Shale Gas in China

-- Development and Challenges

(Draft)

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Abbreviations and Units

bcm: billion cubic meters

CNOOC: China National Offshore Oil Corporation

CNPC: China National Petroleum Corporation, parent company of PetroChina

E&D: exploration and development

GIP: Gas in Place (total volume of natural gas in an underground rock formation)

mcm: million cubic meters

MEP: Ministry of Environmental Protection of PRC

MLR: Ministry of Land and Resources of PRC

mmBtu: million British thermal unit

MOC: Ministry of Commerce of PRC

MOF: Ministry of Finance of PRC

NEA: National Energy Administration of PRC

NOCs: national oil companies

PSA: product service agreement

R&D: research and development

Sinopec: China Petroleum & Chemical Corporation

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I. The State of Shale Gas Exploration/Development in China

In 2012, nearly 57.9% of China's oil consumption and 28.2% of natural gas consumption rely on imports.[1] In 2015, China will need 540 million tons of oil - 12.27% more than the 2012 level, and gas demand will exceed 250 bcm – a 69.95% increase from 2012.[2] This huge demand puts immense pressure on exploring new domestic energy supply.

Shale gas is among China's biggest onshore energy prospects. According to U.S. Energy Information Administration's 2013 estimation, China has 31.6 tcm of technically recoverable shale gas resources, almost as much as U.S. and Canada combined.[3]

As of Feb. 25, 2013, China has invested over $1.14 billion in shale gas survey and exploration. More than 80 shale gas reservoir appraisal wells, including more than 20 horizontal wells, have been finished in China. In 2012, 15 mcm of shale gas has been sold using natural gas pipelines, bringing the accumulative amount of shale gas sold to 30 mcm.[4] This is about 0.0001 of the total natural gas consumption in China in 2012.

Currently, PetroChina and Sinopec are the dominant players in China's domestic shale gas development. PetroChina achieved high production at Sichuan Changning's 201 horizontal well, the first commercial horizontal shale gas well in China. Sinopec's horizontal well at Chongqing Fuling reached initial gas production of 0.2 mcm and a stable production of 0.11 mcm.

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[1] "中国月净进口石油首超美国," *Xinhua News*, March 12, 2013, http://news.xinhuanet.com/fortune/2013-03/12/c_124446727.htm; "我国天然气对外依存度将达 32% 供需形势总体偏紧," *Xinhua News*, February 4, 2013, http://news.xinhuanet.com/energy/2013-02/04/c_124316898.htm.

[2] "China's Crude Oil Demand to Rise Sharply: Forecast," *China Daily*, November 16, 2012, http://www.chinadaily.com.cn/bizchina/2012-11/16/content_15935071.htm; "China's Natgas Consumption Seen at 230 Bcm in 2015: NDRC," *Reuters*, October 25, 2012, http://www.reuters.com/article/2012/10/26/us-china-natgas-consumption-idUSBRE89P04O20121026; Fan Gao, "Will There Be a Shale Gas Revolution in China by 2020?," *Oxford Institute for Energy Studies*, April 18, 2012, http://www.oxfordenergy.org/2012/04/will-there-be-a-shale-gas-revolution-in-china-by-2020/; "China's 2012 Oil Demand up 4.5 Pct, Slowest in 4 Years," *Reuters*, January 18, 2013, http://www.reuters.com/article/2013/01/18/china-oil-demand-idUSL4N0AL5WS20130118.

[3] "Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States," *U.S. Energy Information Administration*, June 13, 2013, http://www.eia.gov/analysis/studies/worldshalegas/.

[4] "三桶油披露页岩气开发'路线图' 将启动百亿市场," *Xinhua News: China Securities Journal*, March 19, 2013, http://news.xinhuanet.com/fortune/2013-03/19/c_124474423.htm.

PetroChina plans to, in the 2013-2015 period, drill 122 horizontal wells, put 113 wells into production and reach the goal of producing 1.5 bcm of commercial shale gas by 2015, with a daily production of 5.38 mcm. It plans to achieve shale gas production capacity of 20 bcm by 2020, and 50 bcm by 2030. Sinopec plans to add new shale gas production capacity by 150 mcm at the end of 2015, and reach annual production of 130 mcm.[5]

The State policy encourages private companies in exploring shale gas. But in reality, they face various difficult barriers (Part III will go into more detail). Ministry of Land and Resources held two separate biddings for 4 and later 19 shale gas blocks in 2012. In the heated second-round bidding, 16 companies won the 19 blocks, among which 6 are central level state-owned enterprises, 8 are provincial level state owned enterprises, and only 2 are private companies. 8 out of the 19 blocks went to power and coal companies. Overall, these winners committed to invest about $21 billion in geographical survey and exploration.[6] However, faced with difficulties in drilling and high investment risks, some smaller companies that won the bid are considering backing out before the actual surveying even begins.

As a result, the planned third round of shale gas bidding is likely to be delayed until 2014 with less than 10 blocks offered. In the meantime, MLR has held four meetings for bid-winners, local governments and local oil & gas resources management agencies, and invited PetroChina to provide technical consultation to the smaller companies. It also tries to improve the bidding process, and connect with the Ministry of Finance for a possible new model where the government would cover the initial seismic assessment and drilling cost and be reimbursed later by bid-winners. [7]

In terms of pipeline infrastructure, China's pipeline network is about 43,452 kilometers by the end of 2011.[8] In June 2013, CNPC announced that it has started building the country's first dedicated shale gas pipeline in Sichuan province. The pipeline will stretch 92.8 kilometers, linking shale gas production wells Ning 201-H1 in the Changning district to the Shuanghe gas

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[5] Ibid.

[6] "国土资源部地质勘查司司长彭齐鸣介绍招标出让的结果和后续工作," *Ministry of Land and Resources of the People's Republic of China*, January 21, 2013, http://www.mlr.gov.cn/wszb/2013/2yyqzb/zhibozhaiyao/201301/t20130121_1176943.htm.

[7] "今年第三轮页岩气探矿权招标或遭遇搁浅," *Security Times China*, June 6, 2013, http://finance.sina.com.cn/stock/hyyj/20130606/213415724543.shtml.

[8] "China - Analysis," *U.S. Energy Information Administration (EIA)*, April 22, 2013, http://www.eia.gov/countries/cab.cfm?fips=CH.

processing station, and connecting to existing Sichuan Naxi to Yunnan Anbian pipelines. It will have a capacity of 4.5 mcm/day. CNPC did not say when the pipeline is due for completion.[9]

12th Five Year Plan

In the 12th FYP, China aims to produce 6.5 bcm of shale gas annually by 2015 and 60-100 bcm by 2020. It sets to complete the country's shale gas surveying and evaluation by 2015, select 30-50 shale gas prospects and 50-80 favorable target areas, achieve major breakthroughs in geological survey technology, and develop shale gas exploration technology and equipments suited to China's geological conditions.

China also plans to construct 44,000 kilometers of new natural gas pipelines (including gathering lines and distribution lines) in the 12th FYP period, increase transmission capacity by 150 bcm per year, and add new natural gas storage capacity of about 22 bcm.[10]

To put the targets in perspective, China's natural gas consumption has seen rapid increase since 2006, but the production has not kept up with the pace. (See Figure 1.) To achieve the 2020 target, shale gas would have to go from almost nothing to provide as much as 56.2% to 93.67% of the natural gas production total of 2012 – this is a very ambitious target to say the least. In fact, Chinese energy experts said that the government was likely to reconsider its shale target. Zhang Dongxiao, director of Peking University's Oil & Gas Research Institute, said China's chance of meeting the 12th FYP shale target is "zero".[11]

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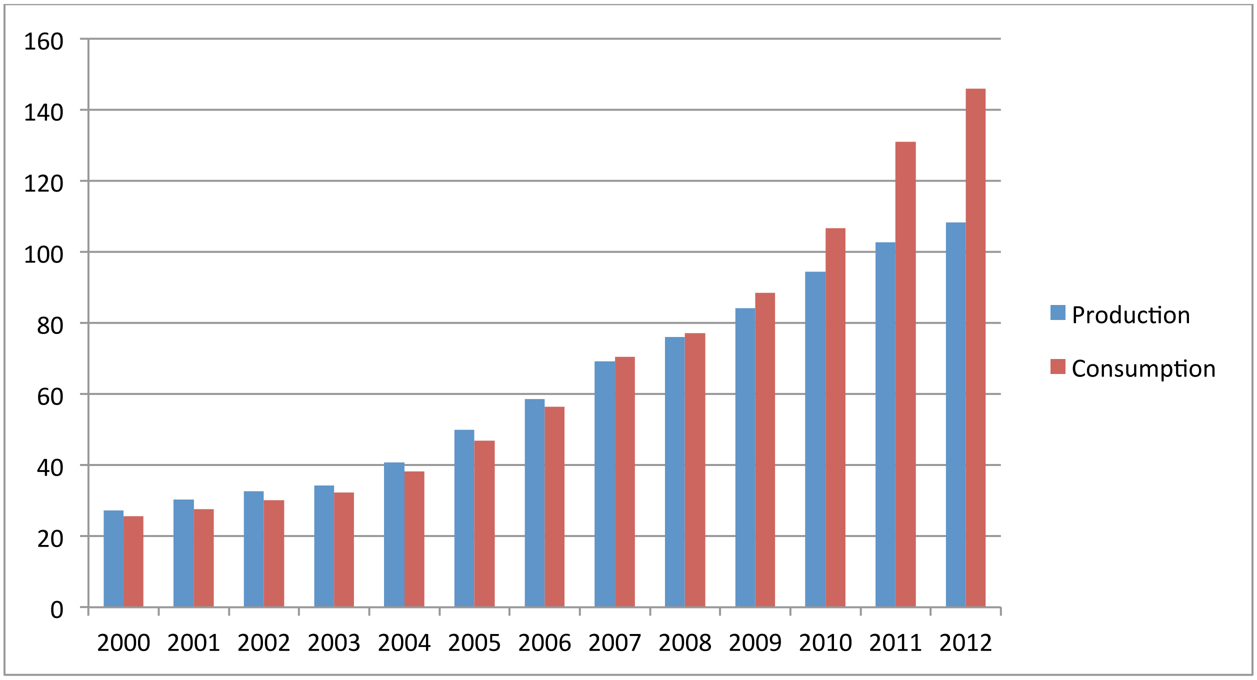
9 "CNPC Building China's First Shale Gas Pipeline," *Xinhua News*, June 19, 2013, http://news.xinhuanet.com/english/china/2013-06/19/c_132468952.htm; "国内首条页岩气试采干线打火组焊," *China Petro News Center*, June 19, 2013, http://news.cnpc.com.cn/system/2013/06/19/001432976.shtml.

10 "发展改革委关于印发天然气发展'十二五'规划的通知," *The Central People's Government of the People's Republic of China*, 2012, http://www.gov.cn/gongbao/content/2013/content_2326571.htm.

11 "China to Reconsider Shale Target?," *UPI*, July 1, 2013, http://www.upi.com/Business_News/Energy-Resources/2013/07/01/China-to-reconsider-shale-target/UPI-46351372694742/.

Figure 1. Natural gas production and consumption in China, 2000-2012, in billion cubic meters.



Source: U.S. Energy Information Administration

II. Regulatory Regime

The Mineral Resources Law of the PRC, adopted on March 19, 1986, amended on August 29, 1996 and effective as amended as of January 1, 1997, is the principal mining law. Foreign investment enterprises are accorded the same treatment as domestic enterprises with regard to exploration rights, mining rights and the transfer of those rights.

China has adopted a licensing-type of system for the exploration and exploitation of the mineral resources. Exploration permits (or licenses) are registered and issued to licensees in the form of 3-year leases (for shale gas and other minerals, 7 years for oil and gas) from the Central or the Provincial Bureau of Land and Resources. When an economic deposit is discovered, the licensee may apply for a 2-year renewal or retention of the exploration right (permit) within thirty days prior to expiration of the permit term, for a maximum period of four years or two extensions, covering the area of the economic deposit. Among the obligations under the permit are scheduled minimum exploration expenditures, reporting requirements with the local county and licensing authority and scheduled payments per kilometer for exploration right (i.e., rentals). The permittee, with approval and compliance with exploration expenditures, may transfer its explorations right.[12] Not many private companies can brave through this cumbersome licensing process, not to mention acquiring various additional permits and approvals required by a number of other regulatory authorities.

Instead of a well-designed and coordinated regime to regulate and provide oversight on three key aspects of shale gas development - exploitation, environmental protection, and trade, China now has at least 7 ministerial level agencies involved, without clear division of responsibilities. They are Ministry of Land and Resources, Ministry of Finance, National Development and Reform Commission, National Energy Administration, Ministry of Commerce, Ministry of Science and Technology, and Ministry of Environmental Protection.[13]

[12] "Mineral and Resources Law of the People's Republic of China 中华人民共和国矿产资源法," *Ministry of Land and Resources of the People's Republic of China*, June 25, 2004, http://www.mlr.gov.cn/zwgk/flfg/kczyflfg/200406/t20040625_292.htm.
[13] Song Wang, "我国探路页岩气监管," *China Mining Journal*, January 21, 2013, http://www.mlr.gov.cn/xwdt/jrxw/201301/t20130121_1176816.htm.

MLR manages the mining rights of shale gas, manages the prospecting and exploration registration, and holds biddings.[14] It is also developing the technical standards and norms for shale gas prospecting and exploration. NEA is mainly responsible for developing plans for conventional and unconventional gas, and establishing policy and incentives to encourage their development. Currently, NEA is also establishing an industry standard commission to set the standards for shale gas supervision.[15] Two departments within NDRC are responsible for making strategy and plans for energy saving and climate change -- Department of Resource Conservation and Environmental Protection and Department of Climate Change. This overlaps, to some extent, with the work of MEP, which is pushing to amend the *Air Pollution Prevention and Control Law of the People's Republic of China*, and Vice Minister Wu Xiaoqing has just submitted a proposal to establish *Guidelines for Environmental Protection in Shale Gas Exploration*.[16] MEP exercises power under the *Environmental Protection Law, Law on Evaluation of Environmental Effects, Water Law, Law on Water and Soil Conservation, etc.* and can penalize entities for environmental violations. As for the market side, usually NDRC is responsible for price supervision and it sets the price for natural gas at every level from production, transmission to consumption.[17] But according to NEA's Shale Gas Development Plan (2011-2015), ex-plant price of shale gas is to be set by the market, not by NDRC.[18]

In order to attract foreign investment in shale gas development, on December 24, 2011, NDRC and MOC jointly issued a revised version of the Foreign Investment Industry Guidance Catalogue (the "Catalogue"), which took effect on January 30, 2012. The new Catalogue specifies that foreign investments in the exploration and development of shale gas and shale liquids in the form of a joint venture with a Chinese partner now falls under the "encouraged" category, which will entitle the foreign investor to certain tax and administrative benefits.[19]

It should be noted that the Ministry of Water Resources is currently not involved in the shale gas regulatory regime.

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[14] "国土资源部关于加强页岩气资源勘查开采和监督管理有关工作的通知," *Ministry of Land and Resources of the People's Republic of China*, November 22, 2012, http://www.mlr.gov.cn/zwgk/zytz/201211/t20121122_1158928.htm.

[15] Wang, "我国探路页岩气监管."

[16] "环保部副部长吴晓青:尽快制定政策引导页岩气开发," *China.com.cn*, March 6, 2013, http://news.china.com.cn/2013lianghui/2013-03/06/content_28152626.htm.

[17] Mingche Lin, Jinjin Li, and Fuqiang Yang, "页岩气发展呼唤监管体制变革," *Caixin*, November 7, 2012, http://www.caixin.com/2012-11-07/100457055.html.

[18] "页岩气发展规划（2011-2015 年）" (National Energy Administration, December 14, 2012), http://zfxxgk.nea.gov.cn/auto86/201203/P020120316383507834234.pdf.

[19] "外商投资产业指导目录" (The National Development and Reform Commission and the State Administration of Commerce, 2012), http://www.ndrc.gov.cn/zcfb/zcfbl/2011ling/W020111229379511927834.pdf.

III. Major Challenges

Shale gas exploitation in China faces many challenging issues: geographical complexities, water constraints, technology and personnel shortage, pipeline access issues, land/mineral/exploitation rights management, and pricing mechanism and market issues.

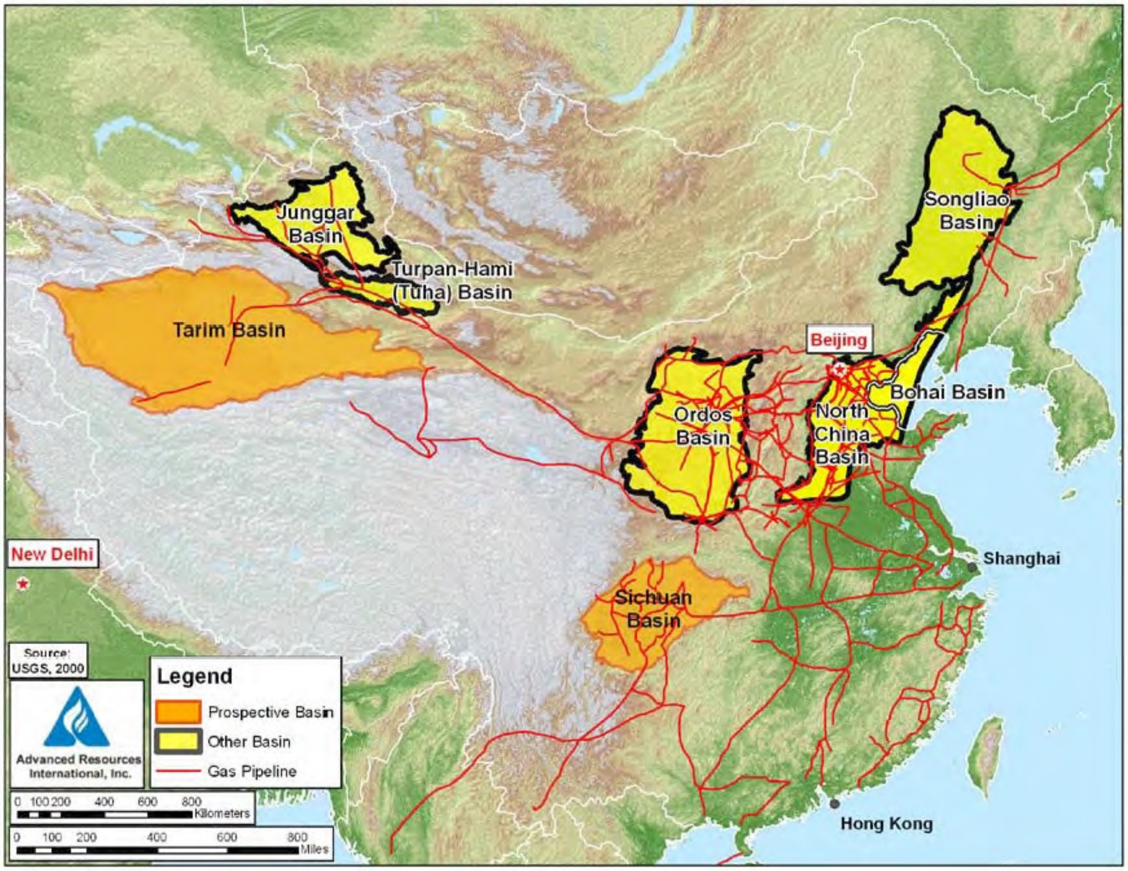
Natural Factors

In terms of geography and tectonics, China's shale gas deposits are buried deeper, and structurally more complex with numerous faults – some seismically active.[20] China's most promising shale gas deposits lie in Sichuan (17.7 tcm), Tarim (6.12 tcm), Junggar (1.02 tcm), and Songliao (0.45 tcm) basins. Unlike much of U.S.' shale gas which is located in the plains, buried under a few hundred meters to 3,000 meters, the shale basins in China are located in mountainous and difficult terrain, with the vertical depths of the deposits at 3,000 to 5,000 meters, some even at 8,000 meters.[21] Tectonical complexity also makes large scale drilling, esp. horizontal drilling and infrastructure (road, pipeline) construction difficult.

Figure 2. Major Shale Gas Basins and Pipeline System of China

[20] "Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States," XX–8.

[21] "U.S. Shale Gas - An Unconventional Resource. Unconventional Challenges" (Halliburton, 2008), http://www.halliburton.com/public/solutions/contents/shale/related_docs/H063771.pdf; "Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States."



Source: U.S. Energy Information Administration, *The World Shale Gas Resources: An Initial Assessment of 14 Regions outside the United States*, Washington, DC, April 2011, p. XI-1.

In addition, water shortage is perhaps the biggest natural constraints for shale gas development in China. China's renewable water resource per capita is estimated at 2,063 m^3 per year in 2011, only one fourth of the world average.[22] Hydraulic fracturing, however, is highly water intensive. It is an activity of drilling and injecting a mixture of thousands of tons water, sand and chemicals into the ground at a high pressure in order to fracturing the shale rocks and release gas. According to an Accenture report, drilling and fracking consume around 19,000 tons of water per well in the U.S..[23] Except for Sichuan basin, the other major shale gas basins in China are located in the arid north. Even in the Sichuan basin where water resources are at 3,040 m^3 per capita annually, higher than China's average, it's still significant lower than US' 17,000 m^3 per

[22] "Renewable Internal Freshwater Resources Per Capita (cubic Meters)," *The World Bank*, n.d., http://data.worldbank.org/indicator/ER.H2O.INTR.PC.
[23] "Water and Shale Gas Development in the U.S.," *Accenture*, December 10, 2012, http://www.accenture.com/us-en/Pages/insight-new-energy-water-shale-gas-development.aspx.

capita, and 80% of its water is used in agriculture.[24] This creates challenges for hydraulic fracturing, and makes groundwater protection and water recycling crucial.

Technological Challenges

Due to the vast geological differences, the technologies used to extract shale gas in the United States may not be a good fit in China. In fact, even in U.S., each well would have its own unique configuration.

From exploration, appraisal, development, to production, there are technological challenges at every step. In the exploration and appraisal stages, reservoir analysis, geomechanics, formation and economic evaluation are crucial. Conventional reservoir modeling and analyses are not effective for shale gas because the latter's complex reservoir characteristics and gas flow make predicting GIP, recovery, production profiles, well placement, and design fracturing programs difficult. In the development stage, companies face challenges in well design, horizontal drilling, hydraulic fracturing and well completion, and in doing it in a way that minimizes costs and environmental impact. In the production stage, companies will need to maintain production rates, reduce scaling, corrosion, and microbial contamination, and meet gas pipeline specifications. China's complex working environment, unbalanced water sources, poor transportation and constrained well locations create additional difficulties for each and every step of shale gas development.

In addition, both horizontal drilling and hydraulic fracturing technologies are controlled by foreign companies. Chinese SOEs as well as private enterprises rely heavily on the technology of Halliburton, Schlumberger, Shell, and Chevron, etc. Many have developed strategic relationships with foreign firms to conduct joint study, exploration and/or production of shale gas.

[24] Jia-guo Zheng et al., "Agricultural Water Savings Possible Through SRI for Future Water Management in Sichuan, China" (Tillage and Cultivation Research Center, Crop Research Institute, Sichuan Academy of Agricultural Sciences, 2011).

Table 1. Joint shale gas study/exploration/ production activities in China

Date	International Companies	Chinese Companies	Activity	Location/ Basin	Status
Oct 2007	Newfield	CNPC	Joint shale gas study	Weiyuan block, Sichuan	Completed in 2008
Nov 2009	Shell	CNPC	Joint shale gas assessment	Fushun-Yongchuan block, Sichuan	Started joint production in Mar 2012
Jan 2010	BP	Sinopec	Joint shale gas assessment	Kaili block, Guizhou; Huangqiao block, Jiangsu	ongoing
Mar 2010	Shell	CNPC	30-year PSA on tight gas	Jinqui block, Sichuan	ongoing
Mar 2011	Total S.A.	CNPC	Joint shale gas production	Sulige South, Inner Mongolia	Began production in May 2012
Apr 2011	Chevron	Sinopec	Shale gas exploration	Longli County, Guizhou	ongoing
Jul 2011	ExxonMobil	Sinopec	Joint shale gas study	Wuzhishan-Meigu block, Sichuan	ongoing
Dec 2012	Shell	CNPC	30-year PSA on tight gas	Zitong block, Sichuan	ongong
Dec 2012	ConocoPhillips	Sinopec	research on shale gas exploration, development and production	Qijiang block, Sichuan	ongoing
Dec 2012	Baker Hughes	Honghua Group	Unconventional gas research and engineering services	Research center in Chengdu, Sichuan	ongoing
Feb 2013	ConocoPhillips	CNPC	Joint Study Agreement	Neijiang-Dazu Block, Sichuan	ongoing
Mar 2013	ENI	CNPC	Joint Study Agreement	Changrong block, Sichuan	ongoing
Mar 2013	Total A.S.	Sinopec	Joint shale gas study	West of Shanghai	negotiation

Chinese companies are also actively acquiring overseas assets to learn about shale technology. In 2010, PetroChina and Royal Dutch Shell Plc. took over Australia's Arrow Energy Ltd. for $3.1 billion to develop a "world-scale LNG plant".[25] In 2011, Sinopec bought Daylight Energy, a Canadian shale producer, for about $2.1 billion in cash.[26] And after CNOOC bought 33.3% interest in Chesapeake's Eagle Ford Shale project in South Texas for $1.1 billion in cash, it paid Chesapeake another $1.3 billion for a second shale deal in early 2011.[27] In early 2012, Sinopec struck a $2.5 billion deal with Oklahoma City-based Devon Energy Corp. for 33% stake in five shale fields and paid for the drilling.[28] In December 2012, PetroChina paid Encana $2.21 billion for a 49.9% stake in a rich shale gas prospect in Canada.[29] In Feb, 2013, Sinopec announced a $1.02 billion acquisition of 50% of Chesapeake Energy Corp's Mississippi Lime oil and gas properties in Oklahoma.[30] All these foreign acquisition activities culminate to China's largest foreign takeover - CNOOC closing a $15.1 billion takeover of Nexen in February 2013, which holds shale gas assets in Canada.[31] These investments, however, did not buy technology transfer, and Chinese companies still largely depend on foreign know-how.

China is pushing for the development of indigenous technology. "Key shale gas exploration and extraction technologies" are listed as one of the National Important Science Projects and a National Energy Shale Gas R&D (Experiment) Center has been established. The government assigned CNPC to lead the efforts. This took away the incentive for cross-sector collaboration between national academies, other NOCs, and private/ foreign enterprises, for developing different approaches and competing for commercialization.

Moreover, it's not just the key technologies China is lacking, but also the corresponding service and equipment suppliers at each chain of exploration and development: drilling machine manufactures/lenders, drilling companies, fracturing fluid supplier, etc. More importantly, China lacks experienced technical personnel and high quality assurance, which may take even longer to nurture than the technological know-how.

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[25] "Shell, PetroChina $3.1 Billion Takeover Approved by Arrow Energy Holders," *Bloomberg*, July 14, 2010, http://www.bloomberg.com/news/2010-07-13/arrow-energy-says-china-s-ndrc-has-approved-shell-petrochina-takeover-bid.html.

[26] "Sinopec to Buy Daylight Energy for $2.1 Billion," *New York Times Deal Book*, October 9, 2011, http://dealbook.nytimes.com/2011/10/09/sinopec-to-buy-daylight-energy-for-2-1-billion/.

[27] "UPDATE 2-Chesapeake, CNOOC Strike Second Shale Deal for $1.3 Bln," *Reuters*, January 30, 2011, http://www.reuters.com/article/2011/01/31/cnooc-chesapeake-idUKN3017000120110131.

[28] "Devon Reaches $2.5 Billion Shale Deal With Sinopec," *Wall Street Journal*, January 4, 2012, http://online.wsj.com/article/SB10001424052970203550304577138493192325500.html.

[29] "PetroChina Strikes $2.21 Billion Deal With Encana," *Wall Street Journal*, December 13, 2012, http://online.wsj.com/article/SB10001424127887324481204578177433511657910.html.

[30] "Sinopec to Buy Stake in Chesapeake Assets for $1.02 Billion," *Reuters*, February 25, 2013, http://www.reuters.com/article/2013/02/25/us-sinopec-deal-chesapeake-idUSBRE91O0GM20130225.

[31] "CNOOC Closes $15.1 Billion Acquisition of Canada's Nexen," *Reuters*, February 25, 2013, http://www.reuters.com/article/2013/02/25/us-nexen-cnooc-idUSBRE91O1A420130225.

Pipeline Access

It was not until 2006 that China saw a significant growth in natural gas consumption, so the country's pipeline infrastructure hasn't kept up. The shortage of necessary pipelines to deliver the shale gas from the wells to the coastal population centers has been one of the major obstacles to growth. U.S. has more than 210 natural gas pipeline systems with 490,850 kilometers of interstate and intrastate transmission pipelines while its natural gas consumption is around 722.1 bcm in 2012.[32] In contrast, the total length of China's pipeline network is about 43,452 kilometers while the consumption is projected to be at 250 bcm in 2015.[33] As previously mentioned, China plans to construct 44,000 kilometers of new natural gas pipelines by 2015. But pipeline inadequacy is not the main problem, rather the accessibility of pipelines.

China's natural gas pipelines are nearly monopolized by CNPC (e.g. West-East Gas Pipeline), holding three-quarter of the market share, and Sinopec (e.g. Sichuan – Shanghai Pipeline). Local distribution networks are operated by various local distributers. This set-up has two consequences: first, it prohibits the emergence of an integrated national gas transmission grid; second, the NOCs are not obligated to accept the shale gas exploited by private companies to their pipelines. This puts CNPC and other NOCs at a strong bargaining position against other upstream producers, and the latter would have to pay a high premium for pipeline access even if the NOCs are willing to negotiate.

The silver lining is that the central government has recognized this issue and Chinese companies have proved to be capable of laying pipelines very efficiently in the past. NEA has listed establishing Management Measures for Natural Gas Infrastructure and Operation Construction ("the Measures") as one of top eight priorities for the Administration in 2013, and the first draft of the Measures has been made. Third-party access to the pipelines is an essential part of this Measures.[34]

National policies do not prohibit private companies from pipeline construction. NEA's Opinions on the Implementation of Encouraging and Guiding Private Capital to Expand Investment in the Energy Sector in June, 2012, instructs "encouraging private capital in the construction of oil

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[32] "About U.S. Natural Gas Pipelines - Transporting Natural Gas," *U.S. Energy Information Administration*, n.d., http://www.eia.gov/pub/oil_gas/natural_gas/analysis_publications/ngpipeline/index.html; "U.S. Natural Gas Total Consumption (Million Cubic Feet)," *U.S. Energy Information Administration*, June 28, 2013, http://www.eia.gov/dnav/ng/hist/n9140us2A.htm.
[33] "China - Analysis."
[34] "《天然气基础设施与运营建设管理办法》初稿已拟定," *Caijing*, March 18, 2013, http://stock.caijing.com.cn/2013-03-18/112599921.html.

and gas pipelines". Nevertheless, there are a myriad of reviews, licensing processes and examinations for private companies to go through in order to apply for pipeline construction. And the NOCs are not necessarily willing to partner up with private companies on this.[35]

Rights Regime

China's rights regime is potentially the biggest bottleneck for shale gas development because it is immensely hard to reform. There are two problems: the first is the lack of private ownership of land/mineral rights. Private ownership makes it easier for land transfer or leasing. It is no coincident that the U.S. shale gas revolution mainly took place on privately-owned land. Yet as previously mentioned, the Mineral Resources Law of China laid out a licensing model for all mineral exploitation. The Development Plan for Shale Gas (2011-2015) gives shale gas developer priority when applying for a land use permit, yet it's just a very small step towards solving this problem.[36]

The second issue is the overlapping land use right, mineral right and exploitation right. Shale gas is a newly added independent mining resource. Corresponding laws and regulations are inadequate. Shale deposits are usually deep under the ground, therefore on the same spot but different depths, several entities can each hold different mineral rights. Current shale gas exploration/development blocks largely overlap with areas where PetroChina and Sinopec hold conventional oil and gas rights, making it very difficult for other companies to enter the race.

According to a Deloitte report, the drilling cost of each well is as high as $16 million.[37] Without clearly defining the rights, it would be hard to raise the interest and enthusiasm of private enterprises.

Pricing Incentives

Shale gas exploration and development requires high initial capital, advanced technology, long-term investment, and incurs high cost, high risk, especially in China's difficult working environment. The Chinese government believes that for the industry to take off, price subsidies,

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[35] "民企遭遇运输管道垄断困局 输送页岩气难避'买路钱'," *Beijing Business Today*, December 3, 2012, http://business.sohu.com/20121203/n359313118.shtml.
[36] "页岩气发展规划（2011-2015 年）."
[37] "2013 年石油与天然气现状盘点," *Deloitte*, 2013, http://www.deloitte.com/view/zh_CN/cn/ind/er/og/fe541771f755f310VgnVCM1000003256f70aRCRD.htm#.

tax deduction or breaks and other measures are required.[38] In November 2012, MOF and NEA announced 0.4 RMB ($6.4 cents) per cubic meter subsidy for shale gas that is developed and consumed from 2012 to 2015.[39]

Low natural gas price has been a disincentive for enterprises to join shale gas exploration. On July 10, 2013, NDRC increased the wholesale price of natural gas for non-residential users for the first time after 2010. The average natural gas price at gate stations (where trunk pipelines connect with local gas distribution networks) increased by around 15.4 percent to 1.95 yuan ($0.31) per cubic meter.[40] Residential natural gas prices are set by local governments after public hearings. The new domestic price would be roughly $8.76 per mmBtu, though in many coastal provinces, the prices will be higher at up to $10-$12 per mmBtu.[41] Nevertheless, China's average LNG import price is still 40% - 60% higher than domestically produced natural gas price. For instance, China paid Qatar $18.77 per mmBtu for LNG in May.[42] This is because the LNG contract is oil-indexed and signed in April 2008.

This natural gas pricing scheme has four problems: One, the prices at various level are set by the government. Two, domestic natural gas price is not linked to international price. Three, it doesn't take into consideration the cost differences to different type of consumers or during peak/off-peak seasons, making municipal fuel gas price lower than industrial gas price, and one unified price even though the demand in peak versus off-peak season is 10:1 in places like Beijing. Four, the prices are calculated using volume, rather than heat values. Since domestic-produced natural gas and imported LNG are mixed in the same pipelines, volume-based price calculation cannot accurately reflect the real price of natural gas against alternative fuels.[43]

According to the NDRC's recent announcement, it will expand the market based pricing mechanism for natural gas it introduced in Guangdong and Guangxi in early 2012. The ultimate

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[38] Yujie Chen, "页岩气开发政策体系正在形成," *China Energy News*, March 25, 2013, http://paper.people.com.cn/zgnyb/html/2013-03/25/content_1215615.htm.

[39] "关于出台页岩气开发利用补贴政策的通知," *Ministry of Finance of People's Republic of China*, November 1, 2012, http://jjs.mof.gov.cn/zhengwuxinxi/tongzhigonggao/201211/t20121105_692290.html.

[40] "China's Gas Price Hike Positive for Companies: Moody's," *Xinhua News*, July 8, 2013, http://news.xinhuanet.com/english/china/2013-07/08/c_132522812.htm.

[41] Clyde Russell, "China's Natural Gas Price Hike to Boost Demand," *Reuters*, July 3, 2013, http://uk.reuters.com/article/2013/07/03/column-russell-china-gas-idUKL3N0F904C20130703.

[42] Aizhu Chen and Nidhi Verma, "China, India Gas Price Reforms Open Door to More LNG Imports," *Reuters*, July 3, 2013, http://www.reuters.com/article/2013/07/04/lng-china-india-idUSL3N0F81ZX20130704; Clyde Russell, "China's Natural Gas Price Hike to Boost Demand," *Reuters*, July 3, 2013, http://uk.reuters.com/article/2013/07/03/column-russell-china-gas-idUKL3N0F904C20130703.

[43] Wenjing Shi, Nandi Ma, and Xuewen Li, "China's Natural Gas Price 我国天然气价格" (China Center for Energy and Development, Peking University, 2012), http://www.nsd.edu.cn/cn/userfiles/Other/2012-07/2012072619193569575249.pdf.

goal is to liberalize wellhead prices of natural gas and allow them to be guided by the market, while the government retains control over tariffs for the pipeline transportation of natural gas.

These policy initiatives will help local natural gas producers and importers, and boost domestic production. The question is how they would be implemented. As aforementioned, the government has announced in principle that shale gas will use market pricing, but it still lacks the market trading mechanism.

IV. Conclusion

The economic, geopolitical and environmental implications of China's shale gas development are immense. As the country struggles to meet the energy demand of a fast-growing economy without depending precariously on foreign imports and coal, it is creating tremendous opportunities for U.S.-China public and private engagement.

It took U.S. 20 years to reach its current preeminence in shale gas exploration. For the shale industry in China to take off, it would need to overcome a series of environmental, technological, and regulatory barriers. Besides water issues, China would have to seriously address the methane leakage in shale gas exploitation. Methane as a greenhouse gas is up to 105 times more potent than carbon dioxide on a 20-year timescale, but right now the shale gas and the natural gas 12th FYPs didn't even mention methane leakage mitigation. Scientists at Chinese Academy of Engineering and NEA officials have been looking into using supercritical carbon dioxide to replace water in hydraulic fracturing.[44] The use of liquefied carbon dioxide in enhanced oil recovery is a proven technology that has been in use in U.S. for over thirty years. To develop the capability of using it for shale gas exploitation, as well as other technologies for exploration, appraisal, and production under China's unique tectonical conditions would require the collaborative efforts of national academies, university labs, NOCs and foreign and domestic private companies, not just CNPC.

More importantly, China would need to reform its existing oil & gas/ mineral regulatory framework and establish a shale gas regulatory and pricing regime that invites the participation of private and foreign enterprises and promotes fair competition. This will face pushbacks from powerful NOCs and some local governments. For instance, the NOCs would not give up their pipeline monopoly easily, nor concede the land access under their oil & gas rights to shale exploitation by a third party. China will also have to carefully design and monitor its shale gas subsidy program so that it would not be abused as the solar subsidy was under the "Golden Sun" program.

[44] Zhonghou Shen, "不能复制美国页岩气模式," *China Economy and Information 中国经济和信息化*, May 10, 2013, http://finance.sina.com.cn/roll/20130510/082715415380.shtml; "张国宝：用液态二氧化碳代替水开采页岩气," *Sina.com*, April 6, 2013, http://finance.sina.com.cn/roll/20130406/222515059623.shtml.

The “shale gas revolution” that swept across U.S. is unlikely to repeat in China by 2020, particularly because of the water resource and land rights bottlenecks. China should be realistic about its shale development outlook and commit to take effective actions to address the various environmental, technological and regulatory challenges.

List of Relevant Laws for Shale Gas Exploration and Development

Mineral Resources Law

Environmental Protection Law

Law on Evaluation of Environmental Effects

The Law of Land Administration

Water Law

Law on Water and Soil Conservation

Law on Prevention and Control of Water Pollution

Law on the Prevention and Control of Atmospheric Pollution

Law on Prevention of Environmental Pollution Caused by Solid Waste

Law on Prevention and Control of Pollution from Environmental Noise

Cleaner Production Promotion Law

The Circular Economy Promotion Law

Law on the Protection of Wildlife

Law on Protection of Cultural Relics

Emergency Response Law

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