 5
Chinese Natural Gas Governance Structure



Bureaucracy

In China, a series of both centralizing and separating efforts were made in its energy governance over the past decades.⁹ Its first attempt to centralize energy governance came with the establishment of the Ministry of Fossil Fuels in 1953. The ministry was then dismantled in 1960 into separate ministries that specialized in electricity, coal and petroleum. This process of separation continued until the establishment of the State Energy Commission to centralize the sector in the mid-1980s. The Ministry of Energy replaced previous ministries as a single unified agency, only

to fall apart in 1993. During the 1990-2000 period, a multitude of ministries and planning commissions were established. After the State Administration of Coal Industry was formed under the State Economic and Trade Commission (SETC), the energy industry was no longer overseen by a single super agency at a ministerial level. The SETC went through a number of changes and eventually became the National Development and Reform Commission (NDRC).

Today, the State Council¹⁰ holds the ultimate control over national issues and ensures the cohesion of policy implementation across agencies.

⁹Cunningham, Edward A. 2015. "The State and the Firm: China's Energy Governance in Context." GEGI Working Paper: Paper 1 (March), pp. 1-44. <https://ash.harvard.edu/files/chinas-energy-working-paper.pdf>

¹⁰According to the government website: "The State Council or the Central People's Government, of the People's Republic of China is the executive body of the supreme organ of state power; it is the supreme organ of State administration." http://english.gov.cn/archive/china_abc/2014/08/23/content_281474982987314.htm

Under the State Council, however, there is no single ministry overseeing national energy policy, as energy policy formulation and implementation are spread across several ministries. To address the lack of unified oversight in energy, the National Energy Commission (NEC) was created as the highest energy consultative body in 2010. The NEC formulates broad national energy strategies and guidance¹¹ and its membership includes the premier and over a dozen ministers from his cabinet.¹² However, the NEC's role does not exceed its overly generic role as a consultative body; the institution has convened only a handful of times since its inception.

China's latest round of institutional reforms in March 2018 did not include a long-awaited, specialized energy ministry. However, natural gas policies are currently in the hands of the powerful economic planning agency NDRC, which plays a major role in energy policy formulation and implementation. The NDRC issues the country's five-year plans, gives orders to the overall energy sector, manages natural gas utilization,¹³ sets prices, and gives approvals to the construction and operations of LNG terminals, among other roles. Its sub-agency, the NEA, focuses on industrial policy research and formulation and manages the day-to-day activities of the NEC. As a deputy-ministerial

institution, the NEA relies on the NDRC in policy implementation as well as when working with the influential NOCs.¹⁴

Other Government Institutions

In addition to the institutions mentioned above which directly manage natural gas, other ministries are mandated to play a role in natural gas and LNG policy. The Ministry of Commerce conducts international trade negotiations on natural gas whereas the Ministry of Finance administers a program subsidizing shale gas development. The latter ministry's Customs Tariff Commission imposed 10% sanctions on U.S. LNG amid the U.S.-China trade tensions in 2018.¹⁵ The Ministry of Natural Resources oversees domestic production of natural gas and shale gas and grants land access to LNG facilities.¹⁶ Because of the government's growing focus on environmental issues, the new Ministry of Ecology and Environment (MEE) took control of departments formerly belonged to other ministries¹⁷ and enforces the implementation of clean energy policy through measures such as inspection of the "coal-to-gas" switch in households. The Ministry of Transport has a role to play as well, due to its oversight of LNG vehicles and LNG bunkering policy.

¹¹Zhou, Yingfeng. 2010. "The Creation of the National Energy Commission succeeds the Institutional Reforms" (in Chinese). Ifeng.com, January 27, 2010. <http://finance.ifeng.com/news/special/gjnyw/20100127/1765925.shtml>

¹²Zhang, Yanling. 2018. "The State Council Makes Changes to the Personnel of the National Energy Commission" (in Chinese). Chinanews.com, July 21, 2018. <http://www.chinanews.com/gn/2018/08-02/8587746.shtml>

¹³NDRC. 2012. "Order of the National Development and Reform Commission of the People's Republic of China: Natural Gas Utilization Policy" (in Chinese). http://www.gov.cn/gongbao/content/2013/content_2313190.htm

¹⁴Bao, Xing'an. 2010. "Zhang Guobao: The Energy Bureau is Small, But State-Business Relationships are Doing Well" (in Chinese). Ifeng.com, February 4, 2010. <http://finance.ifeng.com/news/special/gjnyw/20100204/1795458.shtml>

¹⁵Ministry of Finance. 2018. "Notice of the Customs Tariff Commission of the State Council on Adding Tariffs to Certain Imported Goods Originating in the United States (Second Batch)." http://gss.mof.gov.cn/zhengwuxinxi/zhengcefabu/201808/t20180803_2980950.html

¹⁶Gov.cn. n.d. "Structure of the State Council." <http://www.gov.cn/guowuyuan/zuzhi.htm>

¹⁷Li, Jing. 2018. "China's new environment ministry unveiled, with huge staff boost." China Dialogue, April 19, 2018. <https://www.chinadialogue.net/article/show/single/en/10599-China-s-new-environment-ministry-unveiled-with-huge-staff-boost>

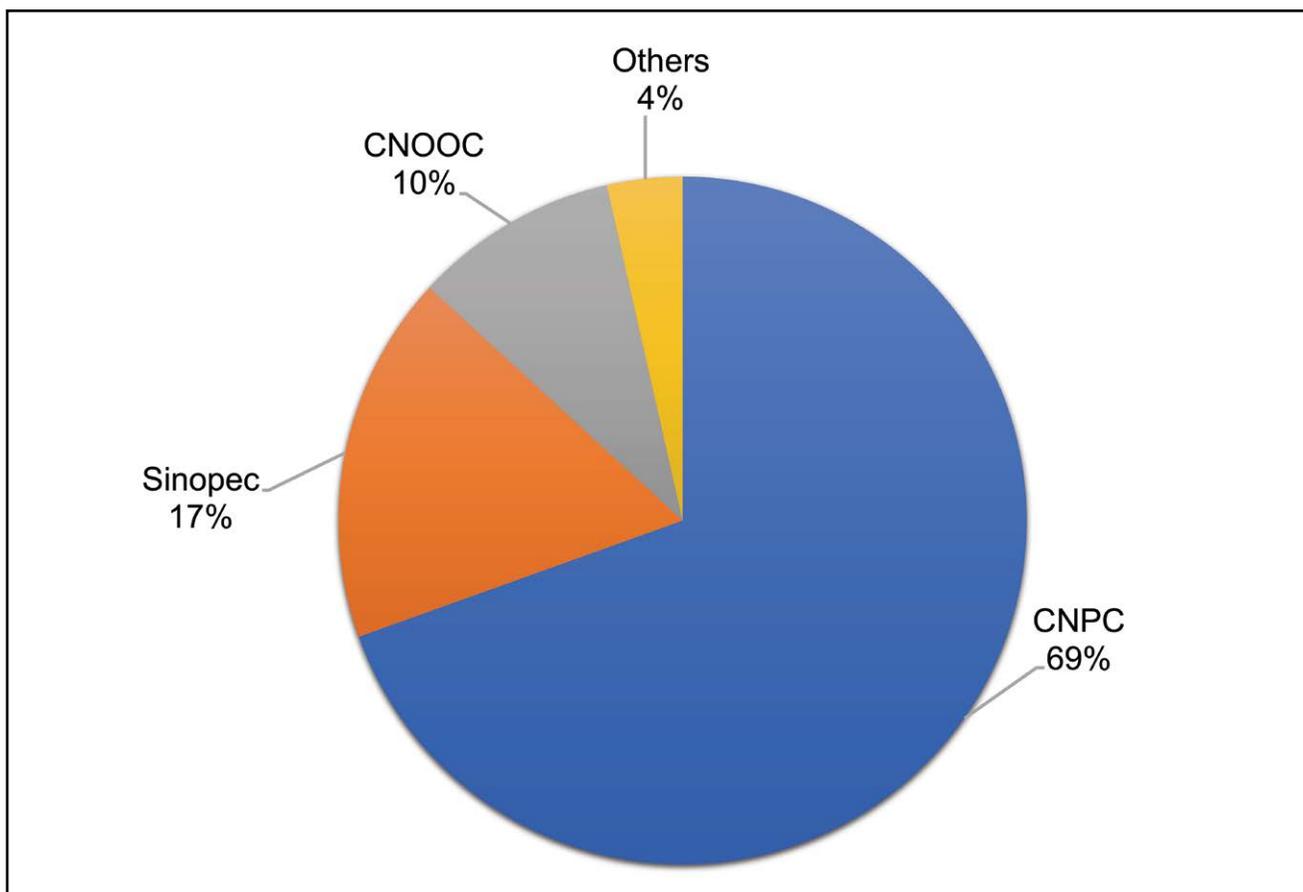
¹⁸Ministry of Transport. 2018. "Letter from the General Office of the Ministry of Transport for the Opinions on Deepening the Advancement of the Application of Liquefied Natural Gas in the Water Operation Industry (Draft for Comment)" (in Chinese). http://zizhan.mot.gov.cn/zfxgk/bnssj/syj/201808/t20180810_3056391.html

The Big Three and Other Enterprises

The Chinese natural gas industry is characterized by an oligopolistic structure, dominated by three major national oil companies (NOCs),¹⁹ or the “Big Three”: China National Petroleum Corporation (CNPC), China Petroleum and Chemical Corporation (Sinopec), and China National Offshore Oil Corporation (CNOOC).²⁰ The

first two were born when upstream and downstream oil enterprises’ ownership rights were separated from the Ministry of Petroleum Industry (MPI) in the 1980s as part of its corporatization efforts. CNOOC was established under MPI in 1982 for collaboration with foreign enterprises on offshore business activities.²¹

Figure 6
China’s Domestic Natural Gas Production by NOCs (2017)²²



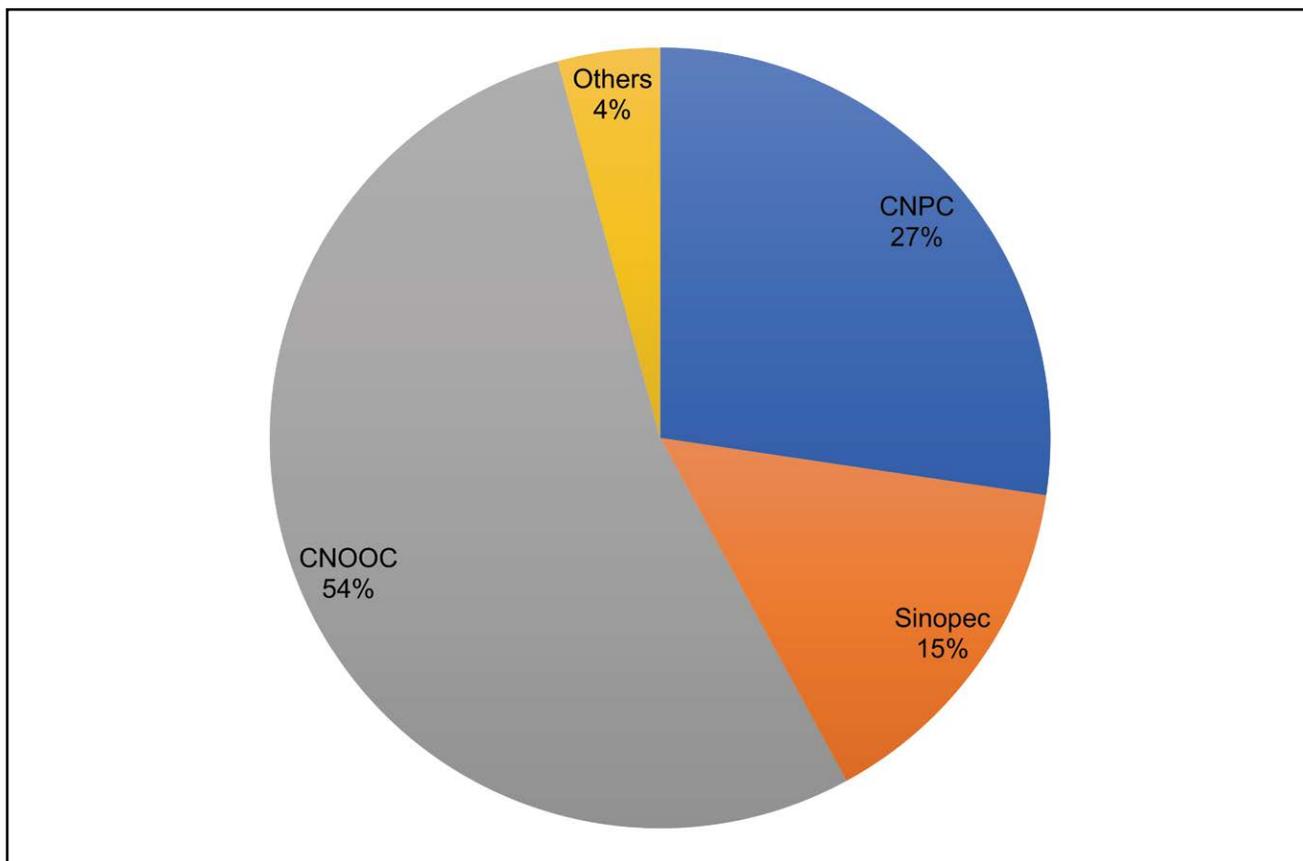
¹⁹With the increasing share of natural gas in their portfolio, the SOEs should now be referred to as national oil and gas companies (NOGCs). However, we use the established term, NOCs, in this report.

²⁰The NOCs are under the State-owned Assets Supervision and Administration Commission (SASAC), a powerful agency directly under the State Council. Tang, Changwei. 2016. “Globalized economy and the Chinese national oil companies.” IAS Newsletter: No. 74 (Summer). https://iias.asia/sites/default/files/IIAS_NL74_07.pdf

²¹Downs, Erica S. 2010. “Who’s Afraid of China’s Oil Companies?” In *Energy Security: Economics, Politics, Strategy, and Implications*, pp. 73-102. Brookings Institution Press. <https://www.brookings.edu/research/whos-afraid-of-chinas-oil-companies/>

²²Data derived from the 2017 annual reports and other documents of CNPC, Sinopec, and CNOOC

Figure 7
China's LNG Imports by NOCs (2017)²³



Initially, the NOCs were separated by specialization in onshore upstream production, refining, and offshore oil and gas exploration. However, the NOCs entered all areas of the gas industry and the distinction between the companies has waned over the years. Producing 103.3 bcm in 2017 (Figure 6), CNPC plays a dominant role in domestic natural gas production,²⁴ followed by Sinopec's 25.84 bcm²⁵ and CNOOC's 14.3 bcm. Although the smallest in terms of production

volume, CNOOC is the principal player in LNG imports. Controlling half of the LNG receiving terminals in the country, CNOOC imported 54% of total LNG in 2017 and reportedly helped stabilize LNG pricing between RMB 4,500-5,100/ton at peak demand (Figure 7).²⁶ CNPC and Sinopec are playing increasingly important roles in LNG as well, each showing 84.30% and 43.70% increases in LNG imports year-on-year in 2017, respectively.

²³Data derived from the 2017 annual reports and other documents of CNPC, Sinopec, and CNOOC

²⁴Chengcheng. 2018. "CNPC reports record-high domestic natural gas output at over 100 billion cubic meters." Xinhuanet, February 8, 2018. http://www.xinhuanet.com/english/2018-02/08/c_136959638.htm

²⁵Sinopec 2017 Annual Report and Accounts. pp.12-22. <http://www.sinopec.com/listco/en/Resource/Pdf/20180325036.pdf>

²⁶CNOOC 2017Annual Report. pp. 29-37. <http://www.cnooc.com.cn/attach/0/1806141618435805115.pdf>

The NOCs pursued commercialization and international collaboration by creating companies that then were listed on international exchanges. PetroChina (82.6% owned by CNPC)²⁷, CNOOC Limited (64.4%, CNOOC)²⁸, and Sinopec Limited (70.9%, Sinopec)²⁹ are listed on the New York and Hong Kong Stock Exchanges and oversee their parent company's core natural gas operations, including offshore activities, exploration and production, pipeline transportation and sales. However, because the Central Organization Department of the CPC holds the ultimate rights to appoint or dismiss top executives, the NOCs are heavily influenced by the party.³⁰ On the other hand, by leveraging their ties with the party NOC executives influence state policy during its deliberation.³¹ This has led to corruption cases linked to some executives in the past.³² The IEA advised that loosening the links between the NOCs' leadership and the CPC may help reduce the NOCs' influence over the NEA and NDRC's decisions. Improvements in the efficiency of the SOEs can also happen through competition and increased market share of private entities.³³

Emerging Role of Second-Tier Players

The emergence of so-called "second-tier" LNG players has begun to challenge the Big Three's monopoly, thanks to the government's liberalization efforts and individual provinces' strategies to lessen their dependence on the NOCs. Second-tier companies are provincial distribution companies,

city-gas operators, power plants, integrated groups and other public and private enterprises in the industry. These companies have a relative advantage over market security, with access to secured markets with high affordability, proximity to end users, and existing distribution channels. Although these entities have made significant progress with local government backing as well as through cooperation with outside partners, they are far from competing head-to-head against the NOCs. SIA Energy reports that the second-tier companies are still weaker than the NOCs in government support, infrastructure access, financial capability, and professional experience. Disparity between support from local governments and the central government and a lack of financial resources and professional experience discourage them from competing against the NOCs.³⁴ The second-tier players are importing LNG in two ways: 1) constructing their own LNG receiving terminals, or 2) leasing the NOCs' LNG receiving terminals.

Construction of receiving terminals is the main indicator of private sector participation. LNG terminals with capacity above three mtpa require the NDRC's approval, whereas smaller terminals only need that of local authorities. A number of entities including Zhejiang Energy, China Huadian, and Guanghui Energy have planned or proposed terminal projects. Even midstream public utilities are entering the business, for example Beijing Gas plans to construct its own receiving terminal near Tianjin.³⁵ Nevertheless, acquiring permissions

²⁷PetroChina 2017 Annual Report.

²⁸CNOOC Limited 2017 Annual Report.

²⁹Sinopec Limited 2017 Annual Report.

³⁰Tang, Changwei. 2016. "Globalized economy and the Chinese national oil companies." IIAS Newsletter: No. 76 (Summer). https://iiias.asia/sites/default/files/IIAS_NL74_07.pdf

³¹The executives also head the party committee of their respective companies and remain influential within the government even after leaving the company. Cunningham, Edward A. 2015. "The State and the Firm: China's Energy Governance in Context." GEGI Working Paper: Paper 1 (March). pp. 20-21. <https://ash.harvard.edu/files/chinas-energy-working-paper.pdf>

³²Former CNPC executives Zhou Yongkang and Jiang Jiemin and Sinopec's Su Shulin were expelled from the CPC and put in jail for corruption cases.

³³Zhang, Dong, and Owen Freestone. 2017. "China's Unfinished State-Owned Enterprise Reforms." p. 3. <https://static.treasury.gov.au/uploads/sites/1/2017/06/5-China-SOE-reforms.pdf>

³⁴Li, Yao. 2016. "China's Emerging 2nd Tier LNG Players and LNG Import Capacity Outlook." SIA Energy: China LNG International Summit. p.9. https://asiapacific.cwclng.com/wp-content/uploads/2016/07/SIA-Energy_Yao-Li_Tier-2-Chinese-Players-and-LNG-Terminal-Capacity-Outlook_201603161.pdf

³⁵Chen, Aizhu, and Meng Meng. 2018. "China's Beijing Gas Figures new direction under helm of Madame Li." Reuters, August 2, 2018. <https://www.reuters.com/article/us-china-pollution-gas-madame/chinas-beijing-gas-figures-new-direction-under-helm-of-madame-li-idUSKBN1KN30Z>

from authorities is challenging and private entities oftentimes fail to meet the requirements such as attracting enough capital. Today, only three private LNG receiving terminals have been put into operation and only ENN's LNG receiving terminal has a capacity of three mtpa, as many other private-sector-funded projects are kept in the approval process.³⁶

Leasing the NOCs' LNG terminals as a third-party entity liberates private entities from strict construction requirements and large upfront capital investments. Depending on the owning company's use of its terminal, third-party entities must wait for a window of availability. Third-party imports constituted 3% of receiving capacity of the CNPC terminals from 2014 to 2016.³⁷ With tightened supply and a small window of availability, no third-party leases were granted by the Big Three in 2017.³⁸ The NDRC is stepping up their effort to address this issue and allow open and third-party access to LNG infrastructure.

Local Authorities

The coordination between national and local authorities is important, but the NDRC has been slow to consider local conditions in its policy formulation. Like the NDRC and the NEA, the provinces have their own development and

reform commissions and energy bureaus. These authorities complement national policy with documents suited for their respective localities. Their responsibilities include issuing five-year plans for energy development, granting permissions for the construction of LNG receiving terminals, and set local natural gas distribution prices. Local authorities in the northern regions, including Beijing and Hebei, pioneered the implementation of the "coal-to-gas" switching in heating. However, overly ambitious environmental plans at the national level put a strain on local governments and households. As a result of the NDRC's decision to convert four million households from coal to gas in the winter of 2017, natural gas supplies became extremely tight, prices surged, and some households and schools had to endure a cold winter without enough heating facilities. In 2018, the national government set a target to convert another four million households to natural gas and electricity. However, this was met by opposition from some local authorities as they considered this plan unfeasible. For instance, Hebei province, which converted a massive 2.54 million households to clean-energy in 2017, stated that no more households would be required to convert to natural gas or electricity in 2018.³⁹

³⁶Li, Qian. 2018. "Private Enterprises' Participation in LNG Receiving Stations" (in Chinese). People.cn, April 9, 2018. http://paper.people.com.cn/zgnyb/html/2018-04/09/content_1847151.htm

³⁷Sohu. 2018. "Understanding the LNG Industry, Pricing Mechanism, and Profitability" (in Chinese). Sohu, August 1, 2018. http://www.sohu.com/a/244536796_117959

³⁸Li, Qian. 2018. "Private Enterprises' Participation in LNG Receiving Stations" (in Chinese). People.cn, April 9, 2018. http://paper.people.com.cn/zgnyb/html/2018-04/09/content_1847151.htm

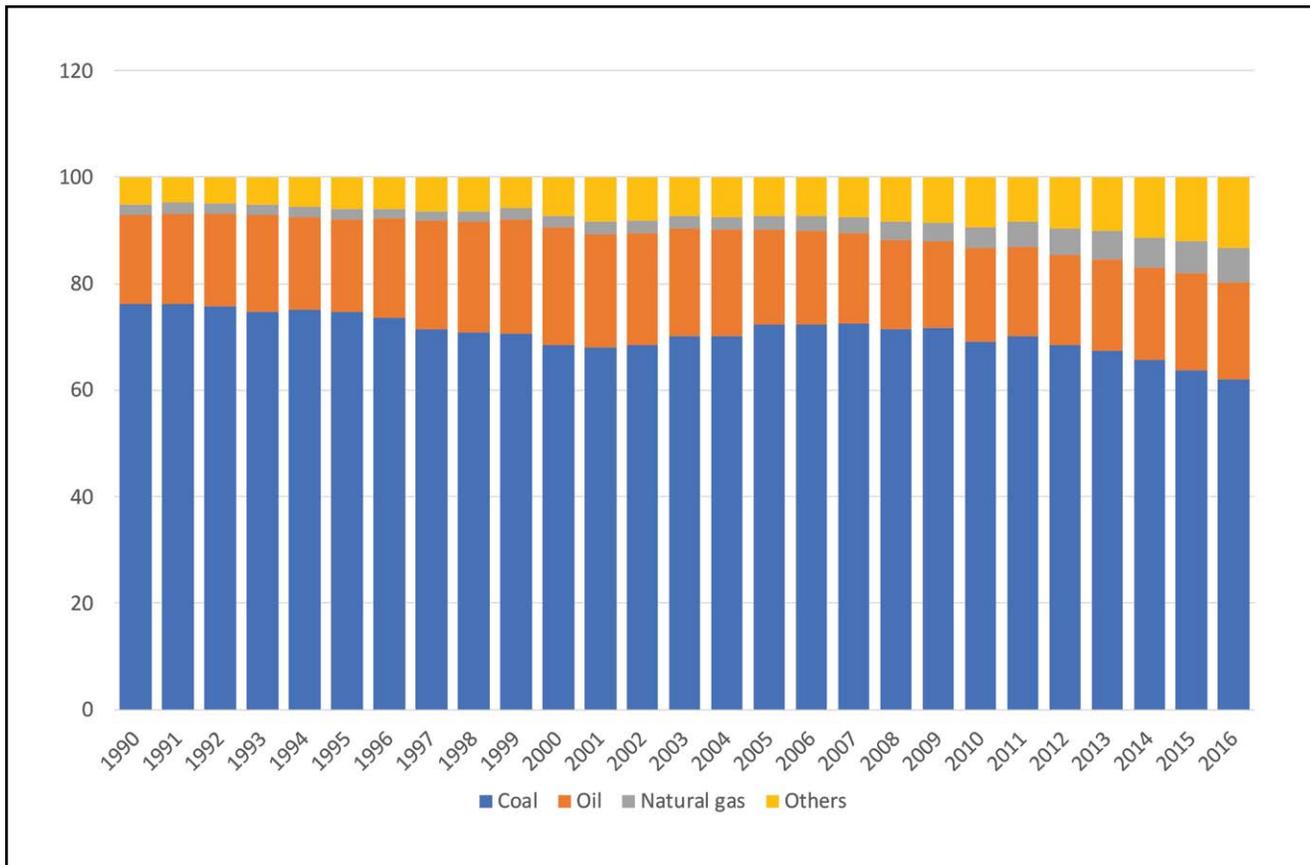
³⁹Zhou, Tailai, Chen Zhou, and Rongde Li. 2018. "4 Million North China Homes Told to Kick Coal Habit as Nation Seeks Blue Skies." Caixin, February 8, 2018. <https://www.caixinglobal.com/2018-02-08/4-million-north-china-homes-told-to-kick-coal-habit-as-nation-seeks-blue-skies-101209259.html>

CURRENT MARKET ENVIRONMENT

China's energy policy has traditionally emphasized production of domestic reserves as opposed to relying on imports. This policy is part of the reason why the energy mix has been so focused on oil and coal, but that will change in the near future. Total proven reserves of Chinese natural gas amount to 5.52 trillion cubic meters (cu.m) and total domestic gas production of 148.7 bcm

in 2017,⁴⁰ and Chinese natural gas consumption reached 237.3 bcm in 2017, up 15% year-on-year (y-o-y).⁴¹ Domestic production is still able to supply most of the nation's consumption of natural gas, however as China needs to replace coal and oil in the energy mix, they will need to increase imports of natural gas to make up the difference.

Figure 8
Composition of Energy Consumption, 1990-2016 (%)⁴²



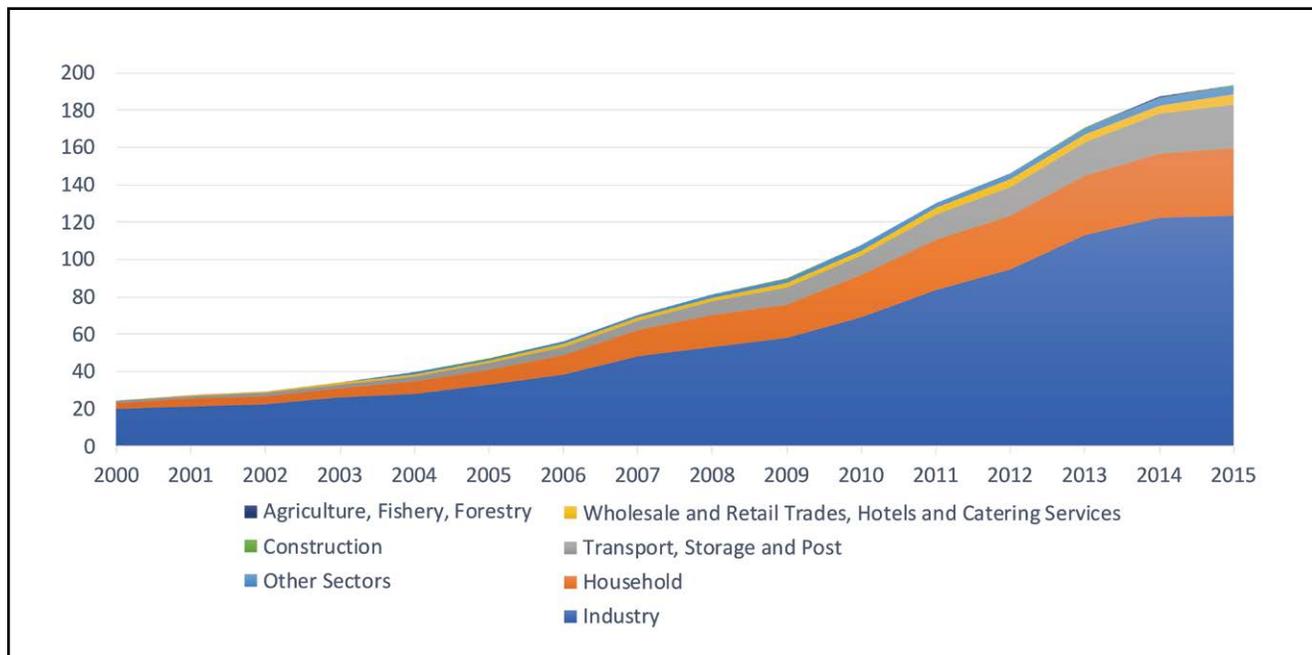
⁴⁰BP (2018), p. 26

⁴¹Abreu, Abache. 2018. "Analysis: China's expanding underground gas storage may reduce LNG winter price volatility." *S&P Global Platts*, July 13, 2018. <https://www.spglobal.com/platts/en/market-insights/latest-news/natural-gas/071318-analysis-chinas-expanding-underground-gas-storage-may-reduce-lng-winter-price-volatility>

As shown in Figure 9 below, industry usage constituted almost two-thirds of total consumption in 2015, followed by households (18.6%) and transport (12.3%). While the former lost 17 percentage points in 2000-2015, transport and households showed rapid growths of nine and five percentage points, respectively. Mainly driven by the Chinese government’s decision for households to switch from coal to gas, the country’s LNG imports increased to 38.1 million tons (42%

growth) in 2017, outpacing South Korea as the second largest importer of LNG.⁴³ The share of natural gas in total energy mix remains at 7.5%,⁴⁴ while coal and oil continue to dominate 80% of total consumption (Figure 8),⁴⁵ but as the state and local governments continue to promote natural gas in households, we anticipate further growth in the share of households in natural gas consumption and LNG demand.

Figure 9
Natural Gas Consumption by Sector, 2000-2015 (bcm)⁴⁶



⁴²National Bureau of Statistics of China

⁴³Zaretskaya, Victoria. 2018. “China becomes world’s second largest LNG importer, behind Japan.” *U.S. Energy Information Administration*, February 23, 2018., <https://www.eia.gov/todayinenergy/detail.php?id=35072>

⁴⁴National Energy Administration. 2018. “Notice of the National Energy Administration on Printing and Distributing the Guiding Opinions on Energy Work in 2018.” http://www.gov.cn/xinwen/2018-03/09/content_5272569.htm

⁴⁵Data derived from the BP Statistical Review of World Energy. 2018.

<https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review/bp-stats-review-2018-full-report.pdf>

⁴⁶Data derived from the National Bureau of Statistics of China. <http://data.stats.gov.cn/english/easyquery.htm?cn=C01>

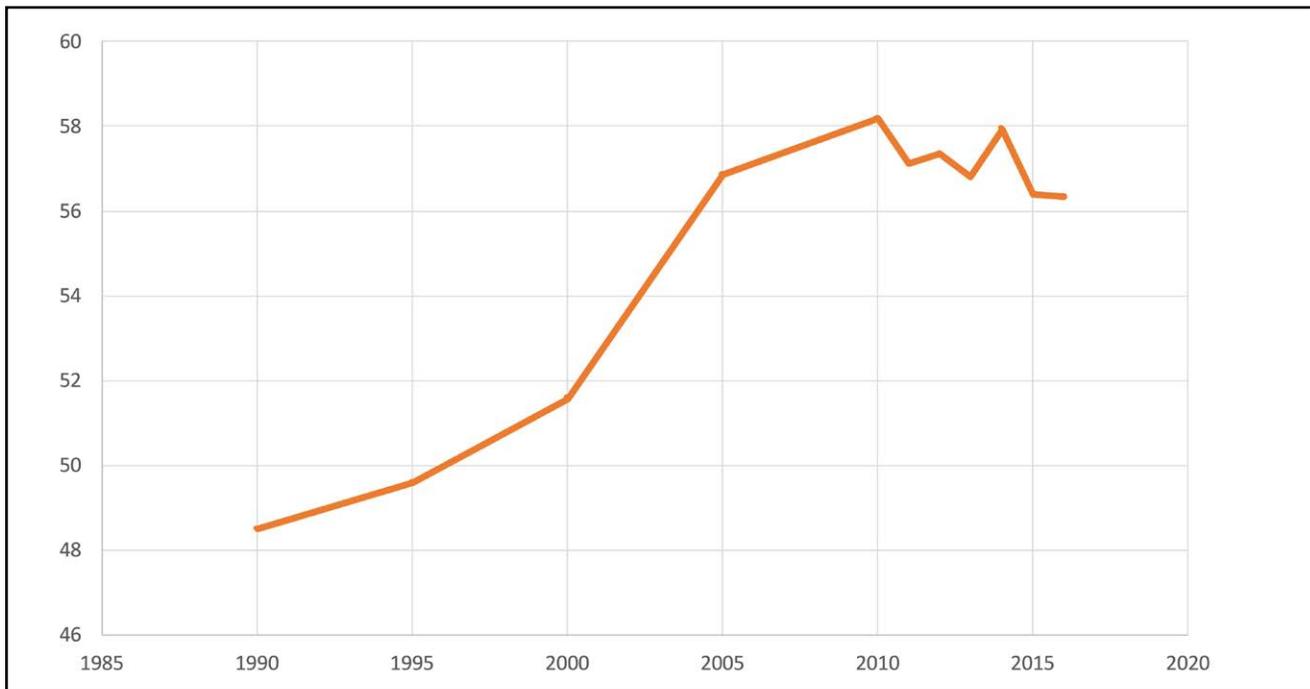
Environmental and Climate Factors

Environmental pollution and seasonal fluctuations play important roles in China’s natural gas sector in the short and long run. Air pollution prompted the country to commit to energy technologies with low air emissions, and China’s environmental policies have moved to soil and water pollution as well. Climate volatility plays a more direct role in determining the level of consumption in the short run. China’s sudden increase in demand in recent years due to colder than usual winters led to some spikes in prices in the Asian LNG market.

Air Pollution

Chinese natural gas policy is motivated by the need to reduce air pollution, a contributory source of respiratory infections, heart disease, and lung cancer, among others.⁴⁷ Due to excessive coal consumption, Chinese cities have been exposed to smog with high levels of PM 2.5. Prior research suggests that in 2004-2008, respiratory deaths per 10,000 people in Shanghai and Beijing were 2.86 and 2.25, respectively, much higher than in the less urbanized Tibet (.05) and Gansu (.17).⁴⁸

Figure 10
PM 2.5 Air Pollution, Mean Annual Exposure in China (micrograms/cm)⁴⁹



⁴⁷World Health Organization. n.d. “Air pollution.”

http://www.wpro.who.int/china/mediacentre/factsheets/air_pollution/en/

⁴⁸Cao, Qilong, Ying Liang, and Xueting Niu. 2017. “China’s Air Quality and Respiratory Disease Mortality Based on the Spatial Panel Model,” *International Journal of Environmental Research and Public Health*, p.8.

⁴⁹World Bank. 2016. “PM2.5 air pollution, mean annual exposure (micrograms per cubic meter).”

<https://data.worldbank.org/indicator/EN.ATM.PM25.MC.M3?locations=CN>

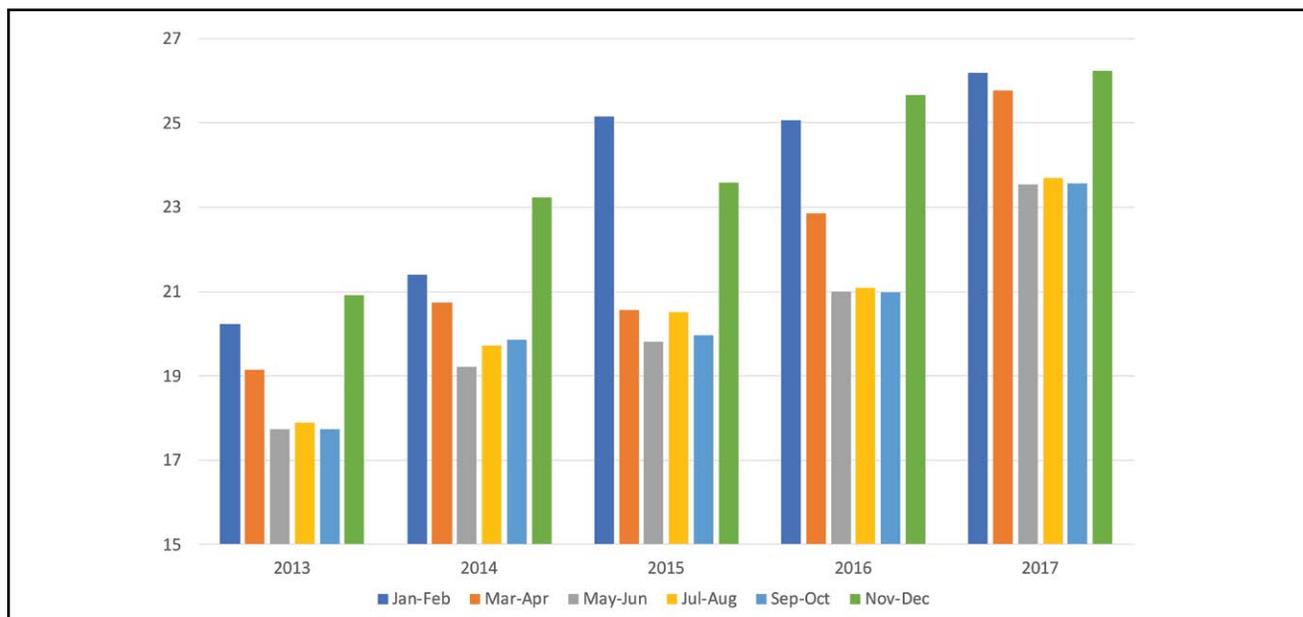
Increasing social unrest and demonstrations against pollution drew heightened government attention. In accordance with the State Council’s 2013 Action Plan on Prevention and Control of Air Pollution,⁵⁰ China plans on maintaining total coal power capacity below 1100 GW by 2020. As a result, the number of “smoggy days” in the Beijing-Tianjin-Hebei area dropped from 71.1 in 2013 to 42.3 in 2017.⁵¹ According to the World Bank, the PM 2.5 level peaked in 2010, but there have not been substantial decreases at nationwide levels (Figure 10). Furthermore, because the State Council’s environmental focus is shifting beyond atmospheric pollution to include other types of pollution,⁵² the main environmental motive for natural gas consumption is not likely to diminish any time soon. As we estimate urban population to surpass the one-billion threshold in 2025-2028

at the current trend, air pollution in cities would remain a central concern of the CCP.

Seasonal Climate Variations

Given tight supply and limited global spare-gas capacity, weather fluctuations significantly contribute to Chinese natural gas market volatility.⁵³ That is, natural gas consumption in China is high in the colder months of the year, surging in November until sharply dropping in spring (Figure 11). This is associated with price surges and supply shortages and has become a headache for the natural gas sector, most profoundly in the winter of 2017. Data from the State-Owned Assets Supervision and Administration Commission (SASAC) indicates that the average peak-to-valley ratio between summer and winter consumption reached 1.71.⁵⁴ It is imperative for China to expand its peak shaving and LNG receiving capacity to address this challenge.

Figure 11
Bimonthly Domestic Gas Production 2013-2017 (bcm)⁵⁵



⁵⁰State Council. 2013. “Notice of the State Council on Printing and Distributing the Action Plan for Air Pollution Prevention and Control” (in Chinese). http://www.gov.cn/zwqk/2013-09/12/content_2486773.htm

⁵¹China Daily. 2018. “Four years on: Beijing-Tianjin-Hebei coordinated development.” ChinaDaily, February 27, 2018. http://www.chinadaily.com.cn/a/201802/27/WS5a949ab4a3106e7dcc13e348_1.html

⁵²This is echoed in the State Council’s 2018 “Opinion on Strengthening Ecological Protection and Pollution Prevention.”
⁵³Bros, Thierry. 2018. “Quarterly Gas Review Analysis of Prices and Recent Events.” *Oxford Institute for Energy Studies*: March 2018.

⁵⁴CNPC. 2017. “2017 China’s Natural Gas Development White Paper: Promoting Natural Gas as a Main Energy Source.” SASAC, August 21, 2018. <http://www.sasac.gov.cn/n2588025/n2588124/c7767721/content.html>

⁵⁵Data derived from the National Bureau of Statistics of China <http://data.stats.gov.cn/english/easyquery.htm?cn=A01>

Current Policy and Implementation

China’s natural gas and LNG policy is directly linked to its environmental and clean energy efforts reflected in the current 13th Five-Year Plan (2016-2020) and documents such as the 2018 Action Plan to Win the Battle for Blue Skies. The 13th Plan states that an increase in the share of natural gas in the country’s energy mix is “the only way” to create a clean, efficient energy system. The document

proposed to increase the share of natural gas in total energy mix from 6% to 10%, while decreasing coal from 64% to 58% in the period from 2015 to 2020. Internationally, China pledged to make natural gas one of the main energy sources by 2030 in accordance with the UN Sustainable Development Goals.⁵⁶ Some significant goals and progresses are outlined in Table 2 below.

**Table 2
Natural Gas Provisions of the 13th Five-Year Plan Goals⁵⁷ and Progress**

Goals	Progress
Promote market access and implement fair access to infrastructure	In 2018, the NDRC issued a draft policy for Third-Party Access to LNG facilities. CNOOC for the first time awarded a regasification slot at its Yuedong terminal via the Shanghai hub.
Set up a market-based price mechanism; reform the price of non-residential and residential gas	The NDRC has undertaken a series of pricing reforms for residential and non-residential users. The price parity between different classes is minimized and a wholesale market pricing mechanism is promoted to a certain extent. Initial efforts were made in regional gas pricing hubs in China.
Expand the storage capacity of existing LNG receiving terminals; build new terminals in areas with high demand (i.e., the Bohai Economic Rim⁵⁸ and the Yangtze River Delta Economic Zone⁵⁹)	Some LNG terminals’ storage capacity has already been expanded and more facilities like the Ningbo terminal expect expansion. Since 2016, five new LNG receiving terminals have been put into operation and over five terminals are approved by the NDRC or under construction. These new projects largely conform to the geographical specifications of the five-year plan.
Replace coal-fired boilers and industrial kilns with natural gas facilities in large cities	In 2017, nearly four million households upgraded their coal-fired boilers and other facilities with cleaner-burning natural gas facilities in the northern regions such as Hebei province. ⁶⁰
Support natural gas vehicles, including LNG-fueled vehicles and LNG-fueled transport ships	In 2017, a fleet of 200,000 natural gas-fueled public transport vehicles were added in Beijing. The Ministry of Transport has announced its intention to use LNG as a clean marine bunker fuel and develop necessary standards and network by 2020.

⁵⁶Ministry of Foreign Affairs of PRC. 2016. “China’s National Plan on the Implementation of the 2030 Agenda for Sustainable Development.” p.33. <https://www.fmprc.gov.cn/web/zyxw/W020161012709956344295.pdf>

⁵⁷National Development and Reform Commission of China. The 13th Five-Year Plan for Economic and Social Development of the People’s Republic of China.”

⁵⁸Economic area including Beijing and Tianjin and surrounding areas.

⁵⁹Economic area in the Yangtze River Delta region including Shanghai city and Jiangsu, Anhui and Zhejiang provinces.

⁶⁰Wang, Changyu. 2018. “Institute of Building Environment and Energy Efficiency, China Academy of Building Research Director Xu Wei’s Remarks.” *Cnenergy.org*, August 27, 2018. http://www.cnenergy.org/yw/201808/t20180827_685175.html

The five-year plans are supplemented by a number of policies at the national and local levels. “Winter Clean Heating Planning in the Northern Region” (2017-2021), one of the national policies, imposed restrictions on heating emissions in two municipalities and 26 cities in the coal-ridden northern region and planned a 23 bcm increase in gas heating. The policy was bolstered by the action plan to “Win the Battle for Blue Skies” (2018-2020), which prioritizes urban areas with severe air pollution. At the local level, provincial authorities set their own targets tailored to local conditions. The Hong Kong Special Administrative Region, for example, was targeted to raise the share of natural gas to 50% in its total energy mix while the coal-dependent Hebei aimed at only 10% in this five-year plan period. These national and local policies in large part have successfully complemented one another.

China’s natural gas policy can be divided into three main goals — increased use of natural gas in a coordinated manner, supply side security, and market-based reforms.⁶¹ Increased natural gas consumption focuses on growths in reserves and production, better infrastructure, and interconnectivity of distribution and transmission systems. Additionally, the continuation of the “coal to gas” switching policy, the introduction of greater distributed natural gas generation, and a widespread use of natural gas and LNG vehicles and filling stations all play an important role in increased consumption. For supply side security, improved peak-shaving systems and construction of pipeline and LNG receiving facilities as well as increased storage capacity are prioritized. The third main goal, pricing and market reforms, is complex and has a number of facets: the promotion of direct transactions between suppliers, further reforms towards a more market-based pricing mechanism,

and open and fair access to pipeline and LNG facilities.

Projections Through 2020

A combination of slow development in unconventional production and delays in the implementation of PNG import projects, the share of natural gas in the total energy mix will likely fall below the NDRC’s target for 2020. The future consumption and imports of LNG is contingent upon natural gas infrastructure development as well as the construction of LNG terminal projects. China projects the share of natural gas in its energy mix to increase to a range of 8.3%-10%, at around 353-391 bcm, provided that China manages to limit its annual energy consumption within five billion tons of Standard Coal Equivalent (or within 3% annual growth) by 2020.⁶² For this, China must achieve 13.3% annual average growth in its demand from the 2015 level of 193.1 bcm. Real demand is projected to fall short of this by 2.4 percentage points, with the 2018 consumption estimated at 263.5 bcm.⁶³ In other words, Chinese consumption is projected to be around 325-330 bcm, slightly below the national target.⁶⁴

In 2016 and 2017, the annual average growth of domestic gas production was only 5%. As of October 2018, China produced 129.5 bcm, up 6.9% y-o-y.⁶⁵ Given the lagging historical performance of natural gas production, it is likely that domestic output will not exceed 179.3 bcm in 2020 as contrasted to the five-year plan’s projection of 207 bcm. PNG imports will likely sustain their recent growth rate and reach approximately 48.3 bcm in 2020. If completed in late 2019, however, the Power of Siberia pipelines are expected to add up to 5 bcm of PNG imports in the first year. Given that domestic natural gas growth has been lagging and remains insufficient to meet the 30 bcm goal, there

⁶¹2018 Energy Work Guidance of China.

⁶²Standard coal equivalent. One-ton SCE equals approximately 786.6 bcm natural gas.

⁶³In 2016 and 2017, China showed an 11.1% annual average growth. NDRC. Regular press conference on October 23, 2018. http://www.china.com.cn/zhibo/content_67728050.htm

⁶⁴This is not far from Wood Mackenzie’s forecast that the Chinese natural gas consumption to grow to 330 bcm by 2020. Wood Mackenzie. 2017. “Will Trump’s Beijing trip win some LNG deals for the US?”

<https://www.woodmac.com/press-releases/will-trumps-beijing-trip-win-some-lng-deals-for-the-us/>

⁶⁵The National Bureau of Statistics of China.

is likely an emerging opportunity to fill the gap of 119 bcm or 88 million tons with LNG in 2020.⁶⁶ For reference, US export capacity at the end of 2018 was 50.65 bcm/y, and according to the December 10, 2018 EIA Today in Energy, additional export terminals and trains in the U.S. are expected to increase the U.S. LNG export capacity to 132.62 bcm/y by 2021. This means that while current U.S. exports could only fulfill about 71% of current Chinese demand, by 2020 the exports from the U.S. alone should far exceed 100%.

Imports will constitute a little less than half of natural gas demand in 2020,⁶⁷ driven largely by continued growth in LNG. Shell projects that LNG will constitute 31% of growth in natural gas supply in China from 2017 to 2030, with an annual growth rate of 4%,⁶⁸ which will make China the largest LNG importer in 2030 if the Japanese government's cut its own LNG consumption to 62 mtpa as currently planned. The IEA report posits that Chinese demand will rise to the level sooner, reaching 67.4 mtpa (93 bcm) in 2023 and showing an annual growth of 10% which will make China the largest LNG importer before 2030 if the Japanese government cuts its own LNG consumption to 62 mtpa as currently planned.

Domestic Production and Shale Gas Potential

Over the next 10-20 years, China's LNG imports growth will fill the residual requirement not met by PNG imports and domestic production of conventional and unconventional natural gas.⁶⁹ The output-and-demand gap is projected to widen in the absence of massive breakthroughs in its shale gas. Moreover, diminishing investments in exploration and production are limiting substantial production growth in unconventional gas.

China's gas reserves are found across basins covering four million square km with sedimentary rocks from the Paleozoic to Cenozoic era. By the end of 2017, accumulated proven geological reserves were about 14.22 trillion cubic meters (cu.m), the remaining technically recoverable reserves 5.5 trillion cu.m⁷⁰ and economically recoverable reserves 3.92 trillion cu.m.⁷¹ Figure 12 shows the largest basins that are concentrated in Tarim (in Xinjiang autonomous region), Ordos (in the mid-northern provinces), and Sichuan (in the Sichuan province region), along with basins in the surrounding seas.⁷² Due to a decrease in investment in oil and gas exploration since 2013 and 2014,⁷³ proven gas reserves could not increase sufficiently in the past few years. In 2017, natural gas production was 148.7 bcm and the

⁶⁶Using the Qatar Gas bcm-to-mtpa conversion.

⁶⁷This is in agreement with other institutes' similar projections. For example, Paulson Institute projected that nearly 50% of natural gas consumption will come through imports by 2020. Hove, Anders. 2017. "Natural Gas in China." *Paulson Institute*, October 4, 2017. <http://www.paulsoninstitute.org/economics-environment/paulson-primers/natural-gas-in-china/> Morgan Stanley expected that the number to be more than 50 percent by 2025. Zheng, Xin. 2018. "CNPC natural gas output increases." *ChinaDaily*, February 9, 2018. <http://www.chinadaily.com.cn/a/201802/09/WS5a7cfff8a3106e7dcc13bbcb.html>

⁶⁸Shell. 2018. "Shell Outlook 2018." p. 12, https://www.shell.com/energy-and-innovation/natural-gas/liquefied-natural-gas-lng/lng-outlook/_jcr_content/par/textimage_864093748.stream/1519645795451/d44f97c4d4c4b8542875204a19c0b21297786b22a900ef8c644d07d74a2f6eae/shell-lng-outlook-2018-presentation-slides.pdf

⁶⁹China became the 6th largest natural gas producer in the world in 2017.

⁷⁰Ministry of Natural Resources. 2018. "National Oil and Gas Resources Exploration and Mining Report (2017)." http://gi.mnr.gov.cn/201807/t20180713_2085143.html

⁷¹State Council Information Office of PRC. 2017. "Ministry of Land and Resources Holds National Conference on Oil and Gas Exploration and Mining Results." *SCIO*, August 15, 2017.

<http://www.scio.gov.cn/xwfbh/gbwxwfbh/xwfbh/gtzyb/Document/1561889/1561889.htm>

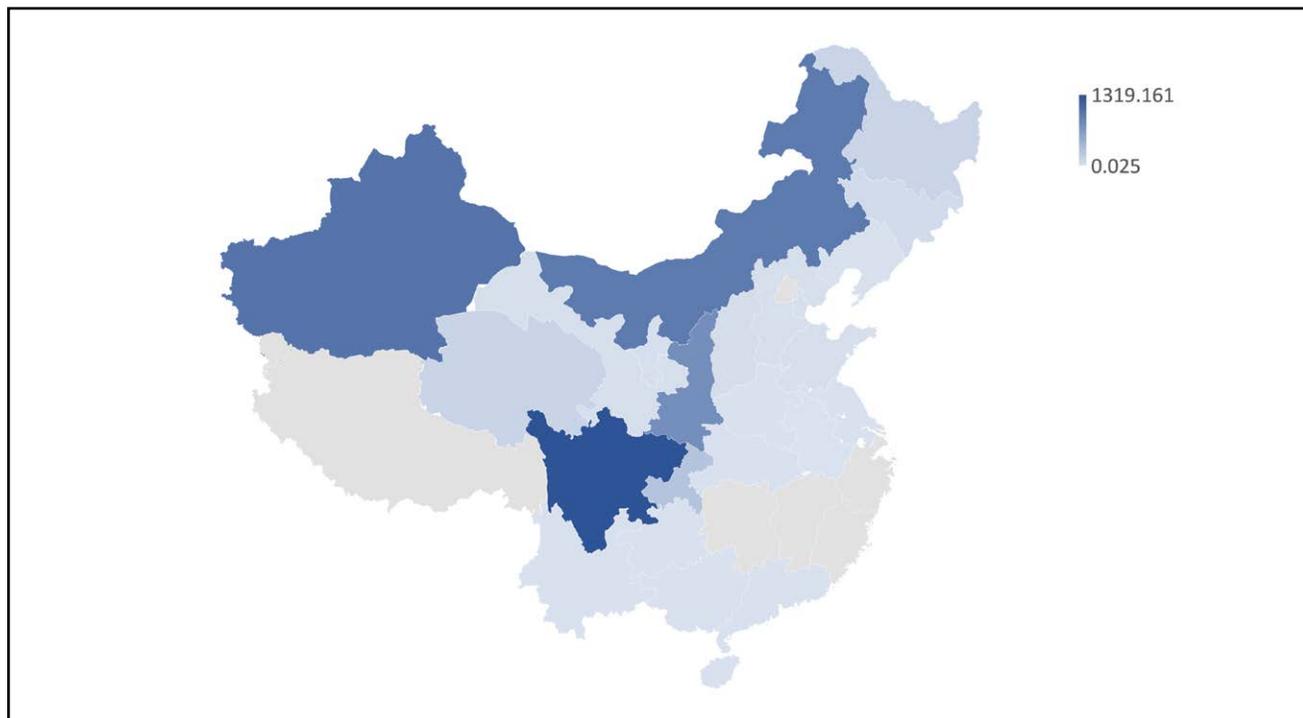
⁷²CNPC. n.d. "Ordos Basin." <http://www.cnpc.com.cn/en/xhtml/pdf/19-Ordos%20Basin.pdf>

⁷³PetroChina, CNOOC Ltd., and Sinopec Ltd. Annual Reports.

reserve-production ratio was 36:1, which is only a third of the average of the Middle East. This could change if the Big Three ramp up their investment projects. Most recently, CNPC plans to invest RMB

150 billion (USD 22 billion) in its Tarim oil and gas production,⁷⁴ which will boost the region’s output of 23.5 bcm in 2017 to 75% by 2020.⁷⁵

Figure 12
China’s Proven Natural Gas Reserves by Region (2006)^{76 77}



Given the large potential reserves in China, the State Council and the SOEs are studying shale gas and coal bed methane (CBM) extensively. The Big Three’s shale gas and CBM production amounted to nine bcm and less than 3.3 bcm in 2017. Sinopec’s Fuling shale gas field in Chongqing produced six bcm of the production that year.⁷⁸ According to

Wood Mackenzie, thanks to drilling technology and cost cutting, shale gas production is estimated to reach 17 million bcm in 2020. However, this projection falls short of the government’s plan of 30 bcm and analysts are not betting big on Chinese shale gas in the short run.⁷⁹

74 China.org.cn. 2018. “CNPC plans 150-bln-yuan investment in Xinjiang.” China.org.cn, July 26, 2018. http://www.china.org.cn/china/Off_the_Wire/2018-07/26/content_57829186.htm

75 Mason, Josephine, Judy Hua, Tom Daly, and Florence Tan. 2018. “In China’s far west, CNPC vows \$22 billion spend to replace ageing oil wells.” *Reuters*, July 24, 2018. <https://www.reuters.com/article/us-china-cnpc-oil-gas/in-chinas-far-west-cnpc-vows-22-billion-spend-to-replace-ageing-oil-wells-idUSKBN1KF07L>

76 Image created by EPRINC, based on data by the National Bureau of Statistics of China, 2016, <http://www.stats.gov.cn/tjsj/ndsj/2017/indexeh.htm>

77 Disclaimer: In this report, we only focus on the LNG sector in the Mainland China and do not intend to touch upon any topic regarding the Cross-Strait relations or China’s territorial sovereignty.

78 Sinopec Group. 2018. “China’s first shale gas field hits ten bcm/year.” *Sinopecgroup*, March 29, 2018. http://www.sinopecgroup.com/group/en/Sinopecnews/20180329/news_20180329_511487208275.shtml

79 Wood Mackenzie. 2018. “Chinese shale gas production will almost double in two years.” <https://www.woodmac.com/news/editorial/chinese-shale-gas-production-will-almost-double-in-two-years/>

Natural Gas Supply and Storage Security and Capacity

Inadequate pipeline capacity and storage facilities are important constraints limiting a more rapid expansion in natural gas consumption. Without scaling up natural gas infrastructure – namely: pipelines, LNG receiving and storage facilities, and underground storages – the government’s aim to amplify consumption could continue to fall prey to price hikes and winter supply shortages. Potential demand growth outside traditional gas consumption remains substantial as LNG trucking and small-scale LNG continue to grow. The 2018 NDRC Notice on the Construction and Operation of Gas Storage Facilities, which encourages local governments to build storage facilities, requires streamlined approval processes and construction of projects as well as improved coordination between gas storage facilities and natural gas pipeline networks.

Trunk Pipelines and PNG

The total length of domestic natural gas trunk pipelines has increased 6.4 times in the past 20 years, from 11,000 km in 1998⁸⁰ to 70,000 km in 2017.⁸¹ The NDRC set targets to grow this length to 104,000 km by 2020⁸² and 163,000 km by 2025.⁸³ Three Central Asian countries supply more than 90% of total PNG imports: Turkmenistan 80% (31.7 bcm), Uzbekistan (3.4 bcm) and Kazakhstan (1.1 bcm).⁸⁴ The remainder of PNG is imported from

Myanmar (3.3 bcm)⁸⁵. The three Central Asia-China lines (A, B, C) have a combined capacity of 55 bcm,⁸⁶ and the fourth line D is currently under construction with no defined date to come into operation.⁸⁷ As the utilization of the current pipelines are nearing their capacity limit, growth in PNG depends on the construction of new pipelines and the Power of Siberia.

Russia’s Power of Siberia is expected to eventually deliver 38 bcm annually to China via its eastern route for 30 years starting in December 2019. If the project comes online as scheduled, it will gradually moderate LNG growth between 2020-2024.⁸⁸ The Power of Siberia II, a 30-bcm proposed project to supply gas to the western China via the Altai Mountains, has been stalled since CNPC signed a Heads of Agreement with Russia’s Gazprom in 2015.⁸⁹ However, it remains to be seen whether the stalling will continue, as China has recently shown strong motives in favor of the project.

Multi-Layered Gas Storage and Peak Shaving Policy

After the price volatility in the winter of 2017, the NDRC identified greater investment in storage capacity as a measure to enhance natural gas supply security. China seeks to increase its peak shaving facilities, which are utilized for surplus storage in order to meet the requirements of peak consumption in the colder months. The NDRC

⁸⁰National Bureau of Statistics of PRC

⁸¹Duan, Zhaofang. 2017. “China Natural Gas Market Status and Outlook.” <https://eneken.ieej.or.jp/data/7693.pdf>

⁸²Xinhuanet. 2017. “China plans to expand oil, gas pipeline networks.” Xinhuanet, July 12, 2017.

http://www.xinhuanet.com/english/2017-07/12/c_136438633.htm

⁸³NDRC. 2017. “Notice on Printing and Distributing the Medium and Long-Term Oil and Gas Pipeline Network Plan” (in Chinese). http://www.ndrc.gov.cn/zcfb/zcfbghwb/201707/t20170712_854432.html

⁸⁴BP. 2018. “BP Statistical Review of World Energy 2018.” p. 36. <https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review/bp-stats-review-2018-full-report.pdf>

⁸⁵Since 2014, Myanmar-China Gas Pipeline never delivered more than 3.9 bcm, albeit the design capacity of 12 bcm.

⁸⁶CNPC. n.d. “Flow of natural gas from Central Asia.”

<https://www.cnpc.com.cn/en/FlowofnaturalgasfromCentralAsia/FlowofnaturalgasfromCentralAsia2.shtml>

⁸⁷Asia-Plus. 2018. “Construction of Tajik section of Turkmenistan-China gas pipeline starts, says Tajik official.” *News.tj*, January 31, 2018. <https://news.tj/en/news/tajikistan/economic/20180131/construction-of-tajik-section-of-turkmenistan-china-gas-pipeline-starts-says-tajik-official>

⁸⁸According to RT, its initial volumes will be five bcm and eventually reach 38 bcm in 2024. RT. 2018. “Russia to become China’s top supplier of gas soon.” *RT*, September 22, 2018.

<https://www.rt.com/business/439105-russia-chinas-gas-exporter/>

⁸⁹Gazprom. 2015. “Gazprom and CNPC sign Heads of Agreement for gas supply via western route.” *Gazprom*, May 8, 2015. <http://www.gazprom.com/press/news/2015/may/article226167/>

plans to promote a multi-layer peak shaving system, in which underground gas storages (UGSs) and coastal LNG receiving terminals are the two main peak shaving facilities.⁹⁰ After 2020, UGSs will be the primary peak shaving facilities while LNG receiving terminals will provide auxiliary services.⁹¹ Key measures are to ramp up the construction of gas storage and peaking facilities, establish a reserve system and support local authorities as well as business entities to build gas storage facilities. A greater peak shaving system with more UGSs and LNG receiving capacity will enable increased LNG imports throughout the year.

Underground Gas Storage Capacity (UGS)

In 2018, the working volume of China's UGS had reached 16 bcm, surpassing the NDRC target of 14.8 bcm for 2020.⁹² However, this capacity represents only around 4-5% of the country's total consumption, against the global storage average of 12-15% of consumption.⁹³ The insufficient LNG storage tank capacity has also become the bottleneck of sustainable growth in natural gas use in China. According to the NDRC, LNG storage tanks account for 2.2% of China's total natural gas consumption and 9% of its total LNG consumption, lower than the levels of Japan and South Korea (each with 15%). The NDRC required NOCs to have storage facilities of at least 10% of their contracted

sales by 2020 and town gas companies 5% by 2020.⁹⁴ Of the existing 25 UGS facilities in China, PetroChina has 23 and Sinopec two.⁹⁵ The two SOEs have plans for UGS projects that will potentially increase the existing capacity three- to five-fold in the next decade. CNPC's plan is to build seven to eight facilities with a capacity of 21.74 bcm starting in 2022. Sinopec, with two UGS, Wen-23 and Wen-96, with a total working capacity of around five bcm,⁹⁶ also plans UGSs with a capacity of 55 bcm.⁹⁷

LNG Receiving Terminals and Storage Tanks

The rapid growth of LNG has been powered by an increase in the number of LNG receiving, regasification, and storage facilities. There are currently 20 LNG receiving terminals in China, with total design receiving capacity of more than 62 mtpa and additional expected capacity of 40 mtpa in the subsequent phases. The total storage at these terminals reaches 8.6 mcm (3.9 mtpa).⁹⁸ CNOOC singly or jointly owns nine LNG receiving terminals with LNG receiving capacity of up to 33.8 mtpa.⁹⁹ CNPC and Sinopec own three each, and ENN Energy owns the only private three mtpa terminal, and other second-tier companies have terminals with capacities under three mtpa.¹⁰⁰

LNG approval process

The State Council approves LNG receiving,

⁹⁰NDRC. "Opinions on Accelerating the Construction of Gas Storage Facilities and Improving the Market Mechanism for Ancillary Services for Gas Storage and Peak Regulation." 2018.

⁹¹Ishwaran, Mallika et al. 2017. "Analysis of China's Natural Gas Infrastructure Development Strategy." In *China's Gas Development Strategies*. p. 242. https://www.researchgate.net/publication/321259962_Analysis_of_China's_Natural_Gas_Infrastructure_Development_Strategy

⁹²NDRC. 2017. "Notice on Printing and Distributing the Opinions on Accelerating the Use of Natural Gas" (in Chinese). http://www.ndrc.gov.cn/gzdt/201707/t20170704_853939.html

⁹³Chen, Aizhu. 2018. "FACTBOX-China's underground natural gas storage facilities." *Reuters*, April 11, 2018. <https://uk.reuters.com/article/china-pollution-gas-storage/factbox-chinas-underground-natural-gas-storage-facilities-idUKL4N1QR2Q1>

⁹⁴Bai, Wansong. 2018. "NDRC holds press conference regarding natural gas production and supply" (in Chinese). *State Council*, April 27, 2018. http://www.gov.cn/xinwen/2018-04/27/content_5286333.htm#1

⁹⁵23 of them are depleted oil and gas reservoirs and two are salt caverns.

⁹⁶Meng, Meng. 2017. "China's Sinopec starts building nation's largest gas storage site." *Reuters*, May 23, 2017. <https://www.reuters.com/article/us-china-sinopec-gas/chinas-sinopec-starts-building-nations-largest-gas-storage-site-idUSKBN18K08S>

⁹⁷Xin, Zheng. 2018. "Sinopec boosts gas storage units." *ChinaDaily*, August 9, 2018. <http://www.chinadaily.com.cn/a/201808/09/WS5b6b84daa310add14f384bc5.html>

⁹⁸Petroleum Economist. 2018. "World LNG Map: 2018 Edition."

⁹⁹CNOOC. n.d. "Gas & Power." <http://www.cnooc.com.cn/col/col6391/index.html>

¹⁰⁰See Appendix 6.

storage, and transportation (including expansion of the existing) projects.¹⁰¹ A proposal is first submitted to a local natural resources department and pre-examined by the Ministry of Natural Resources.¹⁰² Projects with a receiving and storage capacity of 3 mtpa or more are reviewed by the NDRC and submitted to the State Council for approval,¹⁰³ whereas smaller projects are approved by provincial governments.¹⁰⁴ Over the years, the NDRC has relaxed its requirements for the approval of LNG receiving facilities by lowering the required amount of supply agreement with an outside partner to one mtpa for proposed facilities.¹⁰⁵ Nevertheless, the approval process is still deemed complicated. In addition to the different layers of agencies involved in the approval process, the Ministry of Transport reviews onshore terminals and the State Oceanic Administration reviews FSRUs.¹⁰⁶ There are at least 30 project proposals for LNG receiving terminals, yet only five are planned or received approval for construction.¹⁰⁷

After suffering the supply shortages in the winter of 2017, China lifted its LNG import volumes in the warmer seasons of 2018 for peak shaving purposes. China's LNG terminal utilization rate was on average 66% and some even went above their nameplate capacity in 2017.¹⁰⁸ It is likely that China will require additional LNG receiving

capacity in order to meet domestic demand. With the flattening of seasonal fluctuations due to increased UGSs and other storage and peak shaving measures, more LNG imports are possible throughout the year. As of this writing, however, no major LNG terminal is expected to come online through 2020, so the growth must depend on the expansion of the existing facilities. It is not clear whether the expected expansions in the next phases will be completed within the five-year plan period and even if they are, the additional capacity will not match the existing capacity. Total receiving capacity is projected to reach over 100 mtpa by 2020, which is close to SIA Energy's 2016 estimate that the capacity will exceed 110 mtpa by 2020. At the utilization rate of 60% and beyond, the LNG import level in 2020 will likely be between 60 and 70 mtpa. SIA Energy estimates that the total LNG receiving capacity in China will reach nearly 200 mtpa by 2030.¹⁰⁹

Small-Scale LNG Getting Bigger

Small-scale LNG (SSLNG) is used for bunkering, power generation in off-grid locations and heavy road transport, and its capacity range varies between 2,000 and 500,000 tons per annum.¹¹⁰ The technology has a comparative advantage over large LNG facilities in attracting

¹⁰¹State Council. 2016. "Government-Approved Investment Project Catalogue" (in Chinese). http://www.gov.cn/zhengce/content/2016-12/20/content_5150587.htm

¹⁰²CNOOC. 2016. "Jiangsu Binhai LNG receiving station project's pre-trial approved" (in Chinese). CNOOC, September 30, 2016. http://www.cnoc.com.cn/art/2016/9/30/art_311_2436801.html

¹⁰³NDRC. n.d. "NDRC Administrative Examination and Approval Items Directory" (in Chinese). <http://www.ndrc.gov.cn/zfwzx/xzsp/>

¹⁰⁴State Council. 2016. "Government-Approved Investment Project Catalogue" (in Chinese). http://www.gov.cn/zhengce/content/2016-12/20/content_5150587.htm

¹⁰⁵Towngas. n.d. "NDRC relaxes LNG receiving project approval." <http://www.towngas.com.cn/info/1065/1239.htm>

¹⁰⁶Li, Qian. 2018. "Private Enterprises' Participation in LNG Receiving Stations" (in Chinese). People.cn, April 9, 2018. http://paper.people.com.cn/zgnyb/html/2018-04/09/content_1847151.htm

¹⁰⁷See Appendix 7.

¹⁰⁸Corkhill, Mike. 2018. "Chinese LNG terminals hit record utilisation rates." *LNG World Shipping*, March 8, 2018. https://www.lngworldshipping.com/news/view,chinese-lng-terminals-hit-record-utilisation-rates_51033.htm

¹⁰⁹Li, Yao. 2016. "China's Emerging 2nd Tier LNG Players and LNG Import Capacity Outlook." *SIA Energy: China LNG International Summit*, p. 5. https://asiapacific.cwclng.com/wp-content/uploads/2016/07/SIA-Energy_Yao-Li_Tier-2-Chinese-Players-and-LNG-Terminal-Capacity-Outlook_201603161.pdf

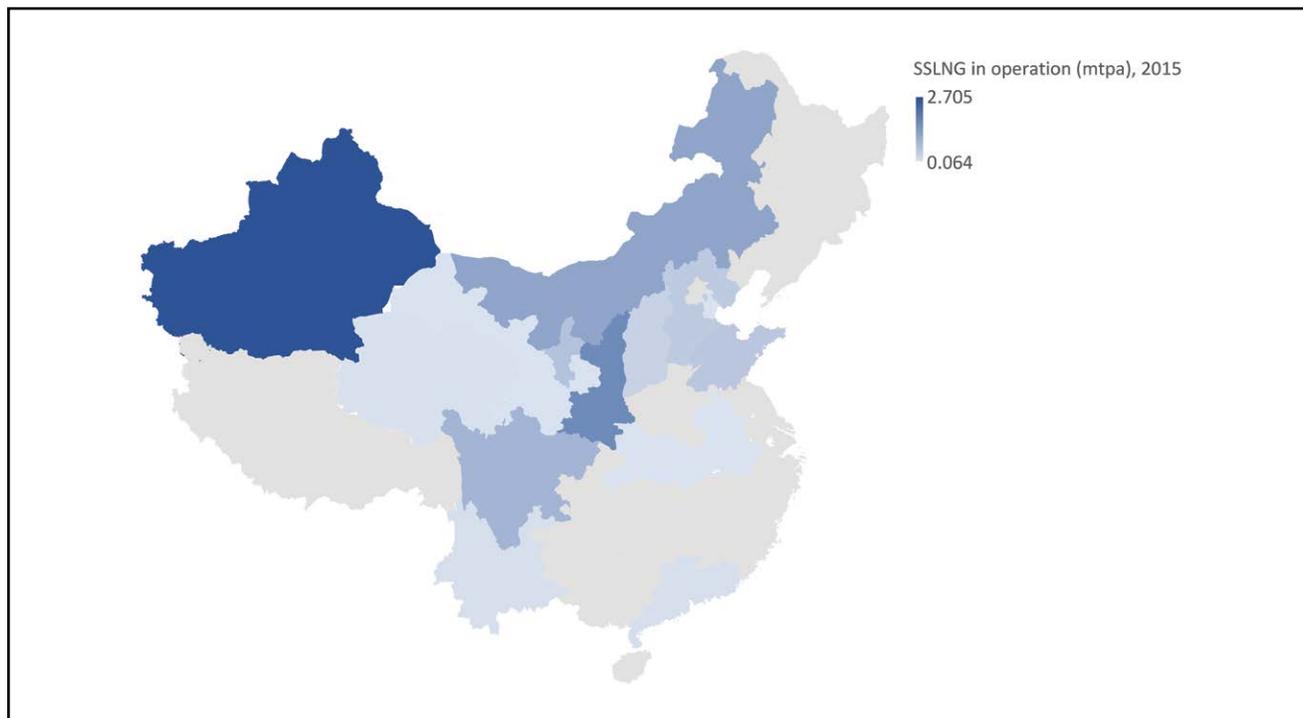
¹¹⁰Kunert, Sebastian, and Bruno Larson. 2008. "Small is Beautiful: Mini-LNG concept." p. 1.

https://dgc-wittenberg.de/vortraege/Small_is_beautiful_Hamworthy_MiniLNG_Concept_June_2008.pdf

investment¹¹¹ because SSLNG offers short-time returns, reduced uncertainty, flexibility, and the potential to create new markets in off-grid locations.¹¹² Additionally, SSLNG plants depend on

large natural gas reserves in a few inland provinces, namely in Xinjiang, Shaanxi, Inner Mongolia, and Sichuan (Figure 13).

Figure 13
Small-Scale LNG in Operation in 2015 (mtpa)¹¹³



China has spearheaded the growth in SSLNG, with 96,000 LNG trucks produced in 2017, up from 19,600 in 2016.¹¹⁴ Largely owing to the government’s ban on diesel trucks in transporting coal to some parts of the country and in combination with its strict emissions standards,¹¹⁵ demand for LNG trucks has climbed. The CPC and State Council’s Notice on Strengthening Ecological

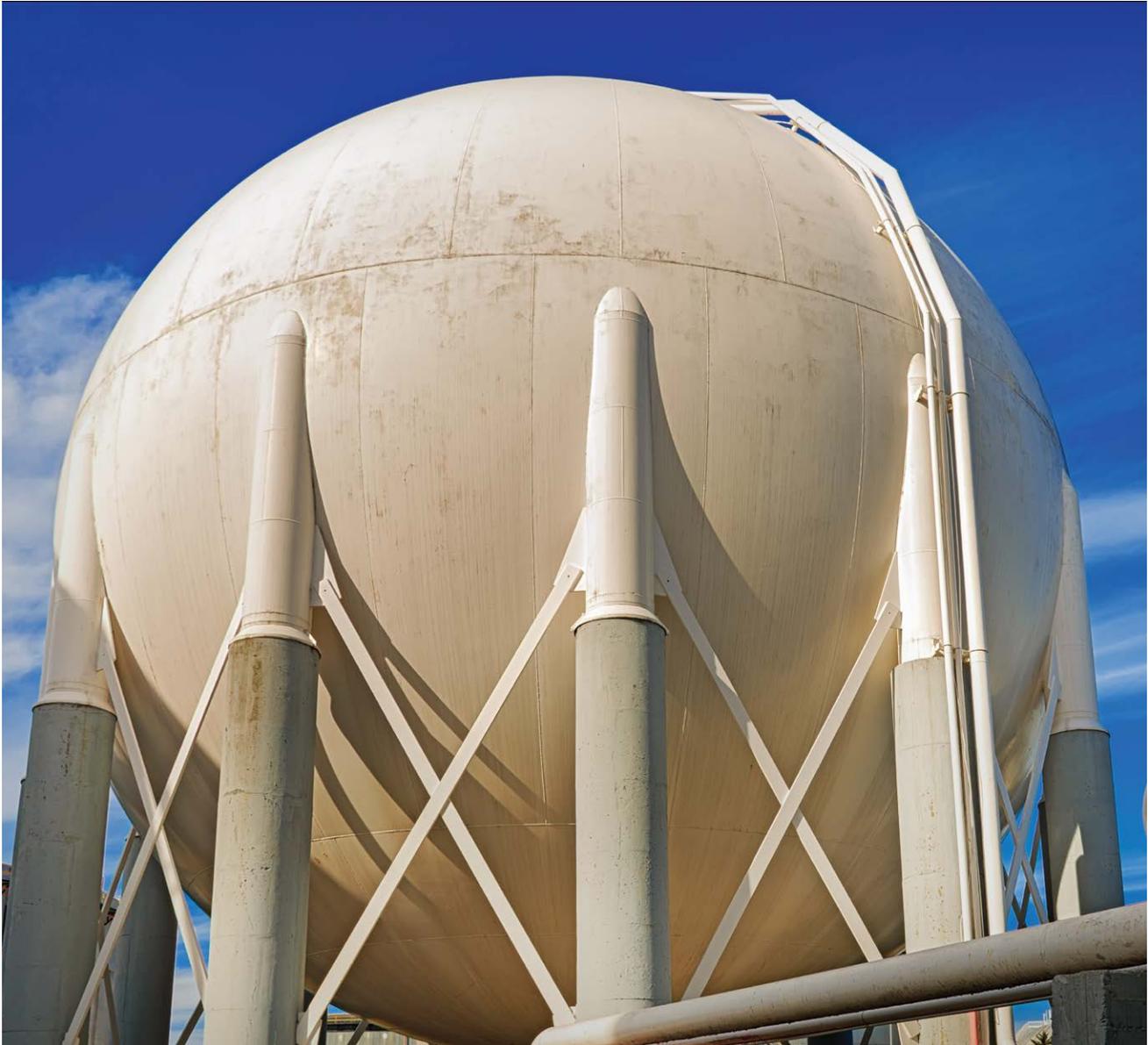
Protection and Pollution Prevention encouraged the further promotion of clean energy vehicles and vessels over diesel trucks.¹¹⁶ Many local trucking companies have expanded the use of these clean energy vehicles because of their environmental and cost benefits relative to diesel trucks. As stated in the 13th Plan, by 2020, there will be ten million gas-fueled vehicles, 12,000 gas stations, and 200

¹¹¹Biscardini, Giorgio, Rafael Schmill, and Adrian Del Maestro. 2017. “Small going big: Why small-scale LNG may be the next big wave.” Strategy&. p. 5. <https://www.strategyand.pwc.com/media/file/Small-going-big.pdf>
¹¹²International Gas Union. 2015. “Small Scale LNG.” 2012 – 2015 *Triennium Work Report* (Program Committee D3). p. 54. http://www.igu.org/sites/default/files/node-page-field_file/SmallScaleLNG.pdf
¹¹³Figure created using data from IGU: http://www.igu.org/sites/default/files/node-page-field_file/SmallScaleLNG.pdf pp.81-83
¹¹⁴Liu. 2018. “China sees gas truck boom amid green drive.” Xinhuanet, January 23, 2018. http://www.xinhuanet.com/english/2018-01/23/c_136918115.htm
¹¹⁵Smith, Brenda. 2014. “LNG for Transportation in China.” pp.7-8 <http://cdn.gladstein.org/pdfs/ACTE2014Presentations/InternationalMarketUpdate/4BrendaSmith.pdf>
¹¹⁶Xinhuanet. 2018. CPC and State Council’s update on environmental policy. http://www.xinhuanet.com/politics/2018-06/24/c_1123028598.htm

ship fueling and bunkering stations. China aims to build 3,000 CNG/LNG refueling stations by 2025.¹¹⁷ As in other areas of LNG, private companies led by ENN are specialized in SSLNG and LNG filling stations and are profiting from the boom in LNG trucks and SSLNG.

In addition to LNG-fueled vehicles, trucking LNG from domestic plants and import terminals

has been instrumental in balancing supply and demand in China. Trucks carrying LNG accounted for a relatively large 12% (19 mtpa) of domestic consumption in the country in 2017.¹¹⁸ However, depending on the distance trucked, LNG prices hiked to some USD 30/MMBtu during the peak of 2017. Wood Mackenzie estimates that the 2017 level will double by 2025, reaching 38 mtpa.¹¹⁹



¹¹⁷Biscardini, Giorgio, Rafael Schmill, and Adrian Del Maestro. 2017. "Small going big: Why small-scale LNG may be the next big wave." *Strategy&*. p. 5. <https://www.strategyand.pwc.com/media/file/Small-going-big.pdf>

¹¹⁸Kallanish Energy. 2018. "China's LNG trucking capacity to reach 35 MTPA by 2025." <http://www.kallanishenergy.com/2018/06/05/chinas-lng-trucking-capacity-to-reach-35-mtpa-by-2025/>

¹¹⁹Wood Mackenzie. 2018. "China's LNG trucking capacity to double in medium term." <https://www.woodmac.com/press-releases/china-lng-trucking3/>

While the commercial decisions of the Big Three clearly remain moderated by the ministries, they are still able to make decisions based on the conditions of the market. In addition, China's LNG market structure is monopolistic and dominated by the NOCs, which yields a certain degree of inefficiency in the NOCs' operations. To drive more efficiency in the gas market, the central government has moved to liberalize natural gas markets by relaxing gas prices and providing equal footing to second-tier players by offering third-party access to LNG facilities. This has been further facilitated by China's efforts to liberalize markets by setting up trading hubs. The primary policies to drive more liberalized markets include:

- ▶ liberalizing domestic gas pricing¹²⁰
- ▶ boosting third-party access to LNG regasification terminals
- ▶ promoting a Chinese trading hub¹²¹

Pricing Mechanism

In an effort bring about reforms in natural gas pricing, since 2010 China has established trading centers and narrowed the parity between residential and non-residential gas prices. However, further reforms are needed to fully liberalize markets and encourage more private sector participation. Specific steps may include unlinking LNG from other fuel prices so that these prices are purely based on market supply-demand conditions, promoting wholesale markets through fully developed trading hubs, and giving full play to liberalization. These steps can be achieved through reduction in the dominance of the NOCs in upstream and midstream and the streamlining

of the legal requirements for constructing LNG terminals and gaining thirdparty access. China is making progress towards these goals, yet the reforms cannot be made overnight due to political, social and economic considerations. China's new pricing program revolves around deepening the market-oriented reform of non-residential prices, improving the residential pricing mechanism, and accelerating the development of the Shanghai and Chongqing trading hubs.¹²²

The Evolution of Pricing Reforms by the NDRC

Self-sufficient in natural gas supply, China's pricing structure was entirely based upon a cost-plus approach until 2010. With LNG and PNG imports beginning in 2005 and 2009, respectively, China became the only country in East Asia to produce and import natural gas. Its pricing mechanism is now contingent upon "three pillars" above, and PNG and LNG prices are dictated by international arrangements and supply-and-demand conditions.

Despite the rapid growth in demand, the old prices were much lower than the new import prices, which posed investment risks and demanded market-based solutions.¹²³ As part of the government's program to encourage pricing reforms in monopolistic industries,¹²⁴ China has pushed forward a series of regulatory reforms in natural gas pricing since 2010, when the NDRC first set benchmarks for domestically produced natural gas prices and increased urban gas prices. However, residential and non-residential gas price reforms were not conducted in parallel, as the government focused on the latter first, since non-residential gas accounts for over 80% of China's total consumption.

¹²⁰National Development and Reform Commission of China, p. 38.

¹²¹Liu, Hong. 2017. "China's Natural Gas Industrial Policy and Reform." p. 13, <https://www.usea.org/sites/default/files/event/-1.1%20China%E2%80%99s%20Natural%20Gas%20Industrial%20Policy%20and%20Reform-EN.pdf>

¹²²NDRC. 2017. "NDRC Opinions on Comprehensively Deepening the Pricing Mechanism Reform." http://www.ndrc.gov.cn/fzgggz/jggl/zcfg/201711/t20171110_866783.html

¹²³Paltsev, Sergey, and Danwei Zhang. 2015. "Natural Gas Pricing Reform in China: Getting Closer to a Market System?" MIT Joint Program on the Science and Policy of Global Change: Report No. 282. <https://core.ac.uk/download/pdf/78063525.pdf>

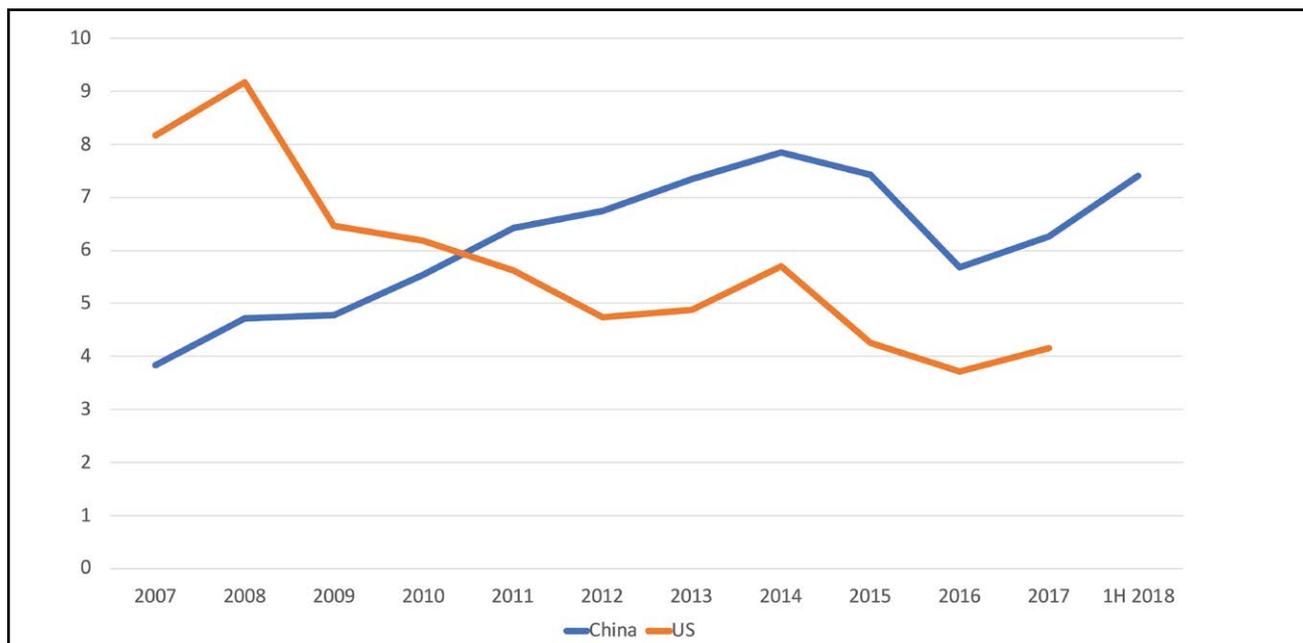
¹²⁴2017 NDRC Opinions on Comprehensively Deepening the Pricing Mechanism Reform http://english.gov.cn/state_council/ministries/2017/11/11/content_281475938688408.htm

*Non-residential gas pricing reforms*¹²⁵

Following a pilot project in Guangdong and Guangxi in 2011, the NDRC made the following major national reforms in 2013:

- ▶ Changed the pricing mechanism of natural gas from ex-factory price to end-user price (i.e., city gate price). Replacing different ex-factory prices by a single price at the city gate was intended to address pricing issues stemming from divergent gas sources and to simplify the entire mechanism.¹²⁶
- ▶ Benchmarked city gate prices to the weighted average price of alternative fuels, i.e., fuel oil and liquefied petroleum gas ($City\ gate = 85\% * (60\% * Fuel\ Oil + 40\% * LPG)$).¹²⁷ Meanwhile, consumers and suppliers were given freedom to negotiate prices within price ceilings.
- ▶ Differentiated the prices of existing and incremental natural gas in order to establish a new pricing mechanism for additional natural gas usage while minimizing the impact on existing gas usage and preventing any opposition to the new system. This policy was eventually replaced in 2015 by the unification of the existing gas usage with incremental gas usage.¹²⁸

Figure 14
Annual Average City Gate Gas Prices in the U.S. and China,
USD/thousand cu.ft (2007-1H2018)¹²⁹



¹²⁵Information here are acquired from sources including: PetroChina. 2018. "Form 20-F." <https://www.sec.gov/Archives/edgar/data/1108329/000119312518137017/d482381d20f.htm> Zhang, ZhongXiang. 2018. "Energy price reform in China." CCEP Working Paper 1805. https://ccep.crawford.anu.edu.au/sites/default/files/publication/ccep_crawford_anu_edu_au/2018-06/zhang_zx_2018_energy_price_reform_in_china_ccep_working_paper_1805.pdf

¹²⁶Corbeau, Anne-Sophie, et al. 2012. "Gas Pricing and Regulation China's Challenges and IEA Experience." International Energy Agency. p. 22. https://www.iea.org/publications/freepublications/publication/chinagasreport_final_web.pdf

¹²⁷Zhang, ZhongXiang. 2018. "Energy price reform in China." CCEP Working Paper 1805. pp. 4-7. https://ccep.crawford.anu.edu.au/sites/default/files/publication/ccep_crawford_anu_edu_au/2018-06/zhang_zx_2018_energy_price_reform_in_china_ccep_working_paper_1805.pdf

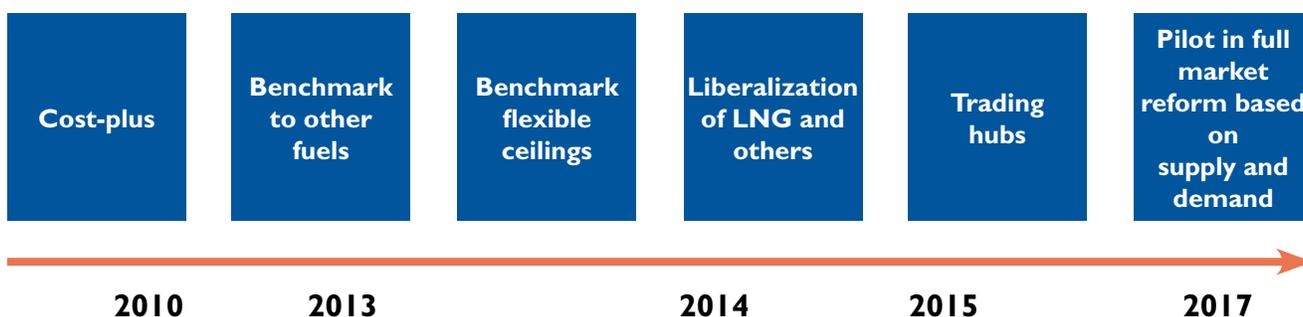
¹²⁸Paltsev, Sergey, and Danwei Zhang. 2015. "Natural Gas Pricing Reform in China: Getting Closer to a Market System?" MIT Joint Program on the Science and Policy of Global Change: Report No. 282. p. 14. <https://core.ac.uk/download/pdf/78063525.pdf>

¹²⁹PetroChina. 2018. "2018 Interim Results Announcement." <http://mms.prnasia.com/00857/20180830/audio/ Petrochina.pdf> U.S. Energy Information Administration. n.d. "Natural Gas." <https://www.eia.gov/dnav/ng/hist/n3050us3a.htm>

Starting in 2014, the prices of LNG and other forms of natural gas were liberalized. In 2016, gas storage facility operations as well as natural gas prices used for fertilizer feedstock were also liberalized. After 2013, the NDRC adjusted the non-residential city gate prices in subsequent years and allowed suppliers and buyers to increase their prices up to 20% above the benchmark. The average city gate price steadily climbed until 2015 due to the reforms from the old “cost-plus”

regime to the new wholesale system with more expensive imported gas (Figure 14). In November 2015, the NDRC slashed the wholesale price of non-residential gas by 28% (RMB 0.7/cu.m or approx. USD 0.11/cu.m)¹³⁰, although the wholesale price picked up in subsequent years. This in stark contrast to the average US gas prices during that time, as the shale revolution had made U.S. production highly competitive.

Figure 15
Timeline of the Reforms in Non-Residential Natural Gas Pricing by the NDRC



Residential gas pricing reforms

In 2010, the first major reform was made when the ceiling for residential gas prices was set at 1.4 RMB/cu.m (about \$ 0.22). Having lagged far behind the non-residential price reforms for years, the residential gas pricing mechanism was finally reformed in 2018. The NDRC’s Notice on the Rationalization of the Price of Residential Gas Stations unified the residential city gate gas prices with the non-residential gas prices using the benchmark of the latter. In this regard, the NDRC made the following reforms:

- ▶ Set a benchmark for natural gas price for each province.¹³¹ Like non-residential gas prices, residential prices can deviate from the benchmark by up to 20%.¹³²
- ▶ Ensured no sudden substantial impact on the consumer price index (CPI), increasing residential prices by no more than 0.35 RMB/cu.m in the full first year of its implementation.¹³³

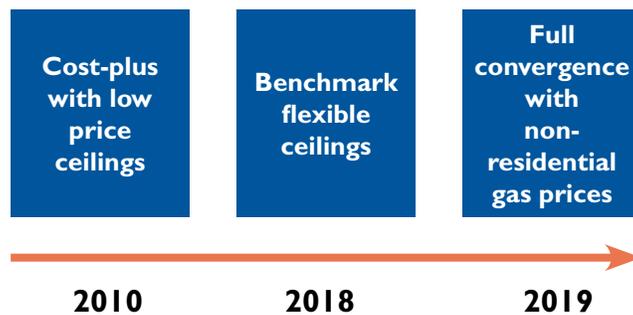
¹³⁰Xinhua. 2015. “China boosts pricing reforms in natural gas sector.” China.org.cn, November 21, 2015. http://www.china.org.cn/business/2015-11/21/content_37123349.htm

¹³¹NDRC. 2018. “Natural gas reference gate price by province.” <http://www.ndrc.gov.cn/zcfb/gfxwj/201805/W020180525555969836410.pdf>

¹³²To eliminate the financial burden of the price increase VAT was reduced from 11% to 10%.

¹³³The government also committed to protect low-income families as well as rural “coal-to-gas” switching families from the increasing prices by subsidies.

Figure 16
Timeline of the Reforms in Residential Natural Gas Pricing by the NDRC



In an effort to conduct pricing reforms in a coordinated manner, the NDRC also reduced its prices for non-residential users by 0.02 RMB/cu.m as part of the recent residential gas reforms.¹³⁴ The NDRC also announced that its price differentiation policy would be pursued based upon seasonal fluctuations,¹³⁵ in part due to the blackouts last winter. Prices were further changed at local levels, as provincial and municipal governments tailored prices to their domestic conditions.¹³⁶ The NDRC currently sets wholesale or city gate LNG prices by linking them to alternative fuels such as liquefied petroleum gas (LPG) and fuel oil.¹³⁷ Imported PNG is priced depending on the international pricing mechanism.¹³⁸

Transportation and Distribution Pricing Mechanism

Despite the introduction of city gate prices, midstream and downstream sectors’ pricing is still

regulated over concerns of monopolistic pricing power. Natural gas transportation prices across provinces are regulated by the State Council, while local distribution benchmark prices are determined by respective local pricing authorities. The NDRC guidance documents¹³⁹ outlined methods for formulating PNG transportation prices across provinces and distribution prices within provinces based on the basic formula: *Natural gas distribution or transportation price = permitted cost + permitted income + expected taxes and other factors*. Costs are determined using benchmarks; permitted rate of return cannot exceed 7% for distribution and 8% for transportation. For distribution prices, local authorities enjoy a certain level of flexibility in setting prices such as in determining the benchmark price. Figure 17 illustrates the composition of gas pricing in China.

¹³⁴Wang, Shuo. 2018. “Beijing’s residential gas prices to increase by 0.35 yuan per cubic meter.” *Chinanews*, July 9, 2018. <http://www.chinanews.com/cj/2018/07-09/8560904.shtml>

¹³⁵In this regard, the NDRC promoted companies to buy and sell natural gas at the Shanghai and Chongqing hubs.

¹³⁶Shi, Xunpeng, and Hari Malamakkavu Padinjare Variam. 2015. “China’s Gas Market Liberalisation—The impact on China–Australia gas trade.” p. 12. https://www.researchgate.net/publication/281036534_China’s_Gas_Market_Liberalisation-The_impact_on_China-Australia_gas_trade

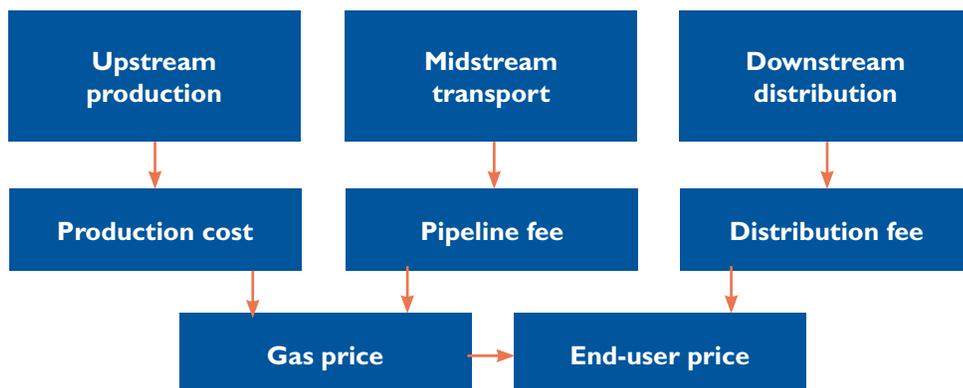
¹³⁷Chen, Aizhu, and Henning Gloystein. “China’s Chongqing gas exchange aims to be Asia price benchmark.” *Reuters*, December 29, 2017. <https://www.reuters.com/article/us-china-gas-exchange/chinas-chongqing-gas-exchange-aims-to-be-asia-price-benchmark-idUSKBN1EN0HN>

¹³⁸CNPC. 2017. “Global Natural Gas Pricing Mechanisms.” <http://center.cnpc.com.cn/bk/system/2017/03/22/001640121.shtml>

¹³⁹NDRC. 2016. “Natural Gas Pipeline Transportation Price Management Measures (Trial)” <http://www.ndrc.gov.cn/gzdt/201610/W020161012539079289091.pdf>, NDRC. 2017. “Guidance on Strengthening Regulations over the Gas Distribution Price.”

<http://www.gov.cn/xinwen/2017-06/22/5204625/files/d829204644294fb9a6431c0bc1c2f749.pdf>

Figure 17
China's Natural Gas Pricing Composition¹⁴⁰



LNG Pricing

LNG pricing is complex due to the over-priced Asian LNG markets and to different contractual types (i.e., spot, short-term and long-term). LNG prices are the most market-driven and are based on supply and demand. However, this flexibility is prone to fluctuations and causes price hikes in the winter.

Medium- and Long-Term Contract Prices

In Northeast Asia, contractual LNG prices are pegged to the Japan Crude Cocktail (JCC)¹⁴¹, which was maintained partly as a result of the early

introduction and sophistication of the Japanese oil and gas industry relative to industries of other countries in the region. When employing JCC, the index or slope serves as the central aspect of commercial negotiations.¹⁴² LNG prices are determined by the weighted average of JCC in applying the general formula: $a * JCC + b$, where a (slope) and b are constant coefficients determined by contract parties.¹⁴³ Contractual prices in Asia are referred to as having an “Asian premium” because of the common practice of indexing LNG prices to oil prices in the Asian markets.

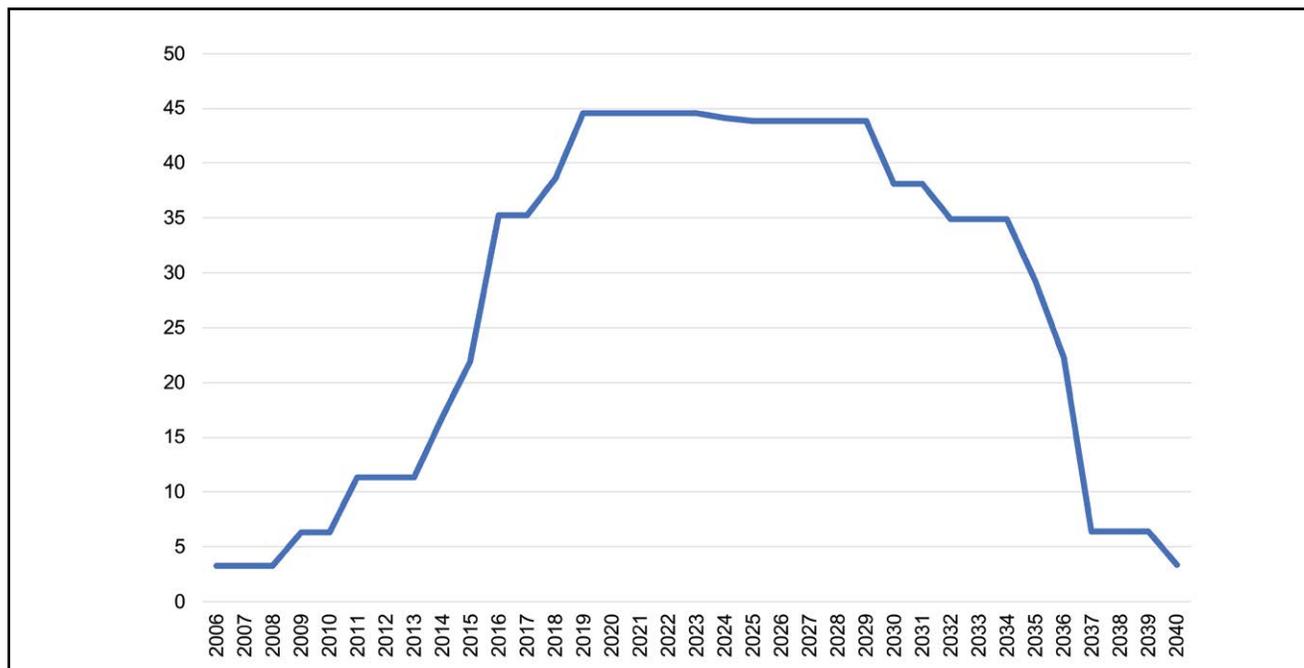
¹⁴⁰“Analysis of China’s natural gas price mechanism in 2018.” <http://www.chyxx.com/industry/201803/616926.html>

¹⁴¹This is also called “Japanese Customs-Cleared Crude Oil,” a basket of the most traded crude oils used as the reference for LNG prices.

¹⁴²Rogers, Howard V, and Jonathan Stern. 2014. “Challenges to JCC Pricing in Asian LNG Markets.” OIES Paper: NG 81. <https://www.oxfordenergy.org/wpcms/wp-content/uploads/2014/02/NG-81.pdf>

¹⁴³Sohu. 2018. “Understanding the LNG Industry, Pricing Mechanism, and Profitability” (in Chinese). Sohu, August 1, 2018. http://www.sohu.com/a/244536796_117959

Figure 18
LNG Supply via Medium- and Long-Term Contracts in China 2006-2040 (mtpa)¹⁴⁴



China’s medium- and long-term contracts have continuously increased over the years. As shown in Figure 18, a few long-term contracts run through as late as 2040. The supply from the existing long-term contracts is expected to peak around 2020-2024 and slide down onwards. However, the projection is likely to change as Chinese companies sign long-term deals in the same year of or a few years in advance of effective dates. Furthermore, the Chinese government has been observed as encouraging companies to sign long-term purchase and sale contracts to maintain uninterrupted growth in natural gas consumption.

Experts speculate that China will have to beef up its LNG trading in spot markets as its incremental long-term agreements were to decrease in 2018/2019.

This was supported by the absence of medium- or long-term contracts in 2017 and increased shorter-term contracts with durations ranging between five and ten years.¹⁴⁵ However, this was proven unsustainable after the supply shortage and price hikes in the winter of 2017. To address the problem, China sought diversification in its LNG mix by signing the first long-term contracts to import U.S. LNG to China with Cheniere Energy.¹⁴⁶ Amid the U.S.-China Trade War, China’s commitment to long-term contracts became even more evident; to minimize the effects of the trade war and ensure stable gas supply, China signed or extended several long-term contracts with Qatar and Australia in 2018.¹⁴⁷

¹⁴⁴In addition to the GIIGNL Annual Reports, the following information were used: Qatargas. n.d. “Qatargas Announces a 22-Year LNG Sale and Purchase Agreement with PetroChina.” <http://www.qatargas.com/english/MediaCenter/Pages/Press%20Releases/Qatargas-announces-a-22-year-LNG-Sale-and-Purchase-Agreement-with-PetroChina.aspx>

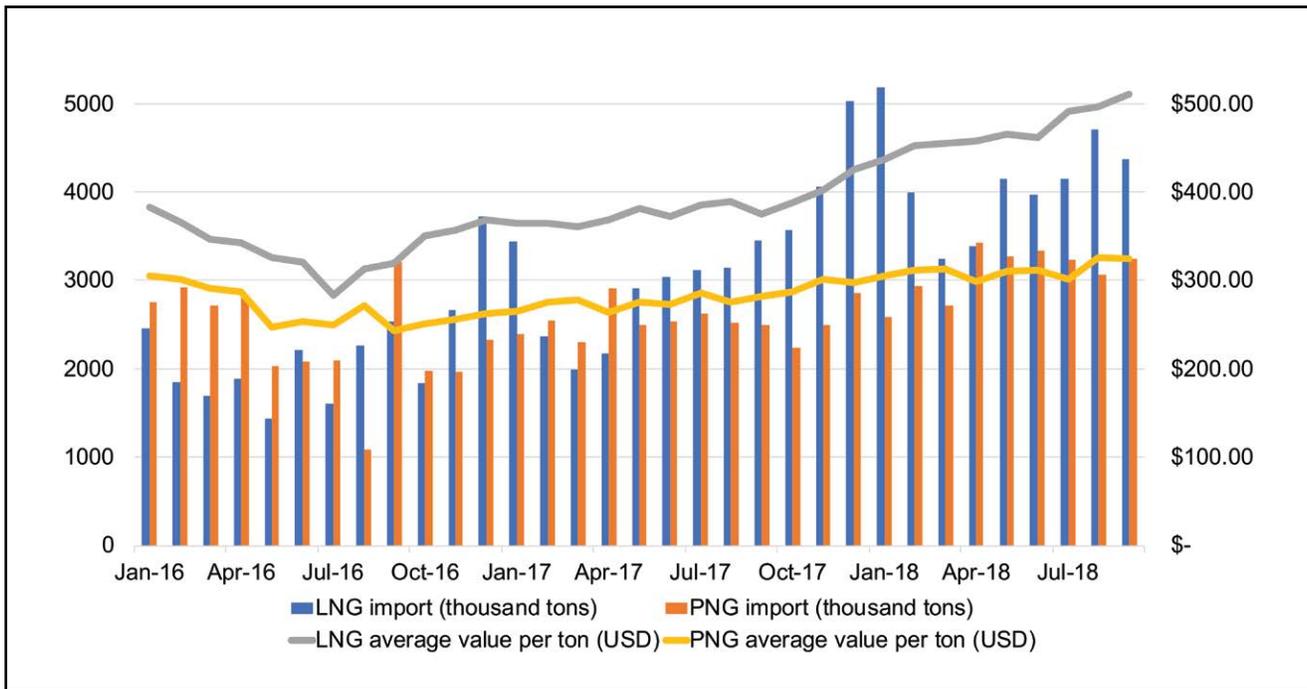
BP. 2015. “BP and China Huadian corporation sign multibillion dollar LNG deal.” <https://www.bp.com/en/global/corporate/news-and-insights/press-releases/bp-and-china-huadian-corporation-sign-multibillion-dollar-lng-de.html>

¹⁴⁵GIIGNL. 2018. “The LNG Industry: GIIGNL Annual Report 2018.” https://giignl.org/sites/default/files/PUBLIC_AREA/Publications/rapportannuel-2018pdf.pdf

¹⁴⁶According to the contract, CNPC’s PetroChina was to purchase LNG of 1.2 mtpa through 2043. <http://www.chinadaily.com.cn/a/201802/10/WS5a7dfd05a3106e7dcc13be53.html>

¹⁴⁷CNOOC extended its contract with Total to 20 years: <https://www.total.com/en/media/news/press-releases/total-and-cnooc-strengthen-their-long-term-cooperation-lng>; PetroChina signed a 22-year deal with Qatargas: <https://www.reuters.com/article/us-qatar-petrochina/qatargas-agrees-on-22-year-lng-supply-deal-with-china-idUSKCN1LQ0DM>

Figure 19
Monthly Imports and Average Values of LNG and PNG in China (Jan 2016 - Sep 2018)¹⁴⁸



In Figure 19 above, LNG imports increased in the colder months of 2016, 2017, and 2018. This was witnessed most significantly in early 2018, when January imports nearly doubled those of 2016, due to increased purchases in spot markets. The average monthly price of LNG surged after this. The average July 2016 LNG price was only 14% higher than PNG prices, but this gap grew to 63% in the same month of 2018 as demand for LNG kept growing. In a similar vein, except for April 2018, LNG imports have continuously been much higher than PNG imports as China prepared to meet winter demand.

Spot and Short-Term Market Pricing

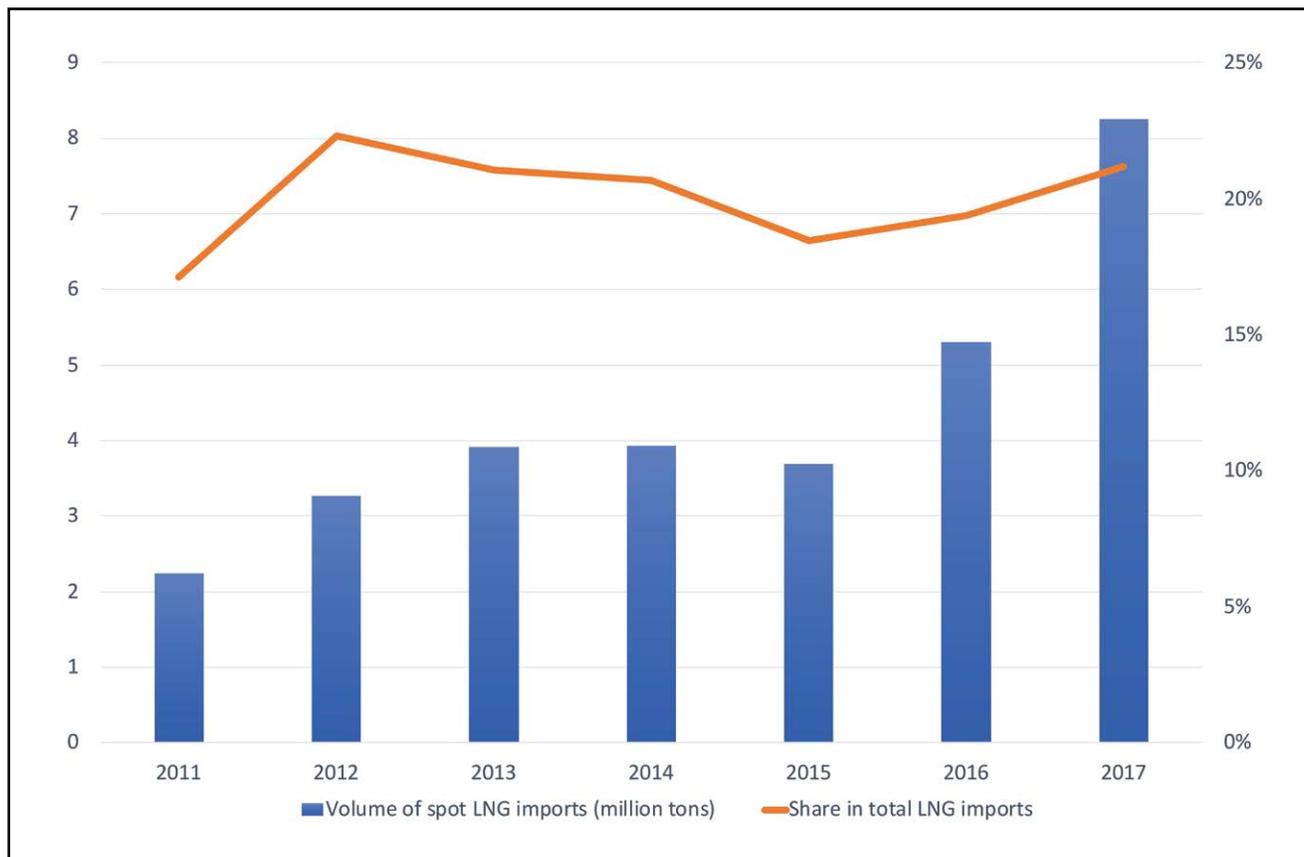
Private companies like ENN have in the past criticized the Big Three for signing and locking themselves in an excessive number of long-term contracts at high prices. These private companies

are increasingly engaged in spot and short-term LNG markets. Spot trading and short-term contracts of up to one year provide flexible supply to consumers with fluctuating demands. This flexibility has impacted global LNG markets in the past, as LNG vessels redirected their routes flowing from the Atlantic Basin to the Pacific Basin in times of opportunities for arbitrage in Asia.¹⁴⁹ Although growing private sector participation boosts short-term contracts and spot market trade, the share of spot markets will likely remain small compared to that of long-term contracts. In 2017, spot and short-term contract trading revealed an immense 56% growth; however, its share in the overall natural gas consumption remained close to the average level between 2011 and 2016 (Figure 20). Despite significant growth in LNG spot markets, long-term contracts are expected to continue to play a vital role for the foreseeable future.

¹⁴⁸EPRINC Figure with data derived from the General Administration of Customs of the People’s Republic of China, <http://www.customs.gov.cn/customs/302249/302274/302277/index.html>

¹⁴⁹Rogers, Howard V, and Jonathan Stern. 2014. “Challenges to JCC Pricing in Asian LNG Markets.” OIES Paper: NG 81. p. 7. <https://www.oxfordenergy.org/wpcms/wp-content/uploads/2014/02/NG-81.pdf>

Figure 20
Short-Term and Spot LNG Imports in China, 2011-2017¹⁵⁰



Third-Party Access

Effective third-party access (TPA) is considered one of the main drivers of greater private sector participation and pricing reforms. To support liquid and open natural gas markets, it is necessary to promote competition and access to infrastructure. TPA to LNG regasification terminals is essential to creating a competitive natural gas market with flexible LNG supplies.¹⁵¹ Private actors, including Jovo, Guanghui, Huadian, Sinochem, and CITIC Group are poised to take advantage of the Chinese government’s strides towards TPA. After the NDRC’s recent draft policy to allow TPA

to LNG facilities, CNOOC has taken the first steps to provide private and second-tier companies with access to its LNG facilities. In September 2018, CNOOC sold a slot at its LNG regasification station at the Yuedong receiving terminal through the Shanghai Petroleum and Gas Exchange (SHPGX).¹⁵² A consortium of Zhenhua Petroleum Holdings and Longkou Shengtong Energy made the purchase of 100 mcm for LNG delivery over a 45-day window period. Authorities expressed their hope that this LNG auction at the SHPGX would lead to a mature system with LNG receiving terminals fully open to third parties.¹⁵³

¹⁵⁰EPRINC table with data derived from GIIGNL Annual Reports from 2011-2017.

¹⁵¹Kate, Warner ten, László Varró, and Anne-Sophie Corbeau. 2013. “Developing a Natural Gas Trading Hub in Asia Obstacles and Opportunities.”

https://www.iea.org/publications/freepublications/publication/AsianGasHub_FINAL_WEB.pdf

¹⁵²Meng, Meng, and Aizhu Chen. 2018. “CNOOC sells third party access to Yuedong LNG terminal in auction.” *Reuters*, September 20, 2018. <https://af.reuters.com/article/africaTech/idAFB9N1UJ017>

¹⁵³Tong, Xiaobo. 2018. “Third Party Access to LNG Receiving Terminal.” *People.cn*, September 24, 2018. http://paper.people.com.cn/zgnyb/html/2018-09/24/content_1883078.htm

Trading Hubs

LNG wholesale markets are generally divided into two main categories: oil-indexed and hub-based. China's vision is to create a hub-based system which would reflect market forces instead of its current system of artificially following Asian oil markets. China progressed towards furthering its liberalization policy by creating two trading hubs within the span of two months between 2016 and 2017. The central government has pressed the Big Three to sell their excess gas at SHPGX and hold open actions for TPA to the NOCs' facilities.

Shanghai Hub

Xinhua News Agency and the NDRC founded the Shanghai Petroleum and Natural Gas Trading Center

(SHPGX) in 2016 to create a Chinese gas pricing hub in Asia. SHPGX was designed to accelerate the market-based reforms in the energy sector, particularly by improving the natural gas pricing mechanism and by deepening international cooperation. Xinhua News Agency (the largest

investor with a 33% stake), the "Big Three," and six other companies have invested capital of one billion yuan (USD144.56 million).¹⁵⁴ The center serves as a platform for spot trading in natural gas, LNG, and other products¹⁵⁵ and is trading wholesale PNG denominated in yuan per cubic meter and LNG in yuan per ton.

Chongqing Hub

Following SHPGX, China established the Chongqing Oil and Gas Exchange for the purpose of creating a regional natural gas trading hub. Taking advantage of geographical proximity, the center is expected to serve as a platform for trade in natural gas from the Sichuan basin, Central Asia and Russia to other parts of China.¹⁵⁶ However, the two Chinese natural gas exchange hubs have not generated substantial interest internationally. It remains to be seen whether the Chinese government's push for a greater number of transactions in these hubs will exceed the current limitations.

¹⁵⁴Li, Xuanmin. 2016. "Shanghai trading platform will support energy market reform." *Global Times*, November 27, 2016. <http://www.globaltimes.cn/content/1020543.shtml>

¹⁵⁵Lin, David, and Brenda Goh. 2016. "China launches commodity trading center in Shanghai, eyes Asia gas hub status." *Reuters*, November 26, 2016. <https://www.reuters.com/article/us-china-gas/china-launches-commodity-trading-center-in-shanghai-eyes-asia-gas-hub-status-idUSKBN13L07T>

¹⁵⁶Chen, Aizhu, and Henning Gloystein. 2017. "China's Chongqing gas exchange aims to be Asia price benchmark." *Reuters*, December 29, 2017. <https://www.reuters.com/article/us-china-gas-exchange/chinas-chongqing-gas-exchange-aims-to-be-asia-price-benchmark-idUSKBN1EN0HN>

CONCLUSION

China's search for blue skies continues. The future of Chinese LNG demand will play out through a large set of complex forces and competing interests, among which are the interests of national and local actors, the current market environment, and state policies and initiatives, among other variables. The current developments in the Chinese gas industry revolve around three forces in the Chinese natural gas market: components of natural gas demand, government policies governing gas supply security and stability, and the pace of market pricing reforms. One conclusion is clear, much of the growth in Chinese natural gas supply will rely upon LNG imports and will be the primary driver of natural gas supply growth through 2020. Supply growth will require an increased number of LNG receiving stations and more storage capacity to fully implement a full-scale peak shaving system

and stable gas supply. This will not be enough as the state will need to fulfill its programs for reforms in pricing and the implementation of TPA to LNG facilities to continue important reforms in this market. Various actors, from state-owned gas enterprises to local utilities to newly emerging private entities, are contributing to this evolving industry in China, as well. However, it is clear from the analysis that the central government will be the most important factor and actor in the future development of LNG as an energy source. The political commitment to improving air quality is not likely to fade as it remains a major concern at the grass roots level throughout China's urban centers. Blue skies are coming to China and LNG will play a key role, but the rate of improvement will be driven by government policy.



**Appendix I
Proposed LNG Receiving Terminals¹⁵⁷**

Terminal Name	Year	Operator	Expected Capacity (mtpa)	Storage (cm)
Jiangyin	2020	Hanas Group	3	
Putian	2019		6	
Zhuhai	2020		6	
Yingko	2020	Hubei Energy, Changlian Petroleum	6	960,000
Zhoushan		Hubei Energy	3 (+6+3)	
Binzhou		Hubei Energy, Changlian Petroleum	6	
FLNG	2019	Changlian Petroleum	3	
Chaozhou	2020	Chaozhou Huafeng Group, Zhongtian Energy	4	520,000
Jiangyin	2018	Zhongtian Energy	2	
Chengmai		China Huadian	6	
Ganyu, Jiangsu	2020		3	
Jiangmen, Guangdong			6	
Fangchenggang		CNOOC	0.6	
Wuhu Yangtze River			3	
Fuqing		PetroChina	3	
Shenzhen			3.2	
Lianyungang		Sinopec	3	640,000
Rudong		GCL-Poly		
Yantai	2020		3	
Hongkong GBS		CLP Power		
Huanghua Port		Hebei Jinjianjia	2	
Rizhao	2019	Royal Golden Eagle (Pacific Oil & Gas), Rizhao Port	2	
Shantou, Guangdong	2018	Sino Gas	3	
Qinzhou		N/A	3	

¹⁵⁷Various internet sources, including Sourcwatch.org.

Appendix 2
The NDRC Natural Gas Pricing Policy, 2010-2018¹⁵⁸

Issued, Effective Date	Description
2010	<p><i>First major reform in natural gas pricing:</i> Created a ceiling on residential gas prices at 1.4 yuan/cu.m (about \$0.22). This increased the average monthly urban gas price by 4.6 RMB. The benchmark price for domestically produced natural gas increased by 24.9%.</p>
2011	<p><i>A pilot reform in Guangdong and Guangxi:</i> Change in the cost-plus pricing method to the ‘netback market value pricing’ approach, in which benchmarks are fixed to alternative fuel prices in competitive markets.</p>
2013 Jun 28, Jul 10	<p><i>Initiation of the adjustment program of natural gas prices:</i> i) changing pricing mechanism of natural gas from ex-factory price to city gate price, and no longer differentiating the prices payable by the users in different provinces; (ii) establishment of the mechanism linking the city gate price of natural gas to the price of alternative energy; (iii) adopting differential pricing approaches towards the existing usage and the incremental usage so as to establish as soon as practicable a new pricing mechanism for natural gas while reducing the impact that the pricing reform will have on existing gas users.</p> <p>Consumers and suppliers can negotiate their specific prices if they do not exceed the price ceilings. This price is pegged to 85 % of the basket price of alternative fuels such as fuel oil and LPG using a 60% and 40% weight, respectively.</p>
2014 Aug 1, Sep 1	<p><i>Price adjustment programs for non-residential use stock natural gas:</i> i) the natural gas city gate price for non-residential uses was increased by RMB400 per thousand cubic meters; (ii) no adjustment was made to the city gate price for natural gas consumed by residential users; and (iii) further actions was taken to implement the policy in connection with the liberalization of the sales price of imported natural gas and the ex-factory prices for shale gas, coal-seam gas and coal gas.</p>
2015 Feb 26, Apr 1 Nov 18, Nov 20	<p><i>Unification of the prices of domestic natural gas of existing and incremental gas volume.</i></p> <p><i>Reduction of the price of natural gas for non-residential use:</i> City gate price ceiling for non-resident users decreased by RMB700/thousand cu.m while the preferential policy and price for natural gas used by fertilizer makers remain unchanged. From November 20, 2016, suppliers and non-residential users can negotiate prices of natural gas up to 20% above the benchmark price for non-residential uses.</p>

¹⁵⁸The table created from data from the 2018 20-F form of PetroChina, p.44, <https://www.sec.gov/Archives/edgar/data/1108329/000119312518137017/d482381d20f.htm>

**Appendix 2 (continued)
The NDRC Natural Gas Pricing Policy, 2010-2018¹⁵⁸**

Issued, Effective Date	Description
<p>2016 Oct 15, N/A</p> <p>Nov 5, Nov 10</p> <p>Nov 11, N/A</p>	<p><i>“Clarifying the Price Policy for Gas Storage Facilities”:</i> Prices for natural gas purchase and sale to be conducted by and the prices of gas storage services to be provided by the gas storage facilities shall be formed through the operation of market.</p> <p><i>“Notice on Enhancing Price Liberalization for Gas Used as Fertilizer Feedstock”:</i> Prices for gas used as fertilizer feedstock were fully liberalized and subject to negotiations between the vendors and the purchasers. The notice encourages the trading of the natural gas used by fertilizer makers in the oil and gas exchange centers in order to achieve open and transparent pricing of gas as fertilizer feedstock.</p> <p><i>“Notice on Relevant Issues concerning the Price Policy for Natural Gas City Gate Price in Fujian Province”:</i> Liberated the city gate natural gas price in Fujian Province and made Fujian the first province that would implement fully liberated city gate natural gas price</p>
<p>2017 Aug 29, Sep 1</p>	<p><i>“Notice on Reduction of the Benchmark City Gate Price of Non-residential Natural Gas”:</i> Reduced the benchmark city gate price of non-residential natural gas by RMB100 per thousand cubic meters</p>
<p>2018 May 25, Jun 10</p>	<p><i>“Notice on the rationalization of the price of residential gas stations”:</i> Rationalized and unified the residential city gate gas prices with the non-residential gas prices using the benchmark of the latter. Based on residential sector pricing, a benchmark for natural gas price was set for each province by the above notice. Prices can deviate the benchmark up to 20%. Residential pricing increases no more than 0.35 RMB/cu.m until June 10, 2019.</p>

¹⁵⁸The table created from data from the 2018 20-F form of PetroChina, p.44, <https://www.sec.gov/Archives/edgar/data/1108329/000119312518137017/d482381d20f.htm>

Appendix 3
Medium- and Long-Term LNG Contracts¹⁵⁹

Export Country	Seller	Buyer	mtpa	Duration	Delivery Format
Qatar	Qatargas III	CNOOC	2	2011-2035	DES
Qatar	Qatargas IV	PetroChina	3	2011-2036	DES
Qatar	Qatargas	PetroChina	3.4	2018-2040	
Australia	Woodside, Shell, BP, Chevron, others	GDLNG	3.3	2006-2031	FOB
Australia	QCLNG	CNOOC	3.6	2014-2034	DES
Australia	APLNG	Sinopec	7.6	2016-2036	FOB
Australia	ExxonMobil	PetroChina	2.25	2016-2036	DES
Malaysia	Malaysia LNG Tiga	CNOOC	3	2009-2029	DES
Papua New Guinea	PNG LNG	Sinopec	2	2014-2034	DES
Shell Portfolio	Shell	PetroChina	2	2016-2036	DES
Shell Portfolio	Shell (Australia/USA)	CNOOC	5	2015-2035	DES
Petronas Portfolio	Petronas LNG	JOVO	0.5	2016-2023	DES
BP Portfolio	BP	CNOOC	1	2019-2039	DES
BP Portfolio	BP	CNOOC	0.5	2019-2039	FOB
Russia	Yamal	CNPC	3	2019-2039	
BP Portfolio		Huadian	< 1	2016-2036	
Chevron Portfolio		ENN	0.65	2019-2029	DES
Origin Energy Limited Portfolio		ENN	0.28	2019-2024	DES
Total Portfolio		ENN	0.5	2019-2029	DES

¹⁵⁹GIIGNL. 2005-2018 editions. "GIIGNL Annual Report: The LNG Industry". <https://giignl.org/publications>

**Appendix 4
Three Separate Phases of CNPC Planned UGSs Starting in 2022¹⁶⁰**

Phase	Gas Fields	Completion Year	Peaking Capacity (bcm)
1	Chongqing: Tongluoxia, Huangcaoxia	2022	1.28
2	Chengdu: Qijiaping, Shengongshan, Xinglongchang, Zhaigou Bay, and Wanshunchang	N/A	7
3	Chongqing: Shapingchang	N/A	13.46
Total			21.74

**Appendix 5
The “2+26” Key Cities Have Different Types of Natural Gas Heating Methods¹⁶¹**

Method	Heating Area	NG Consumption	Share in Total
Gas-fired cogeneration	220 million m2	6.4 bcm	39%
Boiler room	820 million m2	7.6 bcm	47%
Gas-fired wall-hung condensing boiler	200 million m2	1.9 bcm	12%
Natural gas distributed generation	three million m2	100 mcm	>1%

¹⁶⁰Xinhua and various other sources. http://www.xinhuanet.com/fortune/2018-03/18/c_1122553804.htm

¹⁶¹NDRC. 2017. “Winter Clean Heating Plan in the Northern Region (2017-2021).” pp. 43-44
<http://www.ndrc.gov.cn/zcfb/zcfbtz/201712/W020171220351385133215.pdf>

Appendix 6 LNG Receiving Terminals and Storages Operating in China¹⁶²

Terminal name	Year	Operator	Capacity (mtpa)	In phase (mtpa)	Storage (cu.m)
Guangdong Dapeng	2006	CNOOC	6.57	2.3	480,000
Fujian	2008	CNOOC	6.3		640,000
Shanghai	2009	CNOOC, Shen- energy	3	3	495,000
Zhejiang Ningbo	2013	CNOOC	3	3	480,000
Zhuhai	2013	CNOOC	3.5	3.5	480,000
Tianjin (FSRU)	2013	CNOOC	2.2		145,000
Hainan	2014	CNOOC	2	1	320,000
Yuedong	2017	CNOOC	2	2	480,000
Shenzhen Diefu	2018	CNOOC	4		640,000
Jiangsu	2011	PetroChina	6.5	3	680,000
Dalian	2012	PetroChina	6	3	480,000
Caofeidian (Tangshan)	2013	PetroChina	3.5	6.5	640,000 ¹⁶³
Qingdao, Shandong	2014	Sinopec	3	8 ¹⁶⁴	480,000 ¹⁶⁵
Beihai, Guangxi	2016	Sinopec	3	2	640,000
Tianjin	2018	Sinopec	3	8	420,000 ¹⁶⁶
Dongguan	2009	Dongguan Jovo Energy	1.5	3	160,000
Shanghai Wuhaogou	2015	Shanghai Gas	0.5	3	320,000
Qidong, Jiangsu	2017	Xinjiang Guanghui	0.6	2.4	260,000
Zhoushan	2018	ENN Energy	3	2	320,000

¹⁶²Multiple sources, including Petroleum Economist, “World LNG Map: 2018 Edition” and CNOOC articles:

http://www.cnooc.com.cn/art/2018/7/9/art_311_2998061.html

http://www.cnooc.com.cn/art/2017/11/3/art_311_2769921.html

¹⁶³Additional storage of 640,000 cu.m is anticipated.

¹⁶⁴Chen, Aizhu, and Meng Meng. “China’s Sinopec to more than double LNG capacity, boost shale gas output.” *Reuters*, April 2, 2018. <https://www.reuters.com/article/us-china-sinopec-gas/chinas-sinopec-to-more-than-double-lng-capacity-boost-shale-gas-output-idUSKCN1H90VN>

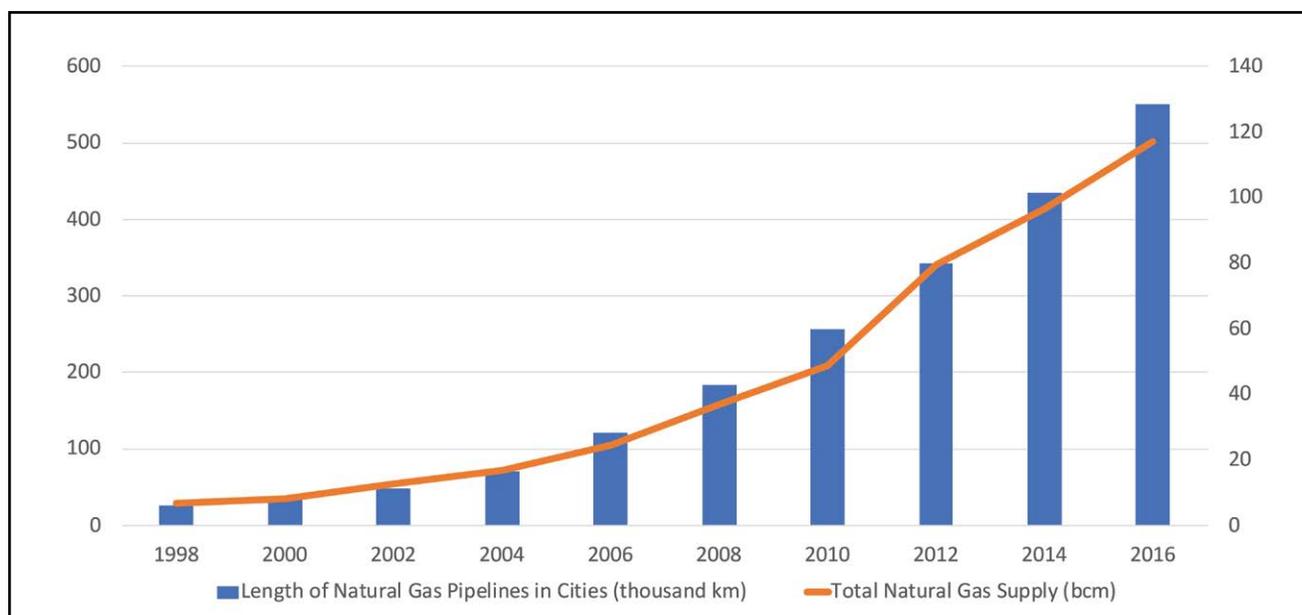
¹⁶⁵Additional storage of 320,000 cu.m is anticipated.

¹⁶⁶Tianjin Daily. 2018. http://epaper.tianjinwe.com/tjrb/html/2018-08/30/content_56143_351442.htm

Appendix 7
LNG Receiving Terminals and Storages Under Construction/Planned in China¹⁶⁷

Terminal Name	Year	Operator	Expected Capacity (mtpa)	Storage (cm)
Jiangsu Binhai (approved)	2021	CNOOC	3	880,000
Zhangzhou, Fujian	2022	CNOOC	3	480,000
Wenzhou, Zhejiang	2021	Sinopec, Zhejiang Energy	3	800,000
Penglai, Yantai	2020	Baota Petrochemical	0.712 ¹⁶⁸	320,000
Yangtze River, Yueyang	2020	China Huadian, Guanghui Energy	0.5	80,000

Appendix 8
Natural Gas Distribution Pipelines and Supplies in Chinese Cities, 1998-2016 (km, bcm)¹⁶⁹



¹⁶⁷Petroleum Economist. 2018. “World LNG Map: 2018 Edition” and CNOOC sources:

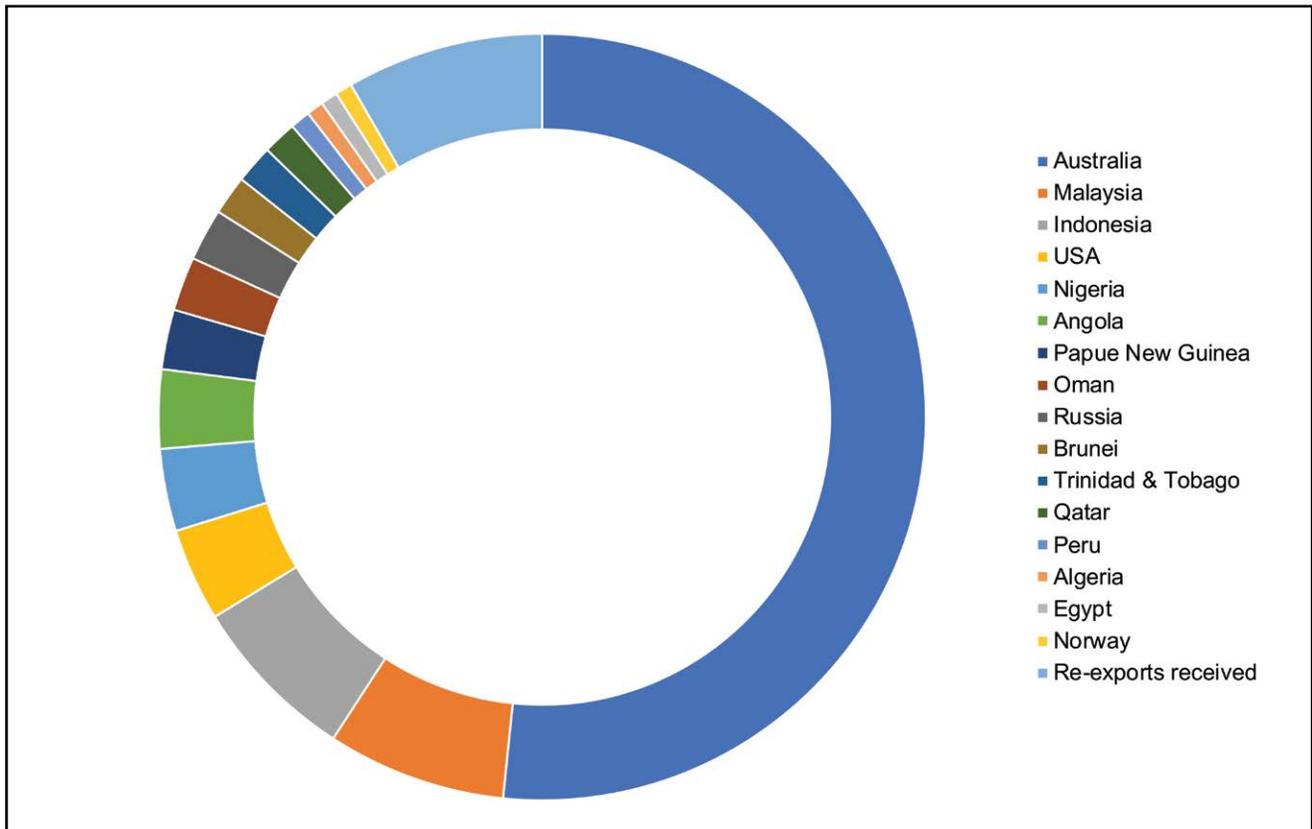
http://www.cnooc.com.cn/art/2018/9/5/art_311_3052811.html

http://www.cnooc.com.cn/art/2017/11/17/art_311_2783081.html

¹⁶⁸IIICORP. 2017. “Ebara and Burckhardt lined up as suppliers for Ningxia Baota’s USD 712m LNG terminal.” *IIICORP*, April 27, 2017. <https://www.iiicorp.com/?opportunities/opportunity/53452?Auth=93917648-813b-4a22-94d8-758d50439414>

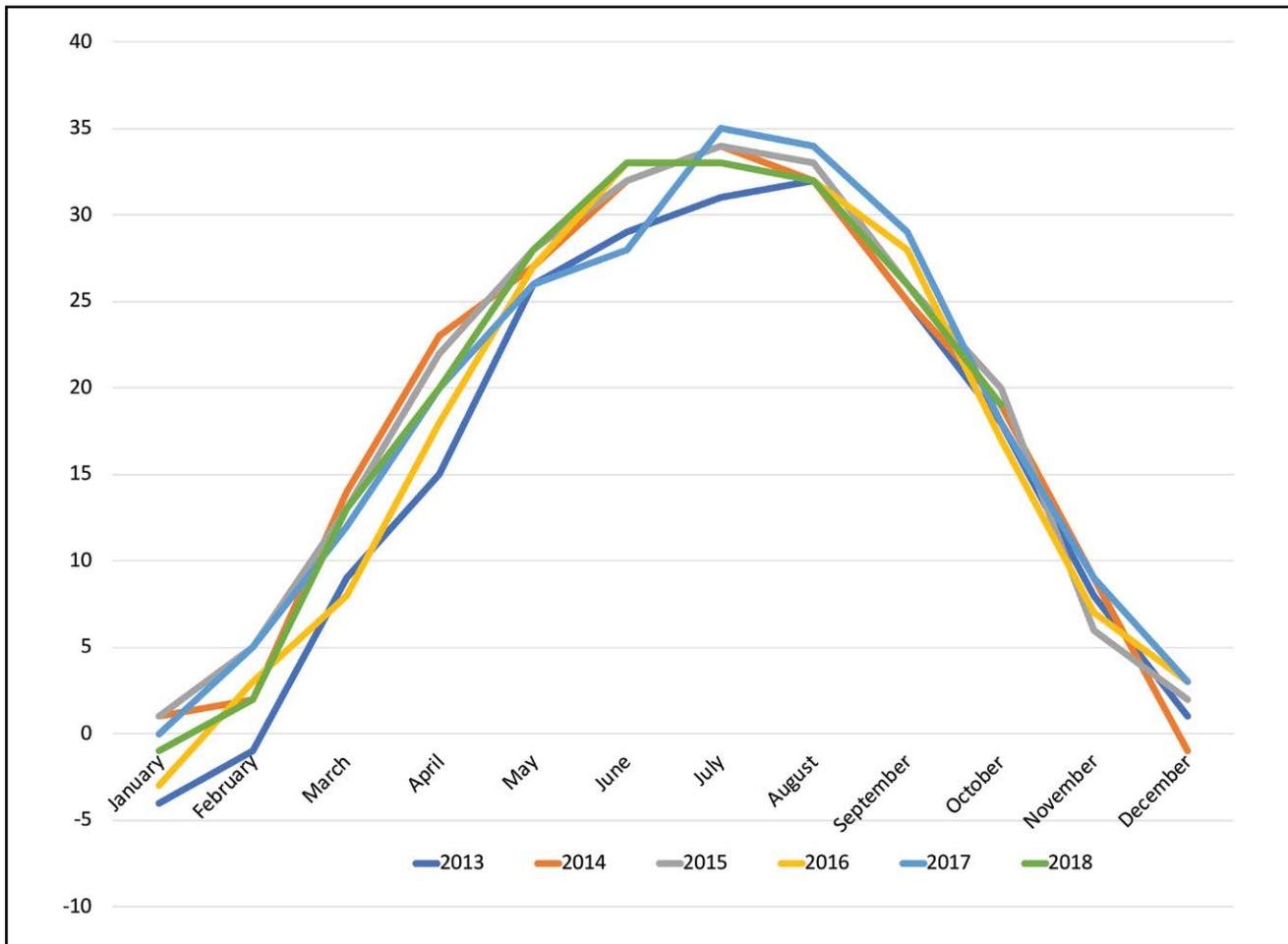
¹⁶⁹National Bureau of Statistics of China. 1999-2017 editions. “China Statistical Yearbook.”

Appendix 9 Short-Term and Spot Market Trade in 2017¹⁷⁰



¹⁷⁰GIIGNL. 2018. "The LNG Industry: GIIGNL Annual Report 2018."
https://giignl.org/sites/default/files/PUBLIC_AREA/Publications/rapportannuel-2018pdf.pdf

**Appendix 10
Beijing Historical Weather, 2013-2017 (Celsius degrees)¹⁷¹**



¹⁷¹World Weather Online. n.d. "Beijing Historical Weather."
<https://www.worldweatheronline.com/lang/en-ca/beijing-weather-history/beijing/cn.aspx>

ABBREVIATIONS

Government Ministries, Departments, and Enterprises

CPC Communist Party of China
NEC National Energy Commission
NDRC National Development and Reform Commission
NEA National Energy Administration
SASAC State-Owned Assets Supervision and Administration Commission
MEE Ministry of Ecology and Environment
MPI Ministry of Petroleum Ministry
SETC State Economic and Trade Commission
CNPC China National Petroleum Corporation
Sinopec China Petroleum and Chemical Corporation
CNOOC China National Offshore Oil Corporation
DRC Development and Reform Agency (local)

Policy Research Organizations and Related Entities

EPRINC Energy Policy Research Foundation, Inc.
IEA International Energy Agency

Natural Gas-Related Terms

LNG Liquefied Natural Gas
PNG Piped Natural Gas
LPG Liquefied Petroleum Gas
CBM Coalbed Methane
FSRU Floating, Storage, and Regasification Unit
SSLNG Small-scale Liquefied Natural Gas
TPA Third-Party Access
UGS Underground Gas Storage

Metrics

cu.f Cubic Feet
cu.m Cubic Meter
mcm Million Cubic Meters
bcf Billion Cubic Feet
bcm Billion Cubic Meters
mcf Thousand Cubic Feet
mmbtu Million British Thermal Units
mmt Million Metric Tons
mtpa Million Metric Tons Per Annum
tcf Trillion Cubic Feet

Other Abbreviations

SHPGX Shanghai Petroleum and Gas Exchange
JCC Japan Crude Cocktail
RMB Renminbi (Chinese yuan)
CPI Consumer Price Index
NOC National Oil Company
PM 2.5 Fine Particles
SOE State-Owned Enterprise

Government Agencies

- Bai, Wansong. 2018. "NDRC holds press conference regarding natural gas production and supply" (in Chinese). State Council, April 27, 2018. http://www.gov.cn/xinwen/2018-04/27/content_5286333.htm#1
- General Administration of Customs of PRC.
<http://www.customs.gov.cn/customs/302249/302274/302277/index.html>
- Gov.cn. n.d. "Structure of the State Council." <http://www.gov.cn/guowuyuan/zuzhi.htm>
- Ministry of Finance. 2018. "Notice of the Customs Tariff Commission of the State Council on Adding Tariffs to Certain Imported Goods Originating in the United States (Second Batch)." http://gss.mof.gov.cn/zhengwuxinxi/zhengcefabu/201808/t20180803_2980950.html
- Ministry of Foreign Affairs of PRC. 2016. "China's National Plan on the Implementation of the 2030 Agenda for Sustainable Development." <https://www.fmprc.gov.cn/web/zyxw/W020161012709956344295.pdf>
- Ministry of Natural Resources. 2018. "National Oil and Gas Resources Exploration and Mining Report (2017)." http://gi.mlr.gov.cn/201807/t20180713_2085143.html
- Ministry of Transport. 2018. "Letter from the General Office of the Ministry of Transport for the Opinions on Deepening the Advancement of the Application of Liquefied Natural Gas in the Water Operation Industry (Draft for Comment)" (in Chinese). http://zizhan.mot.gov.cn/zfxgk/bnssj/syj/201808/t20180810_3056391.html
- National Bureau of Statistics of China, 2016, <http://www.stats.gov.cn/tjsj/ndsjs/2017/indexeh.htm>
- National Bureau of Statistics of China. <http://data.stats.gov.cn/english/easyquery.htm?cn=A01>
- National Bureau of Statistics of China. <http://data.stats.gov.cn/english/easyquery.htm?cn=C01>
- National Energy Administration. 2018. "Notice of the National Energy Administration on Printing and Distributing the Guiding Opinions on Energy Work in 2018." http://www.gov.cn/xinwen/2018-03/09/content_5272569.htm
- NDRC. 2015. "The 13th Five-Year Plan for Economic and Social Development of the People's Republic of China."
- NDRC. 2016. "Natural Gas Pipeline Transportation Price Management Measures (Trial)" <http://www.ndrc.gov.cn/gzdt/201610/W020161012539079289091.pdf>, NDRC. 2017. "Guidance on Strengthening Regulations over the Gas Distribution Price." <http://www.gov.cn/xinwen/2017-06/22/5204625/files/d829204644294fb9a6431c0bc1c2f749.pdf>
- NDRC. 2017. "NDRC Opinions on Comprehensively Deepening the Pricing Mechanism Reform." http://www.ndrc.gov.cn/fzgggz/jggl/zcfg/201711/t20171110_866783.html
- NDRC. 2017. "Notice on Printing and Distributing the Medium and Long-Term Oil and Gas Pipeline Network Plan" (in Chinese). http://www.ndrc.gov.cn/zcfb/zcfbghwb/201707/t20170712_854432.html
- NDRC. 2017. "Notice on Printing and Distributing the Opinions on Accelerating the Use of Natural Gas" (in Chinese). http://www.ndrc.gov.cn/gzdt/201707/t20170704_853939.html
- NDRC. 2017. "Opinions on Comprehensively Deepening the Pricing Mechanism Reform." http://english.gov.cn/state_council/ministries/2017/11/11/content_281475938688408.htm
- NDRC. 2018. "2018 Energy Work Guidance of China."
- NDRC. 2018. "List of natural gas city gate reference price by province." <http://www.ndrc.gov.cn/zcfb/gfxwj/201805/W020180525555969836410.pdf>
- NDRC. 2018. "Regular press conference on October 23, 2018." http://www.china.com.cn/zhibo/content_67728050.htm
- NDRC. 2018. "Opinions on Accelerating the Construction of Gas Storage Facilities and Improving the Market Mechanism for Ancillary Services for Gas Storage and Peak Regulation."
- NDRC. n.d. "NDRC Administrative Examination and Approval Items Directory" (in Chinese). <http://www.ndrc.gov.cn/zwfwzx/xzsp/>

- State Council Information Office of PRC. 2017. "Ministry of Land and Resources held a national conference on oil and gas resources exploration and mining results." SCIO, August 15, 2017.
<http://www.scio.gov.cn/xwfbh/gbwxwfbh/xwfbh/gtzyb/Document/1561889/1561889.htm>
- State Council. 2013. "Notice of the State Council on Printing and Distributing the Action Plan for Air Pollution Prevention and Control" (in Chinese).
http://www.gov.cn/zwggk/2013-09/12/content_2486773.htm
- State Council. 2016. "Government-Approved Investment Project Catalogue" (in Chinese).
http://www.gov.cn/zhengce/content/2016-12/20/content_5150587.htm
- State Council. 2018. "Opinion on Strengthening Ecological Protection and Pollution Prevention."
- U.S. Energy Information Administration. n.d. "Natural Gas."
<https://www.eia.gov/dnav/ng/hist/n3050us3a.htm>
- Zaretskaya, Victoria. 2018. "China becomes world's second largest LNG importer, behind Japan." U.S. Energy Information Administration, February 23, 2018.,
<https://www.eia.gov/todayinenergy/detail.php?id=35072>

Scholarly Publications and Presentations

- Biscardini, Giorgio, Rafael Schmill, and Adrian Del Maestro. 2017. "Small going big: : Why small-scale LNG may be the next big wave." <https://www.strategyand.pwc.com/reports/small-going-big>
- BP Statistical Review of World Energy, 2007-2017
- Bros, Thierry. 2018. "Quarterly Gas Review Analysis of Prices and Recent Events." Oxford Institute for Energy Studies: March 2018.
<https://www.oxfordenergy.org/wpcms/wp-content/uploads/2018/03/Quarterly-Gas-Review-1.pdf>
- Cao, Qilong, Ying Liang, and Xueting Niu. 2017. "China's Air Quality and Respiratory Disease Mortality Based on the Spatial Panel Model," In *International Journal of Environmental Research and Public Health* 14(9): 1081. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5615618/>
- Chyxx. 2018. "Analysis of China's natural gas price mechanism in 2018." Chyxx, March 8, 2018.
<http://www.chyxx.com/industry/201803/616926.html>
- Corbeau, Anne-Sophie, et al. 2012. "Gas Pricing and Regulation China's Challenges and IEA Experience." International Energy Agency.
https://www.iea.org/publications/freepublications/publication/chinagasreport_final_web.pdf
- Cunningham, Edward A. 2015. "The State and the Firm: China's Energy Governance in Context." GEGI Working Paper: Paper 1 (March). <https://ash.harvard.edu/files/chinas-energy-working-paper.pdf>
- Downs, Erica S. 2010. "Who's Afraid of China's Oil Companies?" In *Energy Security: Economics, Politics, Strategy, and Implications*, pp. 73-102. Brookings Institution Press.
<https://www.brookings.edu/research/whos-afraid-of-chinas-oil-companies/>
- Duan, Zhaofang. 2017. "China Natural Gas Market Status and Outlook."
<https://eneken.ieej.or.jp/data/7693.pdf>
- GIIGNL Annual Reports from 2011-2017.
- GIIGNL. 2018. "The LNG Industry: GIIGNL Annual Report 2018."
https://giignl.org/sites/default/files/PUBLIC_AREA/Publications/rapportannuel-2018pdf.pdf
- Higashi, Nobuyuki. June 2009. "Natural Gas in China: Market evolution and strategy." International Energy Agency Working Paper Series.
https://www.iea.org/publications/freepublications/publication/nat_gas_china.pdf
- Liu, Hong. 2017. "China's Natural Gas Industrial Policy and Reform." <https://www.usea.org/sites/default/files/event-/1.1%20China%E2%80%99s%20Natural%20Gas%20Industrial%20Policy%20and%20Reform-EN.pdf>

- Hove, Anders. 2017. "Natural Gas in China." Paulson Institute, October 4, 2017. <http://www.paulsoninstitute.org/economics-environment/paulson-primers/natural-gas-in-china/> Morgan Stanley expected that the number to be more than 50 percent by 2025. Zheng, Xin. 2018. "CNPC natural gas output increases." ChinaDaily, February 9, 2018. <http://www.chinadaily.com.cn/a/201802/09/WS5a7cffb8a3106e7dcc13bbcb.html>
- International Gas Union. 2015. "Small Scale LNG." 2012 – 2015 Triennium Work Report. http://www.igu.org/sites/default/files/node-page-field_file/SmallScaleLNG.pdf
- Ishwaran, Mallika et al. 2017. "Analysis of China's Natural Gas Infrastructure Development Strategy." In China's Gas Development Strategies. https://www.researchgate.net/publication/321259962_Analysis_of_China's_Natural_Gas_Infrastructure_Development_Strategy
- Kate, Warner ten, Lászlo Varró, and Anne-Sophie Corbeau. 2013. "Developing a Natural Gas Trading Hub in Asia Obstacles and Opportunities." https://www.iea.org/publications/freepublications/publication/AsianGasHub_FINAL_WEB.pdf
- Kunert, Sebastian, and Bruno Larson. 2008. "Small is Beautiful: Mini-LNG concept." https://dge-wittenberg.de/vortraege/Small_is_beautiful_Hamworthy_MiniLNG_Concept_June_2008.pdf
- Li, Yao. 2016. "China's Emerging 2nd Tier LNG Players and LNG Import Capacity Outlook." SIA Energy: China LNG International Summit. https://asiapacific.cwclng.com/wp-content/uploads/2016/07/SIA-Energy_Yao-Li_Tier-2-Chinese-Players-and-LNG-Terminal-Capacity-Outlook_201603161.pdf
- Petroleum Economist. 2018. "World LNG Map: 2018 Edition."
- Rogers, Howard V, and Jonathan Stern. 2014. "Challenges to JCC Pricing in Asian LNG Markets." OIES Paper: NG 81. <https://www.oxfordenergy.org/wpcms/wp-content/uploads/2014/02/NG-81.pdf>
- Shell. 2018. "Shell Outlook 2018." https://www.shell.com/energy-and-innovation/natural-gas/liquefied-natural-gas-lng/lng-outlook/_jcr_content/par/textimage_864093748.stream/1519645795451/d44f97c4d4c4b8542875204a19c0b21297786b22a900ef8c644d07d74a2f6eae/shell-lng-outlook-2018-presentation-slides.pdf
- Strategy&. "LNG may be the next big wave." <https://www.strategyand.pwc.com/media/file/Small-going-big.pdf>
- Tang, Changwei. 2016. "Globalized economy and the Chinese national oil companies." IIAS Newsletter: No. 76 (Summer). https://ias.asia/sites/default/files/IAS_NL74_07.pdf
- Zhang, ZhongXiang. 2018. "Energy price reform in China." CCEP Working Paper 1805. https://ccep.crawford.anu.edu.au/sites/default/files/publication/ccep_crawford_anu_edu_au/2018-06/zhang_zx_2018_energy_price_reform_in_china_ccep_working_paper_1805.pdf
- Zhang, Dong, and Owen Freestone. 2017. "China's Unfinished State-Owned Enterprise Reforms." <https://static.treasury.gov.au/uploads/sites/1/2017/06/5-China-SOE-reforms.pdf>

Company Websites

- BP. 2015. "BP and China Huadian corporation sign multibillion-dollar LNG deal." BP, October 21, 2016. <https://www.bp.com/en/global/corporate/news-and-insights/press-releases/bp-and-china-huadian-corporation-sign-multibillion-dollar-lng-de.html>
- BP. 2018. "BP Statistical Review of World Energy 2018." <https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review/bp-stats-review-2018-full-report.pdf>
- CNOOC. 2018. http://www.cnooc.com.cn/art/2018/7/9/art_311_2998061.html
- CNOOC. 2016. "Jiangsu Binhai LNG receiving station project's pre-trial approved" (in Chinese). CNOOC, September 30, 2016. http://www.cnooc.com.cn/art/2016/9/30/art_311_2436801.html
- CNOOC. 2017. http://www.cnooc.com.cn/art/2017/11/17/art_311_2783081.html
- CNOOC. 2017. http://www.cnooc.com.cn/art/2017/11/3/art_311_2769921.html
- CNOOC. n.d. "Gas & Power." <http://www.cnooc.com.cn/col/col6391/index.html>

- CNPC. 2017. "2017 China's Natural Gas Development White Paper: Promoting Natural Gas as a Main Energy Source." SASAC, August 21, 2018.
<http://www.sasac.gov.cn/n2588025/n2588124/c7767721/content.html>
- CNPC. 2017. "Global Natural Gas Pricing Mechanisms."
<http://center.cnpc.com.cn/bk/system/2017/03/22/001640121.shtml>
- CNPC. n.d. "Flow of natural gas from Central Asia." <https://www.cnpc.com.cn/en/FlowofnaturalgasfromCentralAsia/FlowofnaturalgasfromCentralAsia2.shtml>
- CNPC. n.d. "Ordos Basin." <https://www.cnpc.com.cn/en/xhtml/pdf/19-Ordos%20Basin.pdf>
- Gazprom. 2015. "Gazprom and CNPC sign Heads of Agreement for gas supply via western route." Gazprom, May 8, 2015. <http://www.gazprom.com/press/news/2015/may/article226167/>
- Guangdong LNG. n.d. "Project Milestones" (in Chinese).
<http://www.gdlng.com/static/gd-lng-milestrone.html>
- Qatargas. n.d. "Qatargas Announces a 22-Year LNG Sale and Purchase Agreement with PetroChina." <http://www.qatargas.com/english/MediaCenter/Pages/Press%20Releases/Qatargas-announces-a-22-year-LNG-Sale-and-Purchase-Agreement-with-PetroChina-.aspx>
- Shi, Xunpeng, and Hari Malamakkavu Padinjare Variam. 2015. "China's Gas Market Liberalisation-The impact on China–Australia gas trade." https://www.researchgate.net/publication/281036534_China's_Gas_Market_Liberalisation-The_impact_on_China-Australia_gas_trade
- Sinopec Group. 2018. "China's first shale gas field hits ten bcm/year." Sinopecgroup, March 29, 2018.
http://www.sinopecgroup.com/group/en/Sinopecnews/20180329/news_20180329_511487208275.shtml
- Smith, Brenda. 2014. "LNG for Transportation in China."
<http://cdn.gladstein.org/pdfs/ACTE2014Presentations/InternationalMarketUpdate/4BrendaSmith.pdf>
- Total. 2018. "Total and CNOOC Strengthen Their Long-Term Cooperation in LNG." Total, October 22, 2018. <https://www.total.com/en/media/news/press-releases/total-and-cnooc-strengthen-their-long-term-cooperation-lng> <https://www.reuters.com/article/us-qatar-petrochina/qatargas-agrees-on-22-year-lng-supply-deal-with-china-idUSKCN1LQ0DM>
- Towngas. n.d. "NDRC relaxes LNG receiving project approval."
<http://www.towngas.com.cn/info/1065/1239.htm>

NOC Annual Reports

- CNOOC. 2017. "Annual Report." <http://www.cnooc.com.cn/attach/0/1806141618435805115.pdf>
- CNOOC. 2018. "Form 20-F."
http://www.cnoocltd.com/module/download/down.jsp?i_ID=2928981&colID=7531
- PetroChina. 2017. Annual Report.
- PetroChina. 2018. "Form 20-F."
<https://www.sec.gov/Archives/edgar/data/1108329/000119312518137017/d482381d20f.htm>
- PetroChina. 2018. "2018 Interim Results Announcement."
<http://mms.prnasia.com/00857/20180830/audio/petrochina.pdf>
- Sinopec. 2017. "Annual Report and Accounts."
<http://www.sinopec.com/listco/en/Resource/Pdf/20180325036.pdf>
- Sinopec Limited. 2017. Annual Report.

Expert Op-Eds

- Abreu, Abache. 2018. "Analysis: China's expanding underground gas storage may reduce LNG winter price volatility." S&P Global Platts, July 13, 2018. <https://www.spglobal.com/platts/en/market-insights/latest-news/natural-gas/071318-analysis-chinas-expanding-underground-gas-storage-may-reduce-lng-winter-price-volatility>

- Wood Mackenzie. 2017. "Will Trump's Beijing trip win some LNG deals for the US?" <https://www.woodmac.com/press-releases/will-trumps-beijing-trip-win-some-lng-deals-for-the-us/>
- Wood Mackenzie. 2018. "China's LNG trucking capacity to double in medium term." <https://www.woodmac.com/press-releases/china-lng-trucking3/>
- Wood Mackenzie. 2018. "Chinese shale gas production will almost double in two years." <https://www.woodmac.com/news/editorial/chinese-shale-gas-production-will-almost-double-in-two-years/>
- Zhou, Tailai, Chen Zhou, and Rongde Li. 2018. "4 Million North China Homes Told to Kick Coal Habit as Nation Seeks Blue Skies." Caixin, February 8, 2018. <https://www.caixinglobal.com/2018-02-08/4-million-north-china-homes-told-to-kick-coal-habit-as-nation-seeks-blue-skies-101209259.html>

Media

- Asia-Plus. 2018. "Construction of Tajik section of Turkmenistan-China gas pipeline starts, says Tajik official." News.tj, January 31, 2018. <https://news.tj/en/news/tajikistan/economic/20180131/construction-of-tajik-section-of-turkmenistan-china-gas-pipeline-starts-says-tajik-official>
- Bao, Xing'an. 2010. "Zhang Guobao: The Energy Bureau is Small, But State-Business Relationships are Doing Well" (in Chinese). Ifeng.com, February 4, 2010. <http://finance.ifeng.com/news/special/gjnyw/20100204/1795458.shtml>
- Chen, Aizhu, and Henning Gloystein. "China's Chongqing gas exchange aims to be Asia price benchmark." Reuters, December 29, 2017. <https://www.reuters.com/article/us-china-gas-exchange/chinas-chongqing-gas-exchange-aims-to-be-asia-price-benchmark-idUSKBN1EN0HN>
- Chen, Aizhu, and Meng Meng. 2018. "China's Beijing Gas Figures new direction under helm of Madame Li." Reuters, August 2, 2018. <https://www.reuters.com/article/us-china-pollution-gas-madame/chinas-beijing-gas-Figures-new-direction-under-helm-of-madame-li-idUSKBN1KN30Z>
- Chen, Aizhu. 2018. "FACTBOX-China's underground natural gas storage facilities." Reuters, April 11, 2018. <https://uk.reuters.com/article/china-pollution-gas-storage/factbox-chinas-underground-natural-gas-storage-facilities-idUKL4N1QR2Q1>
- Chengcheng. 2018. "CNPC reports record-high domestic natural gas output at over 100 billion cubic meters." Xinhuanet, February 8, 2018. http://www.xinhuanet.com/english/2018-02/08/c_136959638.htm
- China Daily. 2018. "Four years on: Beijing-Tianjin-Hebei coordinated development." ChinaDaily, February 27, 2018. http://www.chinadaily.com.cn/a/201802/27/WS5a949ab4a3106e7dcc13e348_1.html
- China.org.cn. 2018. "CNPC plans 150-bln-yuan investment in Xinjiang." China.org.cn, July 26, 2018. http://www.china.org.cn/china/Off_the_Wire/2018-07/26/content_57829186.htm
- ChinaDaily. 2018. "US company signs LNG deal with China." ChinaDaily, February 10, 2018. <http://www.chinadaily.com.cn/a/201802/10/WS5a7dfd05a3106e7dcc13be53.html>
- Corkhill, Mike. 2018. "Chinese LNG terminals hit record utilisation rates." LNG World Shipping, March 8, 2018. https://www.lngworldshipping.com/news/view,chinese-lng-terminals-hit-record-utilisation-rates_51033.htm
- IIICORP. 2017. "Ebara and Burckhardt lined up as suppliers for Ningxia Baota's USD 712m LNG terminal." IIICORP, April 27, 2017. <https://www.iiicorp.com/?opportunities/opportunity/53452?Auth=93917648-813b-4a22-94d8-758d50439414>
- Kallanish Energy. 2018. "China's LNG trucking capacity to reach 35 MTPA by 2025." <http://www.kallanishenergy.com/2018/06/05/chinas-lng-trucking-capacity-to-reach-35-mtpa-by-2025/>
- Li, Jing. 2018. "China's new environment ministry unveiled, with huge staff boost." China Dialogue, April 19, 2018. <https://www.chinadialogue.net/article/show/single/en/10599-China-s-new-environment-ministry-unveiled-with-huge-staff-boost>
- Li, Qian. 2018. "Private Enterprises' Participation in LNG Receiving Stations" (in Chinese). People.cn, April 9, 2018. http://paper.people.com.cn/zgnyb/html/2018-04/09/content_1847151.htm

- Li, Xuanmin. 2016. "Shanghai trading platform will support energy market reform." *Global Times*, November 27, 2016. <http://www.globaltimes.cn/content/1020543.shtml>
- Lin, David, and Brenda Goh. 2016. "China launches commodity trading center in Shanghai, eyes Asia gas hub status." *Reuters*, November 26, 2016. <https://www.reuters.com/article/us-china-gas/china-launches-commodity-trading-center-in-shanghai-eyes-asia-gas-hub-status-idUSKBN13L07T>
- Liu. 2018. "China sees gas truck boom amid green drive." *Xinhuanet*, January 23, 2018. http://www.xinhuanet.com/english/2018-01/23/c_136918115.htm
- Mason, Josephine, et al. 2018. "In China's far west, CNPC vows \$22 billion spend to replace ageing oil wells." *Reuters*, July 24, 2018. <https://www.reuters.com/article/us-china-cnpc-oil-gas/in-chinas-far-west-cnpc-vows-22-billion-spend-to-replace-ageing-oil-wells-idUSKBN1KF07L>
- Meng, Meng, and Aizhu Chen. 2018. "CNOOC sells third party access to Yuedong LNG terminal in auction." *Reuters*, September 20, 2018. <https://af.reuters.com/article/africaTech/idAFB9N1UJ017>
- Meng, Meng. 2017. "China's Sinopec starts building nation's largest gas storage site." *Reuters*, May 23, 2017. <https://www.reuters.com/article/us-china-sinopec-gas/chinas-sinopec-starts-building-nations-largest-gas-storage-site-idUSKBN18K08S>
- Paltsev, Sergey, and Danwei Zhang. 2015. "Natural Gas Pricing Reform in China: Getting Closer to a Market System?" MIT Joint Program on the Science and Policy of Global Change: Report No. 282. <https://core.ac.uk/download/pdf/78063525.pdf>
- People's Daily. 2001. "China's 'Tenth Five-Year' Special Plan for Energy Development (Full Text)" (in Chinese). <http://www.people.com.cn/GB/jinji/31/179/20010813/533877.html>
- RT. 2018. "Russia to become China's top supplier of gas soon." *RT*, September 22, 2018. <https://www.rt.com/business/439105-russia-chinas-gas-exporter/>
- Sohu. 2018. "Understanding the LNG Industry, Pricing Mechanism, and Profitability" (in Chinese). *Sohu*, August 1, 2018. http://www.sohu.com/a/244536796_117959
- South China Morning Post. 2016. "China's ENN plans surge in LNG purchases, online trading platform to increase market share." *SCMP*, March 29, 2016. <https://www.scmp.com/business/companies/article/1931349/chinas-enn-plans-surge-lng-purchases-online-trading-platform>
- Tianjin Daily. 2018. http://epaper.tianjinwe.com/tjrb/html/2018-08/30/content_56143_351442.htm
- Tong, Xiaobo. 2018. "Third Party Access to LNG Receiving Terminal." *People.cn*, September 24, 2018. http://paper.people.com.cn/zgnyb/html/2018-09/24/content_1883078.htm
- Wang, Changyu. 2018. "Institute of Building Environment and Energy Efficiency, China Academy of Building Research Director Xu Wei's Remarks." *Cnenergy.org*, August 27, 2018. http://www.cnenergy.org/yw/201808/t20180827_685175.html
- Wang, Shuo. 2018. "Beijing's residential gas prices to increase by 0.35 yuan per cubic meter." *Chinanews*, July 9, 2018. <http://www.chinanews.com/cj/2018/07-09/8560904.shtml>
- Xin, Zheng. 2018. "Sinopec boosts gas storage units." *ChinaDaily*, August 9, 2018. <http://www.chinadaily.com.cn/a/201808/09/WS5b6b84daa310add14f384bc5.html>
- Xinhuanet. 2015. "China boosts pricing reforms in natural gas sector." *China.org.cn*, November 21, 2015. http://www.china.org.cn/business/2015-11/21/content_37123349.htm
- Xinhuanet. 2017. "China plans to expand oil, gas pipeline networks." *Xinhuanet*, July 12, 2017. http://www.xinhuanet.com/english/2017-07/12/c_136438633.htm
- Xinhuanet. 2018. CPC and State Council's update on environmental policy. http://www.xinhuanet.com/politics/2018-06/24/c_1123028598.htm
- Xinhuanet. 2018. http://www.xinhuanet.com/fortune/2018-03/18/c_1122553804.htm
- Zhang, Yanling. 2018. "The State Council Makes Changes in the Personnel of the National Energy Commission" (in Chinese). *Chinanews.com*, July 21, 2018. <http://www.chinanews.com/gn/2018/08-02/8587746.shtml>

Zhou, Yingfeng. 2010. "The Creation of the National Energy Commission succeeds the Institutional Reforms" (in Chinese). Ifeng.com, January 27, 2010.
<http://finance.ifeng.com/news/special/gjnyw/20100127/1765925.shtml>

Others

World Bank. 2016. "PM2.5 air pollution, mean annual exposure (micrograms per cubic meter)."
<https://data.worldbank.org/indicator/EN.ATM.PM25.MC.M3?locations=CN>

World Health Organization. n.d. "Air pollution."
http://www.wpro.who.int/china/mediacentre/factsheets/air_pollution/en/

World Weather Online. n.d. "Beijing Historical Weather."
<https://www.worldweatheronline.com/lang/en-ca/beijing-weather-history/beijing/cn.aspx>